European Commission

Assessment of the potential for new feedstocks for the production of advanced biofuels

(ENER C1 2019-412)

Final Report

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Contact: Kitti Nyitrai

E-mail: Kitti.Nyitrai@ec.europa.eu

European Commission
B-1049 Brussels

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AUTHORS

E4tech

- Sébastien Haye (Project Coordinator)
- Yamini Panchaksharam
- Ellie Raphael
- Lucy Liu
- Jo Howes (Quality and Assurance)
- Dr Ausilio Bauen (Project Director)

The International Council on Clean Transportation (ICCT)

- Dr Stephanie Searle
- Yuanrong Zhou
- Kelly Casey
- Jane O'Malley

Cerulogy

- Dr Chris Malins

Guidehouse (Formerly Navigant)

- Sacha Alberici
- Madeleine Hardy

Wageningen Research

- Dr Wolter Elbersen
- Dr. Iris Vural Gursel
- Dr Berien Elbersen

SCS Global Services

- Matthew Rudolf
- Nathan Hall
- Bob Armentrout

1. ABSTRACT (ENGLISH)

The Recast of the EU Renewable Energy Directive (EU RED II) sets a target for the use of biofuels produced from feedstocks listed in Annex IX. New feedstocks may be added to Annex IX by the European Commission, provided that they meet specific criteria (Article 28(6) of EU RED II) and have a limited risk of fraud. This project shortlisted 30 feedstocks from approximately 130 candidates and evaluated them against the Article 28(6) criteria and a set of fraud risk indicators to assess their potential eligibility for inclusion in Annex IX.

The evaluation resulted in seven feedstock categories being marked as of no "particular concern" regarding Art 28(6) criteria, while ten categories raised "significant concerns" in one or more criteria. The rest of the shortlist was marked as having "some concerns", where the overall level of risk might be considered acceptable or where a risk would only materialise in certain conditions. In addition, several categories were evaluated as presenting an overall low/low-medium risk of fraud. High fraud risks were detected when the physical nature of feedstocks cannot be readily identified or when their definition as co-product, residue or waste is not clearly established. The Consortium proposed several recommendations as to how to mitigate these fraud risks.

2. ABSTRACT (FRANÇAIS)

La refonte de la Directive UE sur les énergies renouvelables (EU RED II) établit des objectifs pour l'utilisation de biocarburants dérivés des matières premières listées dans l'Annexe IX. De nouvelles matières premières peuvent ajoutées à l'Annexe IX par la Commission Européenne dans la mesure où elles respectent les critères spécifiés dans l'Article 28(6) de la EU RED II et représentent un risque de fraude limité. Ce projet a sélectionné 30 types de matière première parmi environ 130 candidats pour les évaluer au travers des critères de l'Article 28(6) et d'une série d'indicateurs concernant le risque de fraude et déterminer leur éligibilité potentielle pour une inclusion dans l'Annexe IX.

Au terme de l'évaluation, sept types de matière première ne représentent pas de risque particulier (« no particular concern ») quant aux critères de l'article 28(6). A l'inverse, dix catégories présentent des risques significatifs (« significant concerns ») pour un critère ou plus. Le reste des matières premières présentent des risques spécifiques (« some concerns »), mais avec un niveau général de risque considéré comme acceptable ou limité à des conditions spécifiques. En outre, plusieurs catégories présentent un risque de fraude relativement bas (faible ou faible-moyen). Un fort risque de fraude existe lorsque la nature physique des matières premières ne peut être facilement identifiée où lorsque leur classification comme co-produit, résidu ou déchet n'est pas clairement établie. Le consortium a proposé plusieurs recommandations afin de minimiser ces risques de fraude.

3. EXECUTIVE SUMMARY (ENGLISH)

ES.1) Context

The Recast of the EU Renewable Energy Directive (2018/2001) – also known as "EU RED II" includes a 32% target for renewables in total EU energy consumption in 2030, with a specific sub-target for renewables in transport of 14%. Currently, biofuels constitute the largest share of renewables in transport. EU RED II aims to incentivise the use of advanced biofuels produced from feedstocks listed in Annex IX – Part A, which are associated with lower risks of indirect environmental and socio-economic impacts, and which require advanced technologies for conversion to biofuels. The EU RED II includes a 3.5% sub-target for these advanced biofuels in 2030, with EU Member States being allowed to double count the energy content of advanced biofuels towards these targets. Biofuels produced from feedstocks listed in Annex IX – Part B, which involve the use of mature conversion technologies, can also be double counted towards the renewables in transport target. However, their contribution to these targets is capped.

The EU RED II includes a mechanism (Article 28 Paragraph 6) whereby the European Commission can adopt delegated acts to add feedstocks to Annex IX (part A or part B), but not to remove them. Such delegated acts must build upon a careful evaluation of the characteristics of candidate feedstocks, taking into account circular economy principles, the EU Waste Directive, sustainability criteria, risks of distortive market effects, greenhouse gas savings, other environmental impacts and potential additional demand for land. Fraud risks must also be taken into account, especially regarding the origin and chemical composition of feedstocks.

The main objective of this project was to support the European Commission (DG ENER) in the process of identifying candidate feedstocks for inclusion in EU RED II Annex IX, evaluating them against the criteria laid out in Article 28(6) of EU RED II and informing the Commission on fraud risks associated with feedstocks identified in this project, as well as those listed in Annex IX.

The project was divided into three Tasks:

- **Task 1** established a long list of potential biofuel feedstocks for inclusion in Annex IX and conducted a preliminary assessment of these feedstocks based on basic eligibility criteria to produce a short list for further assessment in Task 2 and 3. The shortlist was based on the Consortium's expertise, a literature review and stakeholder consultation.
- **Task 2** involved the detailed assessment of each shortlisted feedstock against the criteria described in Article 28(6) of the EU RED II. The Consortium provided the European Commission with its conclusions on how each feedstock in the short list performed against these criteria.
- **Task 3** looked specifically at the risk of fraud associated with support for the use of new and existing Annex IX feedstocks. Informed by consideration of documented cases of fraud, the Consortium established a set of fraud risk indicators and considered options available to mitigate identified fraud risks.

ES.2) Task 1 - Literature review, stakeholder consultation & preliminary feedstock assessment

The Consortium conducted a comprehensive **literature review** of 61 publications, including policy regulations, peer reviewed journal articles, technical reports from the private and public sectors, and position papers from the private sector. These helped the Consortium identify novel biofuel feedstocks and contributed to the development of an initial long list of 127 distinct feedstocks. In addition, these publications provided useful information on the origin, production process, alternative uses, feasibility, economics, market impacts, and sustainability performance of the feedstocks, which served as supporting evidence for Tasks 2 and 3. The literature review was complemented by internal expertise and a **stakeholder consultation**, through which experts from various industries and civil society organisations were able to provide evidence, including for less widely used feedstocks which are less documented in the literature, and to help identify additional feedstocks. In the first round of consultation (April-May 2020), 427 feedstock-specific suggestions were received from 79 organisations. A second round was organised (August-September 2020) to collect specific information and insights regarding the nature and production process of specific feedstocks. A total of 35 organisations contributed to the second round.

In the consultation, the Consortium followed a systematic process to review and evaluate the evidence from the literature and stakeholder contributions to determine whether a feedstock qualifies as biomass, whether it qualifies as a food/feed crop and whether it is already covered by Annex IX.

The process resulted in feedstocks being either shortlisted for further investigation in Task 2 and 3 (i.e. those that qualify as biomass, are not considered as a food/feed crop and are not already covered in Annex IX) or rejected.

The preliminary assessment described above led to a **shortlist** of 32 feedstocks, which were further assessed in Task 2 and Task 3 (The list was reduced to 30 feedstocks at the beginning of Task 2, as two feedstock categories were re-evaluated as being already covered in Annex IX).

Most of the non-shortlisted feedstocks were considered by the Consortium as being **currently covered by Annex IX** (See full description in Section 7.3).

ES.3) Task 2 - Detailed feedstock assessments

Shortlisted feedstocks in Task 1 underwent a thorough assessment against the eligibility criteria described in EU RED II Article 28(6). To the extent possible, feedstock assessments rely on independent and verifiable sources, which support the analysis and conclusions on potential eligibility in Annex IX. Direct inputs from stakeholders who responded to the public consultation in Task 1 were also used for technical descriptions, the assessments of environmental and market impacts, and land demand, as long as they could be independently verified by the Consortium.

Feedstock assessments included the following stages:

- **Feedstock description**, **production process(es), and possible uses**.
- **Feedstock alignment with the circular economy principles and the waste hierarchy.** The EU approach to the circular economy primarily relies on the need to reduce waste and prolong the material use of products as much as possible before being preferentially recycled. The Waste Framework Directive defines a hierarchy of actions or steps related to waste, in which energy recovery is preceded by the prevention, reuse and recycling of waste. First, the nature of feedstock as co-product, residue or waste was established, followed by an assessment of whether it could be considered in line with circular economy principles and the waste hierarchy (the waste hierarchy only applies to waste).
- **Potential compliance with sustainability criteria** was established by looking at the **Union sustainability criteria** (Article 28(6) (b) and Article 29(2) to (7) of EU RED II), potential **Greenhouse gas emissions savings** compared to fossil fuels (Article 28(6) (d) of EU RED II) and other **negative impacts on the environment and biodiversity** (Article 28(6) (e)).
- The Consortium evaluated whether an increased use of each feedstock included in the short list might bring about **market distortions**, thus potentially triggering

negative indirect environmental or (socio)economic impacts. The **potential supply and availability of feedstocks in 2030 and 2050** was also evaluated. Several sources were used for this assessment, including statistical databases (EU Agricultural Outlook, 2019-2030, Eurostat, FAOSTAT, World Bank), followed by public reports (from government, international organisations, NGOs and technical groups), academic literature and stakeholder inputs from Task 1 consultation and direct interviews.

- **Additional demand for land** was evaluated based on the assessment of potential market distortions: where these occur, new demand for the main feedstock considered or for other substitute products could lead to additional demand for land. Both direct and indirect land demand were evaluated by considering the likely substitute material and related land demand informed by the Commission's 2015 GLOBIOM ILUC study (Valin et al., 2015).
- **Processing technologies** used to transform feedstocks into biofuel/biogas were assessed as mature or advanced based on their Technology Readiness Level (TRL) or Commercial Readiness Level (CRL). The Consortium established a list of advanced and mature technologies to determine whether feedstocks would fit Part A (advanced) or Part B (mature) respectively. Whenever a feedstock can be processed via either an advanced or a mature technology, the mature technology was used for the assessment. However, if an advanced technology was required (e.g. pretreatment) ahead of the conversion into biofuel/biogas via a mature technology, the whole process was considered as advanced.

The project Consortium conducted 30 feedstock assessments against EU RED II Article 28(6) criteria. The results provided a comprehensive overview of potential risks of their potential inclusion in Annex IX. Some of the risks identified in the assessment, in line with Article 28(6), can be efficiently verified and managed through an independent audit as part of the certification process demonstrating compliance with the requirements of EU RED II by an EU-approved voluntary scheme. This is the case for the Union sustainability criteria and GHG savings (Article 28(6) (b) and (d)). On the contrary, a lack of alignment with circular economy principles, market distortions and additional land demand would not be addressed by such an independent audit against the existing EU RED II requirements. Some concerns may, however, be mitigated by further defining feedstock specificities (e.g. in the case of de-oiled pomace) and/or by inclusion in policy categories with a capped contribution, such as Annex IX - Part B, or characterisation as a co-product from a food/feed crop (7% cap applicable, as defined in EU RED Article 26(1)). Risks that cannot be captured by a REDII compliance audit, or existing policy mechanisms, may require the development of new policy instruments, such as the Implementing Act on voluntary schemes.

Among the assessed feedstocks, seven were marked as "no concern" for all of the criteria used for the assessment: **Raw methanol from kraft pulping, Biomass from degraded/polluted lands (if appropriately evaluated as low ILUC), Damaged crops (unfit for human or animal consumption), Municipal wastewater and derivatives (other than sludge), Brown grease, Other biowaste and Cyanobacteria**.

A total of nine feedstocks raised "significant concerns" over one or more of the criteria: **cover and intermediate crops, animal by-products cat 3 (not fats), animal fats cat 3, dry starch from corn fractionation, fatty acid distillates, molasses, potato/beet pulp, soapstock and derivatives, technical corn oil, and DDGS**.

The remaining 14 feedstocks were marked as having "some concerns", where the overall level of risk might be considered acceptable or where a risk would only materialise in certain conditions. In several cases, existing policy instruments (inclusion in Annex IX - Part B or food/feed cap) or further specification of the feedstock type could mitigate the identified concerns. This would be the case for **Drink production residues and waste,**

Fruit and vegetable residues and waste, Vinasse (by excluding thin stillage and sugarbeet vinasse)**, olive extraction residues** (by considering de-oiled pomace only), **biomass from degraded land** (with a formal validation of the degraded status by an EU-approved voluntary scheme).

Based on EU RED II Article 28(6), only six of the feedstocks were evaluated as being processed via advanced technologies. All of the remaining feedstocks would only be eligible for Annex IX - Part B.

ES.4) Task 3 - Fraud risk and mitigation measures

Task 3 aimed at evaluating fraud risks associated with the shortlisted feedstocks, as well as feedstocks already included in Annex IX. The evaluation was based on existing knowledge of fraud cases and provides recommendations for fraud risk mitigation measures. Task 3 was divided as follows:

- The Consortium reviewed **historical and ongoing cases of fraud** in the EU/US biofuels industry with a view to understanding weaknesses in current systems that can inform the development of fraud risk indicators, as well as recommendations for new measures to reduce fraud risks. Reported cases of fraudulent creation of biofuel credits/certificates or soy biodiesel being fraudulently sold as used cooking oil methyl ester (UCOME) were documented, as well as 4 fraud cases from the forestry industry. In addition, general concerns over UCO and certification violations were also considered.
- Documented fraud cases and internal expertise were used to **characterise fraud risks**. Risks of administrative fraud (e.g. creating fake certificates) or fraud based on the nature of feedstock (e.g. selling feedstocks that are not in Annex IX as waste-based or advanced feedstock) were distinguished from irregularities, which may not lead to a formal case of fraud but could nonetheless reflect systemic weaknesses in the implementation of EU RED II sustainability, traceability and assurance rules.
- A set of **fraud risk indicators** was developed to evaluate shortlisted and Annex IX feedstocks. "Primary" indicators (elements incentivising fraud) were distinguished from "secondary" indicators (amplifiers or elements which make fraud easier). Primary indicators looked at feedstock physical and definition characteristics (e.g. the possibility of purposefully altering one feedstock to make it fit Annex IX feedstock characteristics) whereas secondary indicators addressed supply chain characteristics (e.g. number of intermediaries) and assurance (e.g. traceability issues, competences of auditors). Primary and secondary indicators were ultimately combined to evaluate the overall risk score of each feedstock category.
- **Recommendations for fraud risk mitigation measures** were developed by the Consortium on the basis of existing measures and the practical experience gained by Consortium members in auditing and certification processes. These recommendations primarily concern policy actions at European Commission level.

The evaluation of shortlisted and Annex IX feedstocks led to the following conclusions:

- **Several feedstock categories present an overall low or low-medium fraud risk**. For these feedstocks, fraud risks can be considered limited and would not immediately require specific mitigation measures beyond the existing rules implemented or being developed by the EU and/or voluntary schemes.
- **High risks were detected for several feedstocks and at various levels**, which would require additional mitigation measures. These risks include, but are not limited to:

- Risks related to the physical characteristics of feedstocks are particularly high when the physical nature of feedstocks cannot be readily distinguished from non-Annex IX materials, either visually or through chemical testing (e.g. ligno-cellulosic materials or used cooking oil).
- Fraud risks over feedstock definition are particularly relevant for novel feedstocks, which are not clearly or consistently defined across Member States and outside the European Union, e.g. residues/effluents from cereal processing (e.g. ultrafiltration retentates), feedstocks with a very broad definition (e.g. biowaste) and feedstocks which relate to a type of land or agricultural practice (e.g. intermediate crops).
- Fraud risk amplifiers (secondary indicators) related to the length/complexity of supply chains are particularly relevant for feedstocks produced in multiple locations that can be easily collected and traded globally, such as palm and its derivatives, waste feedstocks (e.g. UCO) and processing residues, which feed into international fuel and chemical markets (e.g. methanol).
- Finally, the novel nature of certain feedstocks and conversion processes entails risks for assurance systems, whereby assurance providers may not have sufficient knowledge or experience of the nature and technicalities of certain feedstocks, thus not being able to detect non-compliance.

There appears to be no significant difference between the existing Annex IX feedstocks and the feedstocks shortlisted in this study with regards to overall fraud risk. To date, used cooking oil remains one of the feedstocks with highest risks of fraud, based on documented and suspected cases. Feedstocks with similarities with UCO (other waste fats and oils) could face similar fraud risks.

Fraud risks may be further mitigated by the extension of existing mitigation measures and the development of new ones. Recommendations from the Consortium regarding fraud risk mitigation measures include, but are not limited to:

- Improving auditor guidelines and training (e.g. typical processing yield, feedstock testing, determining cellulose content, use of remote sensing tools and traceability).
- Tracking of all EU RED II transactions through a common registry (Union Database).
- Harmonisation of feedstock definition (e.g. through voluntary schemes).
- Guidance on local/project-level assessments to evaluate local market conditions and risks related to the diversion of feedstocks from other uses.

Table 1 and **Table 2** summarise the results of Task 2 and Task 3 assessments (See Sections 8 and 9 for details).

Table 1: Overview of Task 2 assessment for shortlisted feedstocks (including Annex IX – Part A/B eligibility)

Feedstock name	T2 Assessment (EU RED II – Art 28)
Bakery and confectionery residues and waste	Some concern / Part B
Drink production residues and waste	Some concern / Part B
Fruit / vegetable residues and waste (except tails, leaves, stalks and husks)	Some concern / Part B
Potato/beet pulp	Significant concern Part A (Bioethanol) Part B (Biogas)
Starchy effluents (up to 20% dry content)	Some concern / Part B
Dry starch from corn fractionation (formerly 'Corn	Significant concern / Part B

processing residues’)	
Dextrose ultrafiltration retentate, hydrol and raffinate from sugar refining (formerly ‘Sugar extraction residues and waste’ or ‘Sugars (fructose, dextrose) refining residues’)	Some concern / Part B
Final Molasses (formerly ‘Molasses’)	Significant concern / Part B
Vinasse	Some concern (sugarcane vinasse) Part B
	Significant concern (thin stillage or sugarbeet vinasse) / Part B
Alcoholic distillery residues and waste	Some concern Part A (fusel oils) Part B (heads and tails)
Brewers’ spent grain (formerly ‘Spent grains’)	Some concern / Part B
Whey permeate	Some concern / Part B
Olive oil extraction residues (formerly ‘Olive pomace and derivatives’)	Some concern (de-oiled pomace) Part B
	Significant concern (non-de-oiled pomace) / Part B
Oil palm mesocarp fibre oil (‘PPF oil’) (formerly ‘Palm mesocarp oil’)	Some concern / Part B
Raw methanol from kraft pulping (formerly ‘Raw methanol from wood pulp production’)	No concern Part B (further investigation required)
Cover and intermediate crops (formerly ‘Grain, starch, sugar, oil, beans and meals derived from rotation crops, cover crops and catch crops’)	Significant concern / Part B
Biomass from degraded/polluted land (Non-lignocellulosic/non-cellulosic)	No concern (Low ILUC only) Part B
	Some concern (Others) / Part B
Damaged crops unfit for human and animal consumption (Formerly ‘Damaged crops’)	No concern / Part B
Category 3 Animal fats (formerly ‘Animal fats Cat 3’)	Significant concern / Part B
Category 2 and 3 Animal by-products (not fats) (formerly ‘Animal residues (non-fat) Cat 2-3’)	Significant concern (Cat. 3) Some concern (Cat. 2) Part A (biofuels) Part B (biogas)
Municipal wastewater and derivatives (other than sludge) (formerly ‘Municipal wastewater and derivatives (non-sludge)’)	No concern Part A (biogas >30% concentration) Part B (biogas <30% concentration and biodiesel)
Soapstock and derivatives	Significant concern / Part B
Brown grease	No concern / Part B
Fatty acid distillates	Significant concern / Part B
Technical corn oil (formerly ‘Various oils from ethanol production’)	Significant concern / Part B
Distillers’ dried grain with solubles (DDGS) (formerly ‘Distillers’ grain and solubles (DGS)’)	Significant concern / Part A
High oleic sunflower oil extraction residues (formerly ‘Residues from oleochemical processing of high oleic sunflower oil’)	Some concern / Part B
Other biowaste	No concern / Part B
Sea algae	Some concern / Part A
Cyanobacteria	No concern / Part B

Table 2 Overview of Task 3 assessment for shortlisted feedstocks

Feedstock name	T3 Assessment (Overall Fraud Risks)
Bakery and confectionery residues and waste	Medium
Drink production residues and waste	Low
Fruit / vegetable residues and waste (except tails, leaves, stalks and husks)	Medium
Potato/beet pulp	Medium
Starchy effluents (up to 20% dry content)	Medium-High
Dry starch from corn fractionation (formerly 'Corn processing residues')	Low
Dextrose ultrafiltration retentate, hydrol and raffinate from sugar refining (formerly 'Sugar extraction residues and waste' or 'Sugars (fructose, dextrose) refining residues')	High
Final Molasses (formerly 'Molasses')	High
Vinasse	Low-Medium
Alcoholic distillery residues and waste	Medium
Brewers' spent grain (formerly 'Spent grains')	Low-Medium
Whey permeate	Low-Medium
Olive oil extraction residues (formerly 'Olive pomace and derivatives')	Low Medium-High
Oil palm mesocarp fibre oil ('PPF oil') (formerly 'Palm mesocarp oil')	High
Raw methanol from kraft pulping (formerly 'Raw methanol from wood pulp production')	Medium
Cover and intermediate crops (formerly 'Grain, starch, sugar, oil, beans and meals derived from rotation crops, cover crops and catch crops')	Low-Medium (Niche or primarily soil-improving cover crops) High (Commodity crops, e.g. corn, soy, wheat)
Biomass from degraded/polluted land (Non-lignocellulosic/non-cellulosic)	High (Degraded lands) Medium (Polluted lands)
Damaged crops unfit for human and animal consumption (Formerly 'Damaged crops')	Medium
Category 3 Animal fats (formerly 'Animal fats Cat 3')	Low
Category 2 and 3 Animal by-products (not fats) (formerly 'Animal residues (non-fat) Cat 2-3')	Low
Municipal wastewater and derivatives (other than sludge) (formerly 'Municipal wastewater and derivatives (non-sludge)')	Low
Soapstock and derivatives	Medium-High
Brown grease	Low-Medium
Fatty acid distillates	Medium
Technical corn oil (formerly 'Various oils from ethanol production')	Medium
Distillers' dried grain with solubles (DDGS) (formerly 'Distillers' grain and solubles (DGS)')	Low
High oleic sunflower oil extraction residues (formerly 'Residues from oleochemical processing of high oleic sunflower oil')	High
Other biowaste	Medium
Sea algae	Medium-High
Cyanobacteria	Medium-High

4. RESUME EXECUTIF (FRANÇAIS)

RE.1) Contexte

La refonte de la Directive UE sur les énergies renouvelables (2018/2001), également connue sous le nom de « EU RED II » inclut un objective de 32% d'énergie renouvelable dans la consommation totale de l'UE en 2030, ainsi qu'un sous-objectif spécifique de 14 % pour les transports. Actuellement, les biocarburants représentent la plus grande proportion d'énergie renouvelable utilisée dans les transports. La EU RED II encourage l'utilisation de biocarburants avancés produits à partir des matières premières listées dans l'Annexe IX – Partie A, pour lesquelles les risques d'impact environnemental et socio-économique indirects sont considérés comme faibles et dont les technologies de transformation sont dites « avancées ». La EU RED II inclut un sous-objectif de 3.5% pour ces biocarburants avancés en 2030 et autorise les états membres à utiliser un double comptage de leur contribution énergétique à l'atteinte de l'objectif. Les biocarburants produits à partir des matières premières listées dans l'Annexe IX – Partie B, ce qui implique des technologies de conversion dites « matures », peuvent également bénéficier du double comptage mais leur contribution à l'objectif est restreinte.

La EU RED II comporte un mécanisme (Article 28, paragraphe 6) permettant à la Commission européenne d'adopter des actes délégués afin d'ajouter des matières premières à l'Annexe IX (Partie A ou B), mais pas d'en retirer. Ces actes délégués doivent se baser sur une évaluation précise des caractéristiques des matières premières candidates, qui tient compte des principes de l'économie circulaire, de la directive UE sur les déchets, de critères de durabilité, des risques de distorsion des marchés, des gains d'émissions de gaz à effet de serre, et de la demande supplémentaire en terres arables que leur utilisation pourrait générer. Les risques de fraude doivent également être pris en compte, en particulier lorsqu'ils sont liés à l'origine ou à la composition chimique de ces matières.

L'objectif principal de ce projet était d'appuyer la Commission européenne (DG ENER) au cours du processus d'identification de matières premières pouvant être ajoutées à l'Annexe IX de la EU RED II en les évaluant selon les critères de l'Article 28(6) de la directive. Le projet consistait également à analyser et informer la Commission des risques de fraude associés aux matières premières identifiées, ainsi qu'à celles figurant déjà dans l'Annexe IX.

Le projet comportait trois tâches :

- **La Tâche 1** a permis d'établir une liste initiale (« long list ») de matières premières pouvant potentiellement être ajoutées à l'Annexe IX. Elle comportait également une évaluation préliminaire de ces matières premières sur la base de critères simples afin de réduire la liste à une « shortlist » qui serait utilisée dans les Tâche 2 et Tâche 3. La shortlist était basée sur l'expertise du consortium, une revue de littérature et la consultation des différents acteurs de la filière biocarburants/biogaz.
- **La Tâche 2** consistait en une évaluation détaillée de chaque matière première dans la shortlist en utilisant les critères de l'Article 28(6) de la EU RED II. L'évaluation se basait sur les connaissances du consortium, la documentation publique et les contributions des parties prenantes consultées au cours de la Tâche 1.
- **La Tâche 3** s'est intéressée spécifiquement au risque de fraude associé à l'utilisation des matières premières shortlistées ainsi que celles figurant déjà dans l'Annexe IX. En se basant sur les cas documentés de fraude, le consortium a établi des indicateurs du risque de fraude et considéré différentes options afin de réduire ces risques.

RE.2) Tâche 1 – Revue de littérature, consultation des parties prenantes et évaluation préliminaire des matières premières

Le consortium a conduit une **revue de littérature** comportant 61 publications, dont des réglementations, des articles scientifiques, des rapports techniques des secteurs privés et publics, ainsi que des prises de position du secteur privé. Cela a permis au consortium d'identifier 127 matières premières, dont beaucoup sont encore peu utilisées. Cette revue de littérature aura également permis d'accumuler des informations sur les caractéristiques techniques, économiques et environnementales de ces matières premières en vue des évaluations de la Tâche 2 et de la Tâche 3. La revue de littérature a été suivie d'une **consultation publique** au cours de laquelle différents experts de l'industrie et de la société civile ont pu suggérer d'autres matières premières à considérer et fournir des informations et de la documentation pour la matières premières concernées. Au cours de la première consultation (Avril-Mai 2020), 427 suggestions ont été reçues de la part de 79 organisations. Une seconde consultation a été organisée en Août-Septembre 2020 pour collecter des informations supplémentaires concernant la nature et les chaines de valeurs de certaines matières premières. 35 organisations y ont participé.

Un processus systématique a été mis en œuvre pour l'évaluation préliminaire et l'utilisation des informations reçues au cours de ces consultation. Ces informations, combinées à l'expertise au sein du consortium et à la revue de littérature ont permis de déterminer si les matières premières suggérées pouvaient bien être considérées comme de la biomasse, si elles ne remplissaient pas les critères correspondant aux plantes alimentaires (« food/feed crops ») et si elles n'étaient pas déjà couvertes dans l'Annexe IX existante.

Suivant cette évaluation préliminaire, les matières premières de la longue liste furent donc shortlistées pour les tâches 2 et 3 ou retirées de la liste si elles ne remplissaient pas les critères. Au sortir de la Tâche 1, la shortlist contenait ainsi 32 types de matières premières, qui allaient pouvoir être explorées plus en détail dans les tâches 2 et 3 (NB : la liste a ensuite été réduite à 20 en début de Tâche 2 car deux catégories ont finalement été considérées comme étant déjà couvertes par l'Annexe IX).

La plupart des matières premières non-shortlistées ont ainsi été considérées par le consortium comme étant **déjà couvertes par l'Annexe IX existante** (voir description complète dans la Section 7.3).

RE.3) Tâche 2 – Evaluation détaillée des matières premières

Les matières premières shortlistées à l'issue de la Tâche 1 ont fait l'objet d'une évaluation détaillée au travers des critères de l'Article 28(6). Les évaluations et les conclusions quant à l'éligibilité des matières premières pour une inclusion dans l'Annexe IX se sont basés prioritairement sur des sources indépendantes et vérifiables. Les informations et la documentation collectées auprès des parties prenantes au cours de la consultation publique (Tâche 1) ont également été utilisées dans la mesure où elles pouvaient être vérifiées par le consortium via d'autres sources.

L'évaluation comportait les étapes suivantes :

- **Description de la matière première, ses procédés de production et ses usages possible.**
- **Alignement des matières premières avec les principes de l'économie circulaire et la hiérarchie de traitement des déchets (waste hierarchy).** L'approche de l'UE concernant l'économie circulaire repose principalement sur la réduction des déchets et la prolongation de l'utilisation matérielle des produits avant leur fin de vie, préférablement le recyclage. La Directive relative aux déchets (Waste Framework Directive) définit une hiérarchie d'actions quant au traitement des déchets, dans laquelle l'utilisation pour générer de l'énergie est précédée par la prévention, la réutilisation et le recyclage des déchets. Dans un

premier temps, la nature de la matière première en tant que co-produit, résidu ou déchet, a été établie, suivie d'une évaluation de son alignement avec les principes de l'économie circulaire et – pour les matières premières considérées comme des déchets – avec la hiérarchie de traitement de ces derniers.

- **La conformité potentielle avec les critères de durabilité** a été évaluée sur la base des critères de l'Union (Article 28(6) (b) et Article 29(2) à (7) de la EU RED II), les **gains d'émissions de gaz à effet de serre** en comparaison des carburants fossiles (Article 28(6) (d)) et les autres **impacts négatifs sur l'environnement et la biodiversité** (Article 28(6) (e)).
- Le consortium a par ailleurs évalué si une utilisation croissante de chaque matière première shortlistée pourrait aboutir à des **distorsions de marché**, ce qui pourrait entrainer des impacts environnementaux ou socio-économiques indirects. **La production et la disponibilité des matières premières en 2030 et 2050** ont également été évaluées sur la base de multiples sources dont les bases de données statistiques (EU Agricultural Outlook, 2019-2030, Eurostat, FAOSTAT, World Bank), des rapports publics (gouvernements, organisations internationales, ONG et groupes techniques), la littérature académique et les contributions des parties prenantes (Tâche 1 et consultation directe).
- **La demande additionnelle pour des terres arables** a été analysée sur la base de l'évaluation des distorsions potentielles de marché : lorsque celles-ci sont attendues, la demande additionnelle pour la matière première ou pour ses substituts pourrait conduire à une utilisation supplémentaire de terres arables en compensation pour la matière première redirigée vers la production d'énergie. La demande directe et indirecte en terre supplémentaire a été évaluée d'après les substituts potentiels aux matières premières considérées, tels que modelés dans l'étude «ILUC » de la Commission en 2015 (Valin et al., 2015).
- **Les technologies de transformation** des matières premières en biocarburant ou biogaz sont considérées comme mature ou avancée suivant le niveau de maturité technologique (Technology Readiness Level ou TRL) ou commerciale (Commercial Readiness Level ou CRL). Le consortium a établi une liste des technologies matures et avancées afin de déterminer laquelle/lesquelles étaient utilisées pour la transformation des matières premières shortlistées et, par conséquent dans quelle partie de l'Annexe IX elles pourraient être intégrées (Partie A si avancée, partie B si mature). Lorsque des technologies de transformation avancées et matures existent pour une même matière première (par exemple gazéification et digestion anaérobie de matière ligno-cellulosique), c'est la technologie mature qui sert de point de référence. Si, toutefois, certaines étapes préliminaires (par ex. pré-traitement) requérant des technologies avancées sont nécessaires, la chaine de transformation dans son ensemble était considérée comme avancée.

Le consortium a évalué 30 matières premières sur la base de ces critères, ce qui a permis d'obtenir une vue d'ensemble complète des risques liés à leur inclusion potentielle dans l'Annexe IX. Certains de ces risques peuvent être efficacement mitigés et monitorés dans le cadre des audits conduits par les schémas de certification volontaires (voluntary schemes) reconnus par l'UE. C'est le cas, par exemple, pour les critères de durabilité de l'Union (Articles 28(6) b et d). A l'inverse, l'alignement avec les principes d'économie circulaire, les risques de distorsion sur les marchés ou la demande supplémentaire en terres arables ne sont pas couverts par de tels audits. Ces risques pourraient toutefois être atténués si les matières premières étaient définies plus précisément (par ex. les grignons d'olive dont l'huile a été extraite) ou en les incluant dans des catégories pour lesquelles un seuil maximal d'utilisation existe (par ex. la partie B de l'Annexe IX ou la catégorie « food/feed crop » qui ne peut représenter au maximum que 7% de la contribution totale). Enfin, pour tous les autres risques non-couverts par ces mécanismes, de nouveaux instruments régulatoires sont nécessaires, à l'image de l'acte d'exécution sur les schémas volontaires attendu prochainement.

Sept des matières premières évaluées ne présentent pas de risque particulier quant aux critères utilisés pour l'évaluation : **Le méthanol brut issu du procédé de Kraft, la biomasse issue de terres dégradées ou polluées (uniquement si « low ILUC »), les cultures endommagées (si impropres à la consommation humaine ou animale), les eaux usées municipales et dérivés (hors boues d'épuration), la graisse brune, les autres déchets biogéniques et les cyanobactéries.**

Neuf des matières premières évaluées ont soulevé des risques significatifs sur un ou plusieurs des critères : **les cultures de protection et intermédiaires, les sous-produits animaux cat. 2-3 (hors graisses animales), l'amidon sec issu du fractionnement du maïs, les distillats d'acide gras, la mélasse finale, la pulpe de patate/betterave, les savons et dérivés issus du raffinage d'huiles végétales (Soapstock), l'huile "technique" de maïs (technical corn oil) et les drêches de distillerie avec solubles (DDGS).**

Les 14 matières premières restantes présentent certains risques spécifiques à des conditions particulières et/ou avec un niveau de risque général considéré comme acceptable. Dans plusieurs cas, les instruments régulatoires existants (par ex. l'inclusion dans la partie B ou les limites à l'utilisation de cultures vivrières) ou une définition plus spécifique des types de matière première pourraient mitiger les risques identifiés. C'est par exemple le cas pour **les résidus et déchets de production de boissons non-alcoolisées, les résidus et déchets de la transformation de fruits et légumes, la vinasse (si l'on exclut le « thin stillage » et la vinasse de betterave), les résidus d'extraction d'huile d'olive (grignons sans huile) et la biomasse dérivée de terres dégradées (avec validation formelle du statut dégradé par un schéma volontaire approuvé par l'UE).**

Sur la base de l'article 28(6) de la EU RED II, six matières premières seulement ont été évaluées comme nécessitant des technologies de transformation avancées (Partie A). La totalité des autres matières premières seraient donc potentiellement éligible pour la partie B de l'Annexe IX.

RE.4) Tâche 3 – Risque de fraude et mesures de mitigation

La Tâche 3 avait pour but d'évaluer les risques de fraude associés aux matières premières shortlistées, ainsi que celles figurant déjà dans l'Annexe IX. L'évaluation se base sur les cas de fraude documentés et propose des recommandations de mesures permettant de mitiger le risque de fraude. La Tâche 3 était divisée comme suit :

- Le consortium a d'abord exploré les **cas historiques et en cours de fraude** dans l'industrie des biocarburants dans l'UE et aux Etats-Unis dans la perspective de comprendre les faiblesses du système actuel, développer des indicateurs du risque de fraude et des recommandations de nouvelles mesures pour réduire le risque. Les cas rapportés de création frauduleuse de crédits/certificats de biocarburants, ainsi que les cas de biodiesel de soja vendu comme methyl-ester d'huile usagée (UCOME) ont été documentés, ainsi que quatre cas de fraude provenant de l'industrie forestière. Des considérations supplémentaires concernant les huiles de cuisson usagées et les violations de certificat ont été prises en compte.
- Les cas de fraude documentés et l'expertise interne ont servi à **caractériser les risques de fraude.** Les risques de fraude administrative (par ex. La création de faux certificats) ou la fraude concernant la nature de la matière première (par ex. faire passer un matériau absent de l'Annexe IX pour une matière première y figurant) ont été distingués des irrégularités n'aboutissant pas nécessairement à un cas de fraude mais pouvant toutefois refléter des faiblesses systémiques dans la mise en œuvre des règles de durabilité, de traçabilité et d'assurance de la EU RED II.

- Une série **d'indicateurs du risque de fraude** a été développée pour évaluer les matières premières shortlistées et celles figurant déjà dans l'Annexe IX. Les indicateurs « primaires » (éléments encourageant la fraude) sont distingués des indicateurs « secondaires » (ou amplificateurs, c'est-à-dire les éléments facilitant la fraude). Les indicateurs primaires couvrent les caractéristiques physiques des matières premières (par ex. la possibilité d'altérer volontairement une matière première pour la faire ressembler à l'une des matières inclues dans l'Annexe IX) alors que les indicateurs secondaires traitaient des caractéristiques de la chaine de valeur (par ex. le nombre d'intermédiaires) et l'assurance (par ex. les règles de traçabilité et les compétences des auditeurs). Les indicateurs primaires et secondaires ont été combinés pour évaluer le risque global de chaque matière première.
- **Des recommandations pour des mesures de mitigation du risque** ont été développées par le consortium sur la base des mesures existantes et de l'expérience pratique des membres du consortium dans les audits et le processus de certification. Ces recommandations concernent en priorité des actions pouvant être mises en œuvre au niveau de la Commission européenne.

L'évaluation des matières premières a conduit aux conclusions suivantes :

- **Plusieurs catégories de matière première présentent un risque de fraude faible ou faible-moyen.** Pour ces matières premières, les risques de fraude peuvent être considérés comme limités et ne nécessitent pas de mesures de mitigation spécifiques au-delà des règles déjà mises en œuvre par l'UE ou les schémas volontaires.
- **Des risques élevés ont été détectés pour plusieurs matières premières**. Ceux-ci nécessitent des mesures de mitigation supplémentaire. Ces risques incluent, entre autres :
    - Les risques liés aux caractéristiques physiques des matières premières, qui sont particulièrement élevés quand la nature de ces matières ne peut pas être distinguée visuellement ou chimiquement de celle des matières ne figurant pas sur l'Annexe IX (par ex. les matières ligno-cellulosiques ou les huiles usagées).
    - Les risques de fraude liés à la définition exacte des matières premières sont particulièrement applicables aux matières innovantes, qui ne sont pas encore bien définies parmi les états membres ou en dehors de l'UE, tels que les résidus/effluents de la transformation de céréales (par ex. les rétentats d'ultrafiltration), les matières à la définition très large (par ex. les déchets biogéniques) et les matières liées à une type de culture ou de pratique agricole (par ex. les cultures intermédiaires).
    - Les amplificateurs de fraude (indicateurs secondaires) en relation avec la longueur ou la complexité de la chaine de valeur sont particulièrement importants pour les matières premières provenant de multiple sources, collectées à grande échelle et échangées globalement, telles que les dérivés d'huile de palme ou certains résidus/déchets vendus sur les marchés internationaux de carburants ou de produits chimiques (par ex. huiles usagées ou méthanol).
    - Enfin, la nature innovante de certaines matières premières et de leurs procédés de transformation présente des risques pour les systèmes d'assurance, car les auditeurs/vérificateurs pourraient manquer de connaissance ou d'expérience quant à la nature et les aspects techniques de certaines matières, ce qui affecterait la détection des non-conformités.

Aucune différence significative n'existe quant au risque de fraude entre les matières premières déjà incluses dans l'Annexe IX et les matières shortlistées pour cette étude. A ce jour, les huiles usagées présentent l'un des plus grands risques de fraude, sur la base sur les cas documentés ou suspectés. Les matières premières présentant des similarités avec les huiles usagées pourraient engendrer des risques similaires.

Les risques de fraude pourraient être mitigés par l'extension des mesures actuelles et le développement de nouvelles mesures. Les recommandations du consortium concernant les mesures de mitigation incluent, entre autres :

- L'amélioration de la formation des auditeurs et des documents-guides à leur intention (par ex. rendements typiques, test des matières premières, détermination du contenu en cellulose, utilisation des outils d'information géo-référés et traçabilité).
- Le suivi de toutes les transactions relatives à l'EU RED II dans un registre commun (Union Database).
- L'harmonisation de la définition des matières premières (par ex. via les schémas volontaires).
- Un accompagnement pour la conduite d'évaluation des conditions locales de marché et des risques liés au détournement d'une matière première de ses autres usages.

La **Table 3** et la **Table 4** résument le résultat des évaluations conduites en Tâches 2 et 3 (Voir Sections 8 et 9 pour plus de détails).

Table 3: Aperçu de l'évaluation en Tâche 2 pour les matières premières shortlistées (incl. l'éligibilité pour la partie A ou B de l'Annexe IX)

Matière première	Evaluation T2 (EU RED II – Art 28)
Résidus et déchets de boulangerie et confiserie	Risque spécifique / Partie B
Résidus et déchets de production de boissons non-alcoolisées	Risque spécifique / Partie B
Résidus et déchets de la transformation de fruits et légumes (à l'exception des queues, feuilles, tiges et coquilles)	Risque spécifique / Partie B
Pulpe de patate ou betterave	Risque significatif Partie A (Bioéthanol) Partie B (Biogaz)
Effluents amidonnés (jusqu'à 20% de matière sèche)	Risque spécifique / Partie B
Amidon sec issu du fractionnement du maïs	Risque significatif / Partie B
Rétentat d'ultrafiltration du dextrose et raffinat issu du raffinage de sucre.	Risque spécifique / Partie B
Mélasse "finale"	Risque significatif / Partie B
Vinasse	Risque spécifique (canne à sucre) Partie B
	Risque significatif ("thin stillage" ou vinasse de betterave) / Partie B
Résidus et déchets de distillation alcoolique	Risque spécifique Partie A (huiles de fusel) Partie B (tête et queue de distillation)
Drêches de brasserie	Risque spécifique / Partie B
Perméat de lactosérum (petit lait)	Risque spécifique / Partie B
Résidus d'extraction d'huile d'olive	Risque spécifique (grignons sans huile) Partie B
	Risque significatif (grignons avec huile) / Partie B

Huile de fibre de mésocarpe de palme (‘PPF oil’)	Risque spécifique / Partie B
Méthanol brut issu du procédé de Kraft	Pas de risque particulier Partie B (analyses supplémentaires requises)
Cultures de protection et intermédiaires	Risque significatif / Partie B
Biomasse issue de terres dégradées ou polluées (non-lignocellulosique/non-cellulosique)	Pas de risque particulier (Uniquement si « Low ILUC ») Partie B
	Risque spécifique (Autre) / Partie B
Cultures endommagées et impropres à la consommation humaine ou animale	Pas de risque particulier / Partie B
Graisses animales cat. 3	Risque significatif / Partie B
Sous-produits animaux cat. 2-3 (hors graisses animales)	Risque significatif (Cat. 3) Risque spécifique (Cat. 2) Partie A (biocarburants) Partie B (biogaz)
Eaux usées municipales et dérivés (hors boues d’épuration)	Pas de risque particulier Partie A (biogaz à concentration >30%) Partie B (biogaz à concentration <30% et biodiesel)
Savons et dérivés issus du raffinage d’huiles végétales (Soapstock)	Risque significatif / Partie B
Graisse brune	Pas de risque particulier / Partie B
Distillats d’acide gras	Risque significatif / Partie B
Huile “technique” de maïs (technical corn oil)	Risque significatif / Partie B
Drêches de distillerie avec solubles (DDGS)	Risque significatif / Partie A
Résidus d’extraction d’huile de tournesol à forte teneur en acide oléique	Risque spécifique / Partie B
Autres déchets biogéniques	Pas de risque particulier / Partie B
Algues de mer	Risque spécifique / Partie A
Cyanobactéries	Pas de risque particulier / Partie B

Table 4 Aperçu de l’évaluation en Tâche 3 pour les matières premières shortlistées

Matière première	Evaluation T3 (Risque général de fraude)
Résidus et déchets de boulangerie et confiserie	Moyen
Résidus et déchets de production de boissons non-alcoolisées	Faible
Résidus et déchets de la transformation de fruits et légumes (à l’exception des queues, feuilles, tiges et coquilles)	Moyen
Pulpe de patate ou betterave	Moyen
Effluents amidonnés (jusqu’à 20% de matière sèche)	Moyen-Elevé
Amidon sec issu du fractionnement du maïs	Faible
Rétentat d’ultrafiltration du dextrose et raffinat issu du raffinage de sucre.	Elevé
Mélasse “finale”	Elevé
Vinasse	Faible-Moyen

Résidus et déchets de distillation alcoolique	Moyen
Drêches de brasserie	Faible-Moyen
Perméat de lactoserum (petit lait)	Faible-Moyen
Résidus d'extraction d'huile d'olive	Faible
	Moyen-Elevé
Huile de fibre de mésocarpe de palme ('PPF oil')	Elevé
Méthanol brut issu du procédé de Kraft	Moyen
Cultures de protection et intermédiaires	Faible-Moyen (Cultures de niche ou ayant pour objectif premier la protection des sols)
	Elevé (Cultures à grande échelle, par ex. maïs, soja ou blé)
Biomasse issue de terres dégradées ou polluées (non-lignocellulosique/non-cellulosique	Elevé (Terres dégradées)
	Moyen (Terres polluées)
Cultures endommagées et impropres à la consommation humaine ou animale	Moyen
Graisses animales cat. 3	Faible
Sous-produits animaux cat. 2-3 (hors graisses animales)	Faible
Eaux usées municipales et dérivés (hors boues d'épuration)	Faible
Savons et dérivés issus du raffinage d'huiles végétales (Soapstock)	Moyen-Elevé
Graisse brune	Faible-Moyen
Distillats d'acide gras	Moyen
Huile "technique" de maïs (technical corn oil)	Moyen
Drêches de distillerie avec solubles (DDGS)	Faible
Résidus d'extraction d'huile de tournesol à forte teneur en acide oléique	Elevé
Autres déchets biogéniques	Moyen
Algues de mer	Moyen-Elevé
Cyanobactéries	Moyen-Elevé

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6. INTRODUCTION AND BACKGROUND

The Recast of the EU Renewable Energy Directive (2018/2001) – also known as "EU RED II" includes a 32% target for renewables in total EU energy consumption in 2030, with a specific sub-target for renewables in transport of 14%. Currently, biofuels constitute the largest share of renewables in transport. However, several conventional biofuels offer limited greenhouse gas savings and are associated with food security and land-use change emissions risks. Consequently, the EU RED II imposes a phase-out by 2030 of conventional feedstocks deemed at higher risk of indirect land use change impacts and defines a cap for other conventional feedstocks. Additionally, EU RED II aims to further incentivise the use of advanced biofuels produced from feedstocks listed in Annex IX – Part A, which are associated with lower risks of indirect environmental and socio-economic impacts, and which require advanced technologies for conversion to biofuels. The EU RED II includes a 3.5% sub-target for these advanced biofuels in 2030, with EU Member States being allowed to double count the energy content of advanced biofuels towards these targets. Biofuels produced from feedstocks listed in Annex IX – Part B (animal fats and used cooking oil), which involve the use of mature conversion technologies, can also be double counted towards the renewables in transport target. However, their contribution to these targets is capped. EU MSs can make a case for extending this cap.

As a potentially large number of raw materials that could meet the requirements for inclusion in Annex IX are at present not included in the list, the EU RED II includes a mechanism (Art 28. Paragraph 6) whereby the European Commission can adopt delegated acts to add feedstocks to Annex IX (Part A or Part B), but not to remove them. Such delegated acts must build upon a careful evaluation of the characteristics of candidate feedstocks, taking into account circular economy principles, the EU Waste Directive, sustainability criteria, risks of distortive market effects, greenhouse gas savings, other environmental impacts and potential additional demand for land. Fraud risks must also be taken into account, especially regarding the origin and chemical composition of feedstocks.

The project "Assessment of potential of new feedstocks for the production of advanced biofuels" has aimed to support the European Commission (DG ENER) in the process of identifying candidate feedstocks for inclusion in EU RED II Annex IX and evaluating them against the criteria laid out in Article 28(6) of EU RED II. In addition, the study has informed the Commission on fraud risks associated with feedstocks listed in Annex IX, and any feedstocks identified as meeting the requirements for addition to Annex IX. The project Consortium has also made proposals for the development of robust and cost-effective fraud mitigation mechanisms.

The project was divided into three Tasks:

- **Task 1** established a long list of potential biofuel feedstocks for inclusion in Annex IX and conducted a preliminary assessment of these feedstocks based on basic eligibility criteria to produce a short list for further assessment in Task 2 and 3. The shortlist was based on the Consortium's expertise, a literature review and two rounds of **stakeholder consultation**. The final selection of the shortlist of feedstocks for consideration under Task 2 and Task 3 were made by the Commission.
- **Task 2** involved the detailed assessment of each shortlisted feedstock against the criteria described in Article 28(6) of the EU RED II. The Consortium provided the

European Commission with its conclusions with regards to how each feedstock in the short list performed against these criteria.

- **Task 3** looked specifically at the risk of fraud associated with support for the use of new and existing Annex IX feedstocks. Informed by consideration of documented cases of fraud, the Consortium established a set of fraud risk indicators and considered options available to mitigate identified fraud risks.

The three tasks in this project are summarised in Figure 1.

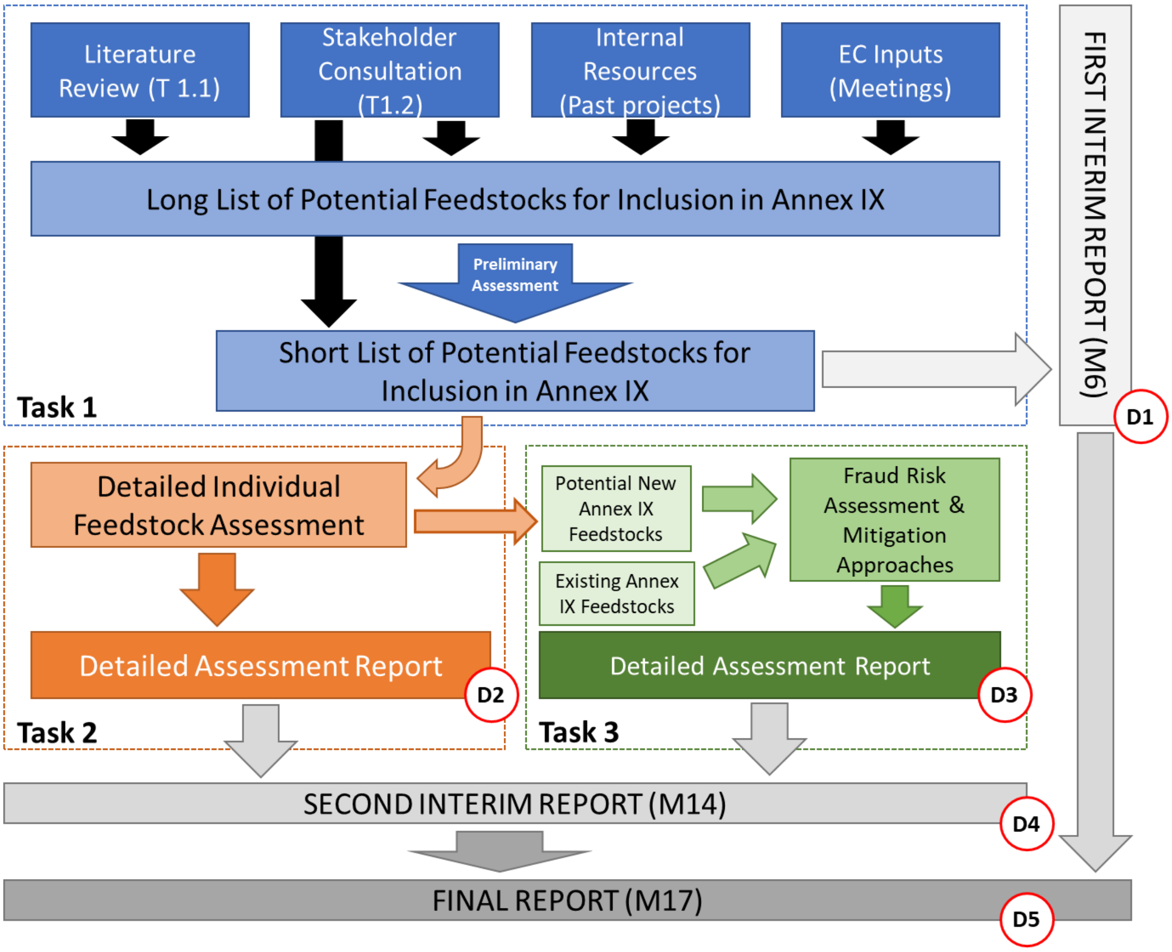

Figure 1: Overview of the project tasks and deliverables

The outcomes of the project will inform the European Commission in the development of a Delegated Act to amend Annex IX, as per EU RED II Article 28(6). The Delegated Act process involves the consultation of experts delegated by EU member states and public/private organisations. To the extent possible outcomes from the expert consultation workshops organised by the European Commission will feed into this project. It is however important to underline the fact that the decision to propose new feedstocks for inclusion in Annex IX lies with the European Commission via the Delegated Act, not with this project.

7. TASK 1 - LITERATURE REVIEW, STAKEHOLDER CONSULTATION & PRELIMINARY FEEDSTOCK ASSESSMENT

7.1. OBJECTIVES

To establish a long list of potential biofuel feedstocks for inclusion in Annex IX and to conduct a preliminary assessment of these feedstocks to produce a short list for further assessment in Task 2 and 3.

7.2. METHODOLOGY

7.2.1. Summary of literature review

The Consortium conducted a comprehensive literature review to identify potential biofuel feedstocks. Specifically, we reviewed 61 publications, including policy regulations, peer reviewed journal articles, technical reports from private and public sectors, and position papers from the private sector. We kept a literature review log, recording for each source the publication type, publication title, authors or publishing organisation, year of publication, a brief summary/description (focusing on information relevant to eligibility for shortlisting and on information relevant to the assessment in task 2and task 3), and noting feedstocks covered. A full list of reviewed publications as well as the feedstocks covered by each publication can be found in Annex A.

Journal articles, technical reports, and position papers from the private sector all helped the Consortium to identify novel biofuel feedstocks and contributed to the development of an initial long list of 127 distinct feedstocks. In addition, these publications provided useful information on the origin and production process of the feedstocks and alternative uses, which served as supporting evidence for the preliminary assessment used to shortlist feedstocks for further assessment in Tasks 2 and 3. Moreover, some of the journal articles and technical reports fed into Tasks 2 and 3 as some studies evaluated the feasibility, economics, market impacts, and sustainability performance of using certain feedstocks for biofuels.

Policy regulations included in our literature review were useful in providing context on definitions of feedstocks and feedstock categorizations. For example, Regulation (EC) 1069/2009 and national regulations helped in identifying the definition of different categories of animal by-products.

While the literature review process was helpful in the preliminary assessment, it was insufficient to comprehensively conduct the preliminary assessment, especially for some feedstocks of low commercial interest, for which limited literature exists. Moreover, different studies sometimes provided contradicting information on certain feedstocks; for instance, one study may have categorized a feedstock as waste while another may have reported the use of that feedstock in some industries. The stakeholder consultation complemented the literature review and helped resolve most of these questions. In particular, experts from various industries were able to provide more detail on the feedstocks they have worked with, especially regarding production processes and alternative uses. Stakeholders also identified additional feedstocks that the Consortium did not capture through literature review (See next section).

7.2.2. Summary of stakeholder consultation

The **stakeholder consultation** organised as part of **Task 1**, was divided in two rounds. These aimed at providing additional expertise and documentation to support the Consortium with the identification of feedstocks to be shortlisted and taken for a more in-depth evaluation in Task 2 and Task 3.

First round

The **first round** was held in April-May 2020. In total, 427 feedstock-specific suggestions were received from 79 organisations. 14 additional contributions were received, but these were high-level comments regarding the process and did not include any specific suggestions regarding the evaluation of feedstocks. These contributions were passed on to DG ENER separately.

Among the contributions received, certain feedstocks or feedstock categories were more significantly represented. The Consortium received:

- 123 suggestions related to residues and waste from food and feed processing;
- 57 suggestions related to animal by-products (including fats);
- 33 suggestions related to intermediate/cover crops;
- 33 suggestions related to soapstock, acid oil, FFA and other derivatives from oleochemical processing; and
- 30 suggestions related to Fatty Acid Distillates (FADs).

The Consortium followed a systematic process to review and evaluate stakeholder contributions. The following criteria were used to evaluate whether feedstocks should be added to the short list for further investigation:

1. **Does the feedstock qualify as biomass?** Feedstocks from non-biogenic origin (e.g. fossil-based plastics) were systematically excluded. CO_2 was not considered to be consistent with the definition of biomass, since it is not biodegradable; furthermore, it is not an energy carrier, and therefore not a biofuel feedstock. CO_2-derived fuels are included in EU RED II as Recycled Carbon Fuels or Renewable Fuels from Non-biological Origin.

2. **Does the feedstock qualify as food/feed crop as per EU RED II definition?** Feedstocks qualifying as food/feed crop were systematically excluded.

3. **Is the feedstock already covered in Annex IX?** The Consortium used the additional description of feedstock production processes and end-uses to establish a solid rationale as to whether the feedstock can be considered covered by Annex IX or not.

Suggestions in favour of the removal of existing Annex IX feedstocks were disregarded, since this was outside the scope of this study.

Qualification of feedstock as **food/feed crop** was not always possible with the current information and documentation provided by stakeholders. It was particularly important to determine whether crop-derived material qualifies as a residue, in which case it could be shortlisted provided that it was not already covered by current Annex IX categories. The Consortium did not come to a clear conclusion regarding the food/feed crop status of four feedstocks, namely potato/beet pulp, molasses, fatty acid distillates (FADs) and distillers grains and solubles (DGS). Following internal discussions, the Consortium came to the conclusion that no simple investigation could be conducted within Task 1 to determine whether these feedstocks would unambiguously qualify as food/feed crop. It was therefore decided to include all four feedstocks in the shortlist to further evaluate them as part of Task 2.

Similarly, **current coverage of some of the suggested feedstocks in Annex IX** was unclear, in particular for Annex IX - Part A d) (Biowaste) and whether feedstocks are fit for use in the food/feed chain. Most of the feedstocks selected for a second round of consultation were those for which additional evidence was needed to determine whether they are already included in Annex IX.

Consequently, the review process resulted in three outcomes for the suggested feedstocks (see Figure 2):

1. "**Include in shortlist"** meant that the project Consortium had enough information to conclude that the feedstock met the evaluation criteria and could be directly shortlisted for further evaluation in Task 2 and Task 3. Four feedstocks (see above), for which alignment with the food/feed crops definition could not be determined, were also added to the shortlist;

2. **"Do not include in shortlist"** meant that the project Consortium had enough evidence to conclude that the feedstock did not meet the evaluation criteria and should not be shortlisted for further evaluation in Task 2 and Task 3. This could be for several reasons (see Figure 1). Although they met the evaluation criteria, the Consortium initially suggested not to include sea algae and cyanobacteria as no meaningful inputs, evidence or documentation was provided during the first stakeholder consultation (both sea algae and cyanobacteria were re-included in the shortlist after the second round of consultation at DG ENER's request); or

3. **"Take feedstock to a second round of consultation"** meant that the project Consortium did not have enough evidence to conclude whether the feedstock is currently covered by Annex IX categories and should, or should not, be shortlisted.

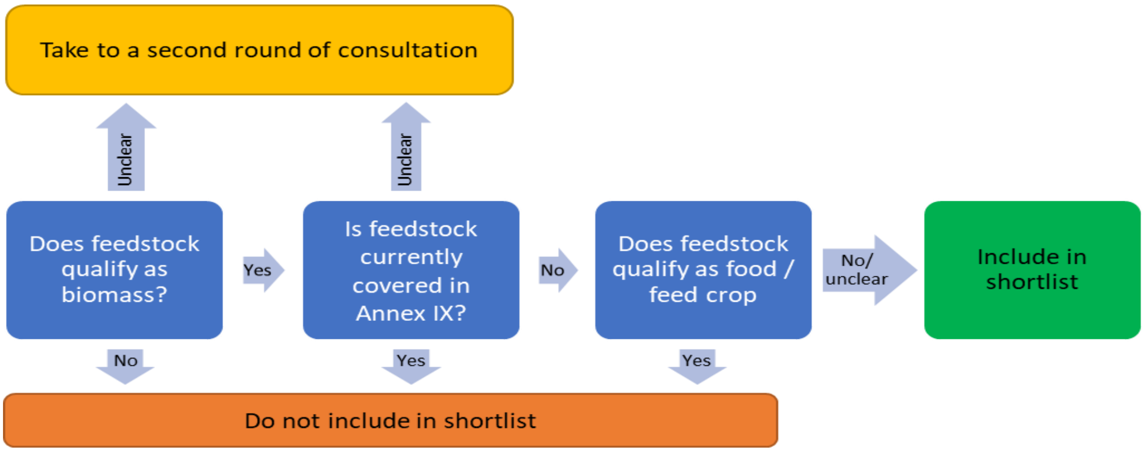

Figure 2: Summary of the review process (1st round)

Second round

The **second round** was held in August-September 2020 and aimed to determine whether to include feedstocks for which the preliminary assessment remained inconclusive after the first round.

Therefore, the second round focused on feedstock-specific questions, namely:

Q1 The following feedstocks appear to be largely used for energy recovery at present (e.g. on-site heat, biogas or liquid biofuels). Is it correct that energy recovery is common from these materials? Are there any other uses currently made of these feedstocks?

- Bakery and confectionery residues and waste (e.g. Residues and waste from bread, biscuits, wafers, etc.)

- Drink residues and waste (e.g. citrus peel and pulp pressing)
- Fruit / vegetable residues and waste (e.g. defective fruit /vegetables)
- Beans, silverskin, and dust (excluding nut shells) generated during processing of cocoa / coffee beans and hazelnuts
- Starchy effluents from corn and wheat processing (e.g. starch slurry, steep water, Dry starch, thin stillage)
- Alcoholic distillery residues and waste (e.g. heads and tails; fusel alcohols/oils; technical ethanol)
- Spent coffee grounds and spent tea leaves
- Dairy waste scum
- Non-edible cereal residues (residues from grain milling)
- By-products obtained during and from the production of rice and its derivatives
- Biogenic fraction (oil) of end-of-life tyres
- Humins (Residues from bio-based FDCA)

Q2 Do you think that Palm mesocarp fibres shall be considered as covered under Annex IX - Part A (g), which covers Empty Palm Fruit Bunches? Why?

Q3 It is our understanding that fish oil is extracted during the processing of fish for food/feed purposes (e.g. filleting), which makes it an animal by-product category 3, as per Regulation EC 1069/2009. Are you aware of any lower-grade fish oil, which could qualify as animal by-product category 2 or 1?

Feedback specific to these three questions posed in round 2 were received from 35 organisations. 6 additional contributions were received which will be assessed and will be passed on to DG ENER separately. The review of stakeholder contributions in round 2 led to the shortlisting of 7 additional feedstocks, resulting in a final shortlist of 32 feedstocks in 8 categories.

Figure 3 summarises the process leading from the initial longlist to the shortlist included in Section 7.3.9.

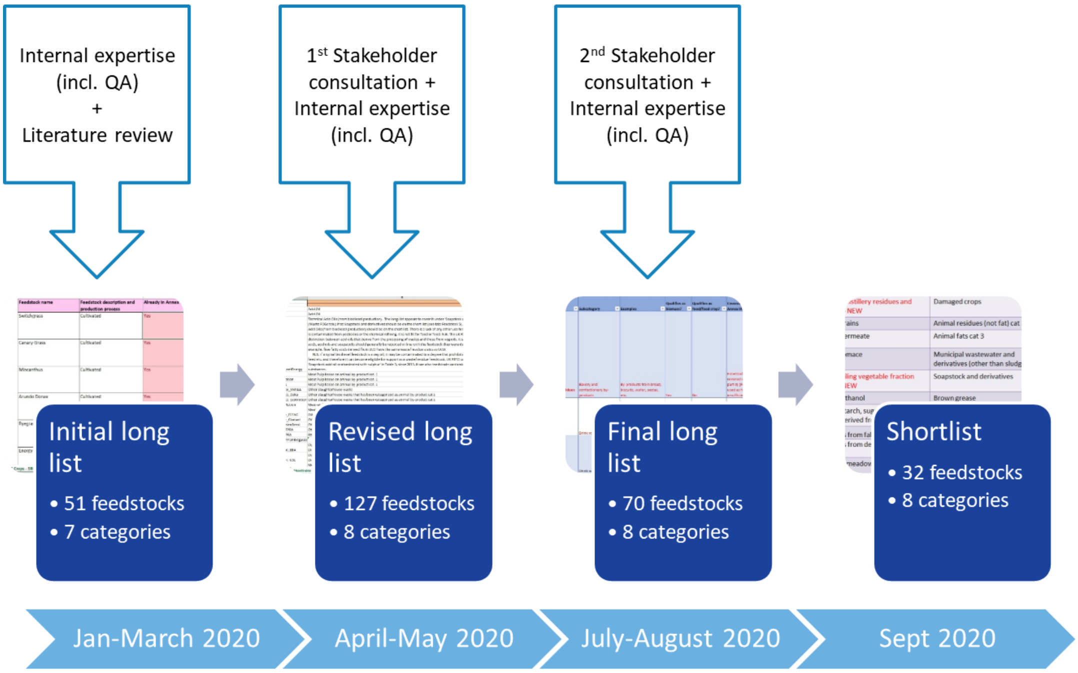

Figure 3 Process involved in working through the initial long list to the shortlist

7.3. RESULTS

7.3.1. Food-feed processing residues and waste

7.3.1.1. Definition

Food and feed processing residues and waste is a broad category, which includes feedstocks generated during the manufacturing of food (e.g. bread, bakery, alcoholic and non-alcoholic drinks, vegetable/fruits, hot beverages, etc.) and feed products. These products are distinct from residues generated on-farm when food or feed crops are harvested and undergo some initial processing (e.g. threshing, winnowing, etc.). This feedstock category does not include animal by-products, which are addressed in a separate section (See Section 7.3.5).

Food and feed processing residues and waste may currently be discarded, used to produce feed or used for energy recovery, including liquid biofuels, biogas or heat generation.

7.3.1.2. Description of feedstocks:

This category includes:

- **Bakery and confectionery residues and waste**. This refers to the residues and waste generated during the manufacture of food products derived from cereals, such as bread, pasta, wafers, biscuits. These feedstocks do not include dairy residues and waste or animal by-products, which are addressed in a separate category.
- **Drink production residues and waste**. This feedstock refers specifically to the residues and waste generated during the making of non-alcoholic drinks, including but not limited to fruit pulp and peeling (e.g. citrus).
- **Drink waste**. This feedstock refers specifically to alcoholic and non-alcoholic drinks considered unfit for human consumption and should otherwise be discarded, as well as spent alcohols.
- **Fruit / vegetable residues and waste**. This feedstock includes materials generated through the processing (e.g. peeling, chopping, pressing etc.) of fruits and vegetables into food items, such as sauces, yogurts, soups, ice creams, etc. They also include tails, leaves, stalks and husks, as well as fruits and vegetables considered defective and unfit for human consumption. Finally, potato/beet pulp generated through the extraction of starch or sugar is also included in this category.
- **Bean shells, silverskin, and dust**. This feedstock includes materials generated through the processing of cocoa, coffee and hazelnut. They do not include nutshells.
- **Shells/husks and derivatives**. This category covers nutshells, soy hulls and all their derivatives (e.g. oil).
- **Starchy effluents (up to 20% dry matter content)**. This category includes various effluents (e.g. slurry, steep water) from the milling and processing of starchy crops such as corn and wheat into food or ethanol. While these effluents include a significant concentration of nutrients such as starch and sugars, they are generally used onsite for additional ethanol production due to fact they tend to degrade rapidly, which would make their storage and shipping difficult practically.

- **Dry starch from corn fractionation** (identified as 'corn processing residues' during the preliminary assessment). This feedstock only includes dry starch when generated through the dry fractionation of corn, which also generates protein-rich meals and corn oil.
- **Sugar extraction residues and waste**. This feedstock includes residues and waste extracted through the processing of cereals (e.g. corn and wheat) to produce sugars such as glucose, fructose or dextrose. Filtration and retention steps generate some residues and waste called 'retentate', which can be used for energy recovery. This category also includes monohydrate hydrol.
- **Molasses**. Molasses is a residue generated through the third round of sugar crystallisation (residues from the 2nd crystallisation are called "égouts pauvres" and are not included in this category). Molasses can be used for food, feed and energy recovery.
- **Vinasse**. This feedstock is the residue from alcoholic fermentation of sugar. Thin stillage from corn fermentation is also included in this category. These feedstocks can be used as adhesives and for energy recovery.
- **Alcoholic distillery residues and waste.** This feedstock includes heads and tails, fusel oils/alcohols and technical ethanol, which are extracted from the making of spirits for human consumption. They are considered as waste under Regulation 200/532/EC.
- **Spent grains**. These residues are obtained after the brewing of grains to produce beer. They contain nutrients in high concentration and are generally used to produce cattle feed, as well as human food items.
- **Residues and waste from production of hot beverages**. This feedstock includes spent coffee grounds and tea leaves (from industrial coffee/tea making, bars and restaurants, as well as households).
- **Dairy waste scum**. This feedstock is a residue from dairy production, which is not considered fit for food or feed consumption.
- **Food waste oil**. This residual oil can be extracted from food waste collected from households, restaurants or industries. This category does not include used cooking oil or brown grease.
- **Whey permeate**. This feedstock is obtained through the curdling and straining of milk, e.g. in the making of cheese. It is rich in protein and is used for feed and food purposes.
- **Non-edible cereal residues and waste from grain milling and processing**. This feedstock includes cereal residues considered unfit for either food or feed purposes, such as bran.
- **Olive oil extraction residues and waste**. This feedstock includes olive pomace, which is generated from the first pressing of olive to generate oil. Pomace can be further pressed to extract lower grade oil and other derivatives. This category also includes olive stones.

7.3.1.3. Summary of the preliminary assessment:

- All the materials considered in this category qualify as **biomass**.
- None of these materials were considered as falling under **EU RED II food/feed crop definition**, with the exception of:
  - *Potato/beet pulp*. While pulp may be considered as a secondary product in specific value chains in which starch or sugar are the primary products, it is not the case in ALL value chains using potato and beet. In value chains

producing potato-derived food products (e.g. chips, fries, mashed potatoes) as well as beets used directly as vegetable, pulp would actually be considered a primary product, thus falling under the food/feed crop definition. Therefore, the assessment was inconclusive.

    - *Dry starch from corn fractionation*. Although the dry fractionation process for corn produces outputs (protein-rich meal and corn oil) with a higher value per tonne than dry starch , , dry starch accounts for a large share of the overall value. In its more fundamental food/feed use, dry starch is an essential nutrient and cannot be universally considered as a residue. Here again, the assessment was inconclusive.

    - *Molasses*. Although molasses is considered a low-grade residue from sugar refining, it is widely used for food and feed purposes, and therefore could possibly be considered one of the multiple primary products from sugarcane or sugar beet production. Therefore, the assessment was inconclusive.

- All materials, which were defined as waste through the preliminary assessment are considered as **being currently covered under Annex IX - Part A** b), c) or d) and therefore not shortlisted. These include:

    - Drink waste

    - Fruit/vegetable tails, tops/leaves, stalks and husks (subset of fruit/vegetable residues and waste)

    - Bean shells, silverskin and dust. Note that cocoa bean shells are considered covered in Annex IX - Part A p), i.e. as cellulosic material.

    - Residues and waste from production of hot beverages

    - Dairy waste scum

    - Food waste oil

    - Olive stones

In addition, nutshells and soy hulls are covered by Annex IX - Part A l) and p).

All other materials in this category were shortlisted for further assessment, including starchy effluents and sugar refining residues, for which the coverage under current Annex IX could not be unequivocally established.

Shortlisted feedstocks in this category therefore include:

- **Bakery and confectionery residues and waste.**

- **Drink production residues and waste.**

- **Fruit / vegetable residues and waste (except tails, leaves, stalks and husks).**

- **Potato/beet pulp.**

- **Starchy effluents (up to 20% dry matter content).**

- **Dry starch from corn fractionation.**

- **Sugar extraction residues and waste.**
- **Molasses.**
- **Vinasse.**
- **Alcoholic distillery residues and waste.**
- **Spent grains.**
- **Whey permeate.**
- **Olive pomace and derivatives.**

7.3.1.4. *Outlook for Task 2 and Task 3*

A large number of individual feedstocks were grouped in this category and required specific assessments in Task 2 and Task 3 to fully understand their potential for inclusion in Annex IX. Understanding potential other uses and the impact of an increased used for biofuels, bioliquids or biogas on other sectors (esp. the feed sector) using the same material was particularly important in this category. In certain cases, the practicality and economic viability of other uses will need to be evaluated in detail, for example with feedstocks that tend to degrade rapidly and for which an on-site use is appropriate. Finally, participants in the stakeholder consultation flagged a significant potential for fraud in these feedstock definitions that involve the notion of being unfit for human or animal consumption, non-edible or "spent". A risk exists that operators may purposefully transform food or feed products into non-edible products to benefit from related incentives. These risks were evaluated and addressed in Task 3.

7.3.2. Agricultural / Forestry residues and waste

7.3.2.1. *Definition:*

This category of feedstocks includes raw materials corresponding to the EU RED II definition, namely residues (and waste) that are directly generated by agriculture (…) and forestry and that do not include residues from related industries or processing.

It is important to note that the selection of agricultural and forestry residues and waste made for this project did not intend to comprehensively cover all residues and waste, since many were already covered in the existing Annex IX.

7.3.2.2. *Description of feeds*tocks:

This category includes the following feedstocks:

- **Agricultural harvesting residues.** This feedstock includes materials left on the field after harvesting and on-farm processing of the main product (e.g. cereals, oilseeds, beets, etc.) and include straws, stems, stalks, shells (NB: not nuts, which are treated separately), among others. Note these do not include residues from off-farm processing of agricultural products (e.g. food manufacturing).

- **Palm harvesting residues.** This feedstock includes residues left on the field after harvesting palm fruit bunches (e.g. palm fronds), palm tree trunks removed from the plantation, and palm mesocarp fibres[1].
- **Cotton seeds.** Cotton seeds are extracted from cotton bolls, along with cotton lint. Cotton seeds contain some oil, which can be used for food, feed or cosmetic purposes.
- **Wood processing residues.** This feedstock includes materials obtained through the wood pulping process, including crude tall oil and raw material.
  7.3.2.3. *Summary of* the preliminary assessment:

- All feedstocks included in this category were unequivocally considered as **biomass**, as per the EU RED II definition.
- None of the feedstocks included in this category were evaluated as <u>not</u> fitting the '**food/feed crop**' definition, apart from cottonseeds:

  - **Agricultural harvesting residues** were unequivocally evaluated as not fitting the food/feed crop definition, since they are not the primary aim of the agricultural production process.

  - Similarly **palm harvesting residues** were unequivocally evaluated as not fitting the food/feed crop definition, since they are not the primary aim of the palm oil production process.

  - The case of **cotton seeds** required more investigation and discussion. The suggestion to shortlist cottonseeds came from Greek stakeholders, who provided a comprehensive set of references, which tend to demonstrate that cottonseeds are currently being used for biodiesel production without creating competition with other uses. In addition, stakeholders quoted market prices for cottonseeds amounting to around 10% of the price for cotton fibres. Additional investigation by the project Consortium, however, revealed some geographic variability in the use of cotton seeds, which are widely used as feed or for cosmetic production in other regions[2]. In addition, other price statistics tend to show that the relative value of cottonseeds to cotton fibres could be significantly higher than 10%. Given that feedstocks listed in Annex IX cannot be restricted to specific geographies, the Consortium concluded that cottonseeds fit the definition of food/feed crop in certain contexts.

  - **Wood processing residues** were unequivocally evaluated as not fitting the food/feed crop definition, since they are generated from non-crop chains (forestry).

- **Current coverage in Annex IX** yielded variable results for this category, specifically:

  - All **agricultural harvesting residues** in the selection were unequivocally considered as being covered under Annex IX - Part A (p) as *other non-food cellulosic material*.

  - **Palm fronds** were considered as being covered in Annex IX - Part A p), since these are composed of cellulose, but with a lower lignin content than ligno-cellulosic material. In turn, **palm trunks** (non-log grade) were also considered covered by current Annex IX - Part A q), i.e. *other ligno-*

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[1] Technically, palm mesocarp fibers are not harvesting residues, since they are generated during the process of oil extraction from palm fruits. These were grouped with palm harvesting residues to reduce the number of feedstock categories in the preliminary assessment.
[2] See examples in https://apps.fas.usda.gov/psdonline/circulars/oilseeds.pdf

cellulosic material except saw logs and veneer logs, although fraud risk around their significant starch content will require further evaluation. **Palm mesocarp fibres** were taken to a second round of consultation, which led the project Consortium to conclude they can be considered covered by Annex IX - Part A p), i.e. *Non-food cellulosic material*. **Oil palm mesocarp fibre oil** (identified as 'palm mesocarp oil' during the preliminary assessment), in turn, is not currently covered by any category in Annex IX.

- **Cotton seeds** are not covered in Annex IX.

- **Raw methanol from wood pulp production.** While several wood processing residues are specifically mentioned under Annex IX - Part A o), namely *Biomass fraction of wastes and residues from forestry and forest-based industries*, this is not the case for raw methanol generated through wood pulp production.

As a result of the preliminary assessment, the Consortium suggested shortlisting the following feedstocks for an in-depth evaluation in Task 2 and Task 3:

- **Oil palm mesocarp fibre oil**
- **Raw methanol**

7.3.2.4. *Outlooks for Task 2 and Task 3:*

The project Consortium did not anticipate any major issue with the evaluation of palm mesocarp fibres. One important point is that the oil extracted from mesocarp fibres is chemically comparable to crude palm oil (although it is of lower grade) and cannot be considered as feedstock for advanced biofuel conversion technologies. This similarity would create fraud risks, as mesocarp fibre oil cannot be easily distinguished from crude palm oil if physically mixed.

Although not retained in the shortlist, palm trunks illustrate the complexity of classifying trees/crops containing both ligno-cellulose and starch/sugar. In such case, a risk exists that ethanol produced out of the starch contained in palm trunks would also count as "advanced" while it is obtained through a conventional technology. More investigation of the actual likelihood of such case should be pursued.

Raw methanol is an important chemical with multiple uses, including as a fuel. Potential competition and knock-on (market) effects were further investigated during Task 2 evaluation.

7.3.3. Intermediate crops

7.3.3.1. *Definition*

Intermediate crops are not the primary crop cultivated on an agricultural land. They include cover crops, catch crops and rotation crops, which EU RED II does not fully define. Therefore, additional definitions were developed for the purpose of this evaluation.

- EU RED II defines **cover** (and ley) **crops** as "temporary, short-term sown pastures comprising grass-legume mixture with a low starch content to obtain fodder for livestock and improve soil fertility for obtaining higher yields of arable main crops." Under this definition, cover and ley crops are already covered in Annex IX - Part A p) (non-food cellulosic material). The use of the term "pasture" in the definition seems, however, to exclude other type of agricultural lands. Therefore, this project aims to explore the possibility to use a broader definition of a **cover crop**, in line with the InterActive Terminology for Europe (IATE), which has several definitions revolving around the purpose of cover crops being the reduction of erosion and the improvement of soil fertility. Therefore, the definition of a cover crop in this project is "any crop, natural or introduced, that is not the primary crop cultivated in a field, which protect lands from erosion and/or increase soil fertility by forming a living vegetative cover".

- EU RED II only mentions catch crops and cover crops as <u>examples</u> of **intermediate crops**. The IATE defines a **catch crop** as "a fast-growing crop planted in a field in a period when no main crops are being grown there, either for market or to prevent the soil losing nutrients". Other examples of intermediate crops may exist.

- The IATE database includes definitions of **rotation** as an "agricultural practice in which different crops are cultivated in succession on the same area of land over a period of time so as to maintain soil fertility and reduce the adverse effects of pests", as well as "any field or aquatic crops, which may be produced after the harvest of a pesticide treated primary crop (or in some cases replanting of crops after failure of the pesticide treated primary crop)" (Original Ref: OECD[3]).

Finally, IATE's definition of an intermediate crop is "a fast-growing crop planted in a field in a period when no main crops are being grown there, either for market or to prevent the soil losing nutrients" (Original ref: Eurostat[4]). Therefore, in the context of this evaluation, an intermediate crop is a crop grown on an agricultural land, which is not the primary crop cultivated, include catch crops, cover crops and rotation crops. The primary crop occupies land over the longest period in the year and requires the largest share of agricultural inputs (work, fertilisers, pesticides).

7.3.3.2. *Description of feedstocks:*

This category includes:

- **Grain, starch, sugar, oil, beans and meals derived from rotation crops, cover crops and catch crops.** Examples include camelina, *Brassica carinata*, castor, *Silphium perfoliatum*, tall wheat grass or tobacco grown as intermediate crop. Any part of the plants (e.g. grain, starch, oil, beans, meals, etc.) can be used under this category.

7.3.3.3. *Summary of the preliminary assessment:*

- Feedstocks under this category match the definition of **biomass** in EU RED II.

- **Grain, starch, sugar, oil, beans and meals derived from rotation crops, cover crops and catch crops.** The Consortium concluded that this category corresponds to the definition of intermediate crops (See above), which are namely excluded from the **food/feed crop definition in EU RED II**.

- None of the feedstocks in this category were considered currently covered in Annex IX.

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[3] http://www.oecd-ilibrary.org/environment/oecd-guidelines-for-the-testing-of-chemicals-section-5-other-test-guidelines_20745796
[4] http://ec.europa.eu/eurostat/statistics-explained/index.php/Glossary:Arable_land_covered_with_cover_crop_or_intermediate_crop

As a result of the preliminary assessment, the Consortium suggested shortlisting the following feedstocks for an in-depth evaluation in Task 2 and Task 3:

- **Grain, starch, sugar, oil, beans and meals derived from rotation crops, cover crops and catch crops.**

7.3.3.4. *Outlook for Task 2 and* Task 3:

The notion of intermediate crop defined in this category is broad and includes a large number of crops grown covering several geographic and agricultural situations. Therefore, the Consortium anticipated the need to look more specifically at each crop type to properly address their characteristics in Task 2 and Task 3. The notion of "primary crop" vs secondary or tertiary crop may be challenging to define unambiguously whenever several crops of high economic value are cultivated in rotation. The Consortium further defined the conditions under which crops could be considered as being used in rotation with primary crops (See Task 2). The approach used for this category built upon other EU-funded projects revolving around the notion of "low indirect land-use change", which regards a number of agricultural practices allowing the extraction of biofuel feedstocks without a significant demand for additional land.

7.3.4. Landscape care biomass

7.3.4.1. *Definition*

The notion of "landscape care (management) biomass" is not included in EU RED II; it was developed in the EU-funded S2Biom project[5]. Under this notion, the Consortium included activities requiring the removal of biomass to protect and/or maintain the state and functions of natural or non-natural (e.g. agricultural lands, residential areas, roads, etc) landscapes. Such activities include the removal of invasive species, the maintenance of protected areas, roadside mowing, the rehabilitation of degraded or polluted lands and the harvesting of biomass from fallow land or mixed meadows.

Therefore, any plant harvested for such purposes and its component (e.g. grain, fruits, stems, leaves, nuts, etc.) is covered under this definition.

7.3.4.2. *Description of feedstocks:*

This category includes:

- **Biomass from fallow land.** In line with the European Environment Agency's definition[6], fallow land in this project is defined as "Land area normally used for crop production but left unsown for one or more growing seasons."

- **Biomass from degraded/polluted land.** EU RED II considers lands as "severely degraded" if, for a significant period of time, they have either been significantly salinated or presented significantly low organic matter content and have been severely eroded. For the purpose of this preliminary assessment, degraded and polluted lands are considered as lands being eroded, salinated or polluted by chemicals to a point, which prevents natural regeneration, crop production according to standard practices or animal grazing. The exact definition of degraded and polluted lands was further

[5] https://www.s2biom.eu/en/
[6] https://www.eea.europa.eu/help/glossary/gemet-environmental-thesaurus/fallow-area

discussed and finalised in Task 2 and Task 3, in consultation with the European Commission.

- **Biomass from maintenance operations**. This subcategory includes biomass extraction activities required to maintain/protect roadsides, railways, agricultural lands, recreational natural areas and environmental protection areas, among others. This includes the removal of invasive species and reduction of bush encroachment.

- **Biomass harvested from mixture meadow.** A mixture meadow is a type of grassland used primarily and permanently for hay. Unlike fallow, it is not used to grow crops outside fallow periods. The types of plants found in a mixture meadow include Timothy grass, tall fescue and clover/legumes.

- **Damaged trees.** This feedstock includes trees, which no longer qualify as timber, log or pulp grade, due to natural causes. Intentionally induced damage is not covered in this category.

- **Damaged crops.** This feedstock includes crops which are no longer usable for food or feed purposes, for example due to an excessive contamination by pollutants or infection by bacteria, fungi, viruses or any other pest. Intentionally induced damage is not covered in this category.

- **Unused feed/fodder from ley.** This feedstock includes biomass harvested from ley land, which is not used as feed or fodder.

7.3.4.3. *Summary of the preliminary assessment:*

- All feedstocks under this category match the definition of **biomass** in EU RED II.

- None of the feedstocks included in this category was considered covered by the **food/feed crop definition in EU RED II**. This is either because feedstocks are not crops, or because they became unfit for food/feed production.

- Several feedstocks under this category were considered currently covered in Annex IX, namely:

    - **Biomass from maintenance operations.** Biomass harvested for maintenance purposes from public parks or garden can be considered as biowaste under Annex IX - Part A c). Biomass harvested for forest maintenance would either fall under p) (non-food cellulosic material) or q) (non-log/veneer ligno-cellulosic material) of Annex IX - Part A. Finally, any weed or bush harvested for maintenance purposes on other environmental protection areas would be considered covered by Annex IX - Part A p) or q).

    - **Damaged trees.** Wood from damaged trees do no longer qualify as log or veneer grades and is therefore covered under Annex IX - Part A q). Other parts of trees can be considered covered under Annex IX - Part A o).

    - **Unused feed/fodder from ley.** Biomass from ley crops is covered by the definition of non-food cellulosic biomass under Annex IX - Part A p).

All other feedstocks were considered as not being currently covered in Annex IX. Ligno-cellulosic and non-food cellulosic biomass from fallow land, mixture meadow and damaged crops would be covered under Annex IX - Part A p) and q), but not other parts of the plants such as fruits, seeds or grain.

As a result of the preliminary assessment, the Consortium suggested shortlisting the following feedstocks for an in-depth evaluation in Task 2 and Task 3:

- **Biomass from fallow land (Non-lignocellulosic/non-cellulosic).**
- **Biomass from degraded/polluted land (Non-lignocellulosic/non-cellulosic).**
- **Biomass harvested from mixture meadow (Non-lignocellulosic/non-cellulosic).**
- **Damaged crops.**

7.3.4.4. *Outlook for Task 2 and Task 3:*

This feedstock category also includes a large number of feedstocks from different plants growing in a wide range of conditions. Therefore, Task 2 and Task 3 took their specificities into consideration when evaluating their potential eligibility for inclusion in Annex IX and their fraud risks.

An important focus will be put on ambiguous terms such as degraded land or damaged crops, which will require further discussion with DG ENER. The conditions under which a land can be considered degraded or plants considered damaged will need to be precisely defined and consistently applied. It will be particularly important to evaluate the fraud risk of damaged crops.

7.3.5. Animal residues and waste

7.3.5.1. *Definition*

Animal residues and wastes are generated in the process of slaughtering livestock and preparation of meat, in line with the residue and waste definitions of the EU RED II and Waste Framework Directive. These materials are usually the parts not desirable for human consumption having no value in the food market. There are three categories of animal by-products in accordance with European Legislation (EC) 1069/2009: category 1 is for the most contaminated by-products with high risk; category 2 is also classified as high risk and is for by-products not falling under category 1 or category 3; category 3 is for the least contaminated by-products that are fit for human consumption but are not intended to be for commercial reasons.

7.3.5.2. *Description of feedstocks:*

This category includes:

- **Animal fat (Category 1-2).** This refers to poultry, swine fat and tallow (cattle fat) that is considered suitable only for energy generation and chemicals.
- **Animal fat (Category 3).** This refers to poultry, swine fat and tallow (cattle fat) that can be used for animal feed, cosmetics and petfood (e.g. parts of slaughtered animals, which are fit for human consumption in accordance with EU legislation, but are not intended for human consumption for commercial reasons).

- **Animal residues (Non-fat; Category 2, 3).** These are the non-fat residues, such as organs, ligaments, blood vessels, feather and bones derived from the production of meat. It may be possible to use these residues to produce biogas, or otherwise extract remaining fatty acids for biodiesel and renewable diesel production (e.g. poultry feather acid oil).

- **Manure and derivatives.** This refers to animal excreta and derived materials including wet manure, dry manure, and manure wash water.

- **Other slaughterhouse waste (Animal residues – Non-fat Category 1).** This refers to inedible animal tissues other than fat (organs, integument, ligaments, tendons, blood vessels, feathers, bone) derived from the production of meat.

- **Waste fish oil.** This refers to oil derived from fish that have been exposed to environmental pollutants, or from fish segregated at harvest centres due to quality (e.g. diseased fish). It is unsuitable for food or feed use.

7.3.5.3. *Summary of the preliminary assessment:*

- All the materials considered here qualify as **biomass** and do not fall under the REDII **food/feed crop definition** as they all originate from animals and are not crops.

- **Waste fish oil (Category 1-2) and animal fat Category 1-2** are already included in Annex IX - Part B and were not shortlisted.

- **Other slaughterhouse waste (Animal residues – non-fat Category 1)** are considered to constitute industrial biowastes and were therefore not shortlisted.

- **Manure and derivatives** are already included on Annex IX - Part A (f) and were not shortlisted.

As a result of the preliminary assessment, the Consortium suggested shortlisting the following feedstocks for an in-depth evaluation in Task 2 and Task 3:

- **Animal fats (Category 3).**

- **Animal residues (not fat; Category 2, 3).**

7.3.5.4. *Outlook for Task 2 and* Task 3:

Category 3 animal by-products, including fats and residues, can be used in other industries, such as feeding livestock, producing pet food, and producing oleochemical products. The Consortium made a deeper assessment on potential market distortions from an increased use of animal by-products category 3 in Task 2. Differentiated treatment between different categories of animal by-products could affect the value hierarchy between categories of material and may create financial incentives in favour of categorising material that is potentially category 3 as category 2 (or categorising material that is potentially category 2 as category 1). This was considered in Task 3.

7.3.6. Wastewater and derivatives

7.3.6.1. *Definition:*

Wastewater is defined here as unwanted and contaminated water from domestic, commercial, and industrial uses. Wastewater is either collected at wastewater treatment plants or discharged directly to natural land or waterbodies without treatment. Wastewater and derivatives often contain organic matter and biogenic elements, and therefore can produce bio-methane through anaerobic digestion at treatment plants once necessary infrastructure is installed. Treated wastewater may be reused in industries and agriculture.

7.3.6.2. *Description of feedstocks:*

This category includes:

- **Municipal wastewater and derivatives (non-sludge).** This feedstock includes both wastewater generated from domestic water use as well as derivatives extracted from the municipal wastewater, such as fats, oils, and greases (FOGs).

- **Municipal wastewater (sewage) sludge.** This is a semi-solid material from sewage treatment of municipal wastewater.

- **Industrial wastewater and derivatives.** This feedstock includes wastewater and extracted derivatives from industrial origins. Examples include biodiesel wastewater and food processing wastewater, such as potato sludge and oil mill wastewater.

- **Palm oil mill effluent (POME)** and palm sludge oil. POME is the wastewater generated from palm oil milling. Palm sludge oil is the residual oil floating on top of POME.

7.3.6.3. *Summary of the preliminary assessment:*

- All feedstocks under the wastewater and derivatives category qualify as (containing) biomass and are not food/feed crops. Municipal wastewater (sewage) sludge is explicitly covered under Annex IX - Part A (f). Informed by inputs from the stakeholder consultation, the consortium considered industrial wastewater and derivatives as already covered under Annex IX - Part A (d) "biomass fraction of industrial waste not fit for use in the food or feed chain". POME is explicitly included as Annex IX - Part A (g) and the consortium considered palm sludge oil to fall within the scope of POME, and thus these were also not shortlisted.

- The Consortium therefore only included municipal wastewater and derivatives (non-sludge) in the shortlist for further analysis in task 2 and task 3. The consortium considered whether non-sludge municipal wastewater and derivatives were already covered under Annex IX - Part A (b) "biomass fraction of mixed municipal waste...under point (a) of Article 11(2) of Directive 2008/98/EC" or (c) "biowaste as defined in point (4) of Article 3 of Directive 2008/98/EC from private households". The Directive 2008/98/EC is the Waste Framework Directive and wastewater is outside the scope of this Directive, reflecting that non-sludge municipal wastewater and derivatives is currently not included in Annex IX.

As a result of the preliminary assessment, the consortium suggested shortlisting the following feedstocks for an in-depth evaluation in Task 2 and Task 3:

- **Municipal wastewater and derivatives (non-sludge).**

7.3.6.4. *Outlook for Task 2 and Task 3:*

The consortium did not foresee any particular issues in the further assessment of non-sludge municipal wastewater and derivatives.

7.3.7. Fats, oils and greases (FOGs)

7.3.7.1. *Definition:*

Fats, oils, and greases (FOGs) are industrial residues and waste derived from the extraction, processing and/or use of vegetable oils and animal fats for food, feed and energy purposes. They are composed of fatty acids that may be converted into biodiesel or renewable diesel. This category does not include animal by-products, as defined in the Waste Framework Directive (See Section 7.3.5).

7.3.7.2. *Description of feedstocks:*

This category includes:

- **Soapstock and derivatives.** Soapstock is a residue from the alkaline refining of vegetable oils. Soapstock consists of free fatty acids, an emulsion of lipids, and salts. Soapstock can be further acidulated to make soapstock acid oil, which is mainly free fatty acids and glyceride. Multiple studies have investigated using soapstock and derivatives to make biodiesel.

- **Brown grease.** This is the oily material collected from grease traps before water enters the wastewater disposal system and is different and lower quality from used cooking oil (yellow grease).

- **Industrial storage settlings.** Waste FOGs can accumulate in the bottom of industrial storage tanks. Examples include biodiesel storage settlings, biodiesel distillation residues, and waste tank bottom oil.

- **Fatty acid distillates.** This feedstock includes fatty acids distilled from crude vegetable oil during the refining process. Examples include palm fatty acid distillates (PFADs) and other oilseed fatty acid distillates.

- **Used vegetable ester and oil.** This feedstock includes materials generated through the segregated collection of bio-lubricant or other biobased industrial products at the end of life. It is usually disposed of as a waste mixed with mineral oil-based lubricant or products.

7.3.7.3. *Summary of the preliminary assessment:*

- All feedstocks under the FOGs category qualify as biomass as they all have bio-origins.

- Some of these materials are crop-derived, and fatty acid distillates in particular may generate a non-negligible fraction of crop revenue. The consortium considered whether the fatty acid distillates constitute residues and should therefore be excluded from being treated as food and feed crop feedstocks. It is debatable whether fatty acid distillates constitute residues or could be considered one of the end products that oil crop production seeks to produce. Making a final determination on that point is beyond the scope of this exercise, and therefore the consortium felt that these materials should be kept on the shortlist for further assessment. Both POME and PSO were considered covered under Annex IX - Part A (g).

- The consortium believes that industrial storage settlings and used vegetable ester and oil are already covered under Annex IX - Part A (d) “biomass fraction of industrial waste not fit for use in the food or feed chain”, since they are both understood to be wastes with no other uses, and so they were not shortlisted.

As a result of the preliminary assessment, the consortium suggested shortlisting the following feedstocks for an in-depth evaluation in Task 2 and Task 3:

- **Soapstock and derivatives**
- **Brown grease**
- **Fatty acid distillates**

7.3.7.4. Outlooks for Task 2 and Task 3:

Since soapstock and derivatives as well as fatty acid distillates are sourced from oil crops and have existing productive uses, the potential land impacts from using these by-products for biofuels and potential associated market distortions were evaluated.

7.3.8. Others

7.3.8.1. *Definition:*

This category is for feedstocks that cannot be readily categorized within the above seven feedstock groups.

7.3.8.2. *Description of feedstocks*

This category includes:

- **Biogenic fraction of municipal solid waste, refuse and compostable waste.** Examples include municipal solid waste (MSW), refused derived fuels (RDF), bio-stabilized materials, bio-based plastic and compost.
- **Plastic waste.** These wastes are generated by industry and as a constituent of MSW, and may be of both fossil and biogenic origin.
- **Biogenic fraction of end-of-life tyres.** Tyres may include a share of natural rubber that can potentially be separated from non-bio portions.
- **Various oils from ethanol production.** These are by-products from ethanol production. Examples include technical (distillers) corn oil.
- **Distillers grains and solubles (DGS).** Distillers grains are a by-product from ethanol production from grains.
- **Trees/bushes (not sawlog/veneer grade).** Examples include damaged trees.
- **Recycled/waste wood.** This is the wood generated from demolition or generated at construction sites and furniture workshops.

- **Ligno-cellulosic crops or fraction of crops.** These are the crops with high ligno-cellulosic content. Examples include energy cane, energy crops and grasses, grass pulp, and bagasse.

- **Opuntia or "prickly pear".** This genus belongs to the cactus family, may grow on arid lands and produces fruits, which can be used for food or feed purposes.

- **Humins.** These are by-products from producing bio-based furandicarboxylic acid (FDCA) and are currently considered as wastes.

- **Residues from oleochemical processing of high oleic sunflower oil.** This category includes high boiling vegetable fraction (FAV) and Keto, which are specifically generated during the extraction of pelargonic acid, azelaic acid and glycerin from high oleic sunflower oil.

- **Spent bleaching earth.** This is a solid residue generated through degumming and bleaching vegetable oil during vegetable oil refining.

- **Waste biogenic CO_2 and CO_2 from direct air capture.** Biogenic CO_2 is waste from upgrading biogas or from combustion of biomass. CO_2 from direct air capture is the atmospheric CO_2 that is captured.

- **Other biowastes.** Biowaste as defined in point (4) of Article 3 of Directive 2008/98/EC and are neither from households nor from industries (e.g. restaurants).

- **Sea algae and cyanobacteria.** Sea algae grow naturally in the sea and are distinct from micro-algae. Cyanobacteria such as *Arthrospira platensis* can be cultivated as a source of biomass.

7.3.8.3. *Summary of the preliminary assessment:*

- All feedstocks in this group qualify as biomass except for fossil plastic wastes and the non-biogenic fraction of end-of-life tyres. CO2 (both biogenic and non-biogenic) is not an energy carrier and therefore could not constitute a biofuel feedstock in the sense of the EU RED II. None of these feedstocks are food/feed crops.

- None of the materials in this category qualifies as food/feed crop, except opuntia, when purposefully cultivated to harvest fruits. It should be noted that opuntia cultivated on degraded or polluted land would be *de facto* covered under landscape care biomass (See Section 7.3.4).

- The biogenic fraction of waste is already covered under Annex IX - Part A (b) "Biomass fraction of mixed municipal waste", (c) "Biowaste as defined in point (4) of Article 3 of Directive 2008/98/EC from private households subject to separate collection", and part (d) "Biomass fraction of industrial waste not fit for use in the food or feed chain" and was not shortlisted. Trees/bushes are covered under Annex IX - Part A (p) "Other non-food cellulosic material" and (q) "Other ligno-cellulosic material except saw logs and veneer logs" (as long as the material does not qualify as a saw or veneer log) and were not shortlisted. Ligno-cellulosic crops or fraction of crops are covered under Annex IX - Part A (c), (j) "bagasse", (p) and (q) and were not shortlisted. Recycled/waste wood is covered under Annex IX - Part A (q) and was not shortlisted. Spent bleaching earth, humins, and the biomass fraction of end-of-life tyres are considered to be covered under Annex IX - Part A (d) and were not shortlisted.

As a result of the preliminary assessment, the consortium suggested shortlisting the following feedstocks for an in-depth evaluation in Task 2 and Task 3:

- **Various oils from ethanol production**
- **Distillers grains and solubles (DGS)**
- **Residues from oleochemical processing of high oleic sunflower oil**
- **Other biowaste**
- **Sea algae**
- **Cyanobacteria**

7.3.8.4. Outlooks for Task 2 and Task 3:

The Consortium foresaw several issues in tasks 2 and 3, with regards to competing uses with non-energy sectors and potential market distortions.

7.3.9. Suggested shortlist and list of feedstocks considered currently covered by Annex IX:

The preliminary assessment described in the previous section led to the following **shortlist** of feedstocks (Table 5), which were further assessed in Task 2 and Task 3:

Table 5: Suggested shortlist of feedstocks to be assessed in Task 2 and Task 3

Category	Feedstock sub-category/examples
Food-feed processing residues and waste	Bakery and confectionery residues and waste Drink production residues and waste Fruit / vegetable residues and waste (except tails, leaves, stalks and husks) Potato/beet pulp Starchy effluents (up to 20% dry content) Corn processing residues (later renamed as “Dry starch from corn fractionation”) Sugar extraction residues and waste Molasses Vinasse Alcoholic distillery residues and waste Spent grains Whey permeate

	Olive pomace and derivatives
Agricultural / Forestry residues and waste	Palm mesocarp oil (later renamed as "Oil palm mesocarp fibre oil")[7] Raw methanol from wood pulp production
Intermediate crops	Grain, starch, sugar, oil, beans and meals derived from rotation crops, cover crops and catch crops
Landscape care biomass	Biomass from fallow land (Non-lignocellulosic/non-cellulosic) *Note: this was re-evaluated at the beginning of Task 2 and eventually considered as being currently covered in the existing Annex IX.* Biomass from degraded/polluted land (Non-lignocellulosic/non-cellulosic) Biomass harvested from mixture meadow (Non-lignocellulosic/non-cellulosic) *Note: this was re-evaluated at the beginning of Task 2 and eventually considered as being currently covered in the existing Annex IX.* Damaged crops
Animal residues and waste	Animal fats Cat 3 Animal residues (non-fat) Cat 2-3
Wastewater and derivatives	Municipal wastewater and derivatives (non-sludge)
Fats, oils and greases (FOGs)	Soapstock and derivatives Brown grease Fatty acid distillates
Others	Various oils from ethanol production Distillers grains and solubles (DGS) Residues from oleochemical processing of high oleic sunflower oil Other biowaste Sea algae Cyanobacteria

[7] Palm mesocarp oil was left in this category for practical reasons. Technically, it is nevertheless not a harvesting residue, since it is obtained during the processing of palm fruits at the mill.

The list of feedstocks considered as **currently covered by Annex IX** is included in Table 6:

Table 6: Feedstocks considered as currently covered in Annex IX

Category	Feedstock sub-category/examples
Food-feed processing residues and waste	Drink waste *[Annex IX - Part A d)]* Fruit / vegetable residues and waste (Only tails, leaves, stalks and husks) *[Annex IX - Part A d)]* Bean shells, silverskin, and dust *[Annex IX Part - A d) and p)]* Shells/husks and derivatives *[Annex IX - Part A l) and p)]* Residues and waste from production of hot beverages *[Annex IX - Part A b), c) and d)]* Dairy waste scum *[Annex IX - Part A b), c) and d)]* Food waste oil *[Annex IX - Part A b) and d)]* Non-edible cereal residues and waste from grain milling and processing *[Annex IX - Part A d)]* Olive stones *(Olive oil extraction residues and waste) [Annex IX - Part A d)]*
Agricultural / Forestry residues and waste	Agricultural harvesting residues *[Annex IX - Part A p)]* Palm fronds, palm trunk *[Annex IX - Part A p) and q)]* Crude tall oil *[Annex IX - Part A o)]*
Landscape care biomass	Biomass from maintenance operations *[Annex IX Part A c), o), p), q)]* Damaged trees *[Annex IX - Part A q)]* Unused feed/fodder from ley *[Annex IX - Part A p)]*
Animal residues and waste	Waste fish oil *[Annex IX B]* Animal fats Cat 1-2 *[Annex IX - Part B]* Other slaughterhouse waste *(Animal residues (non-fat) Cat 1) [Annex IX - Part A d)]* Manure and derivatives *[Annex IX A part f)]*
Wastewater and derivatives	Municipal wastewater (sewage) sludge *[Annex IX - Part A f)]* Industrial wastewater and derivatives *[Annex IX - Part A d)]*

	Palm Oil Mill Effluent (POME) *[Annex IX - Part A g)]* Palm sludge oil (PSO) *[Annex IX - Part A g)]*
Fats, oils and greases (FOGs)	Industrial storage settlings *[Annex IX - Part A d)]* Used vegetable ester and oil (waste stream) *[Annex IX - Part A d)]*
Others	Biogenic fraction of municipal solid waste, refuse and compostable waste *[Annex IX - Part A b), c) and d)]* Biogenic fraction of end-of-life tyres *[Annex IX - Part A d)]* Trees / bushes (Not sawlog/veneer grade) *[Annex IX - Part A p)]* Recycled/waste wood *[Annex IX - Part A (q)]* Ligno-cellulosic crops or fraction of crops [Annex IX - Part A c), j) or p)] Humins *[Annex IX - Part A d)]* Spent bleaching earth *[Annex IX - Part A d)]*

7.4.CONCLUSIONS

All activities in Task 1 of the project were successfully completed. The consortium's internal resources were adequately complemented by the European Commission's inputs, the literature review and the stakeholder consultation to inform and strengthen the preliminary feedstock assessment and resulting shortlist.

The stakeholder consultation was successful beyond expectations, with more than 400 contributions received in the first round. In line with the actions taken by the consortium to communicate transparently about the project (dedicated webpage and social media), we consider that these efforts adequately respond to the expectations of the private and public sector, with regards to an open and transparent process. It should be noted, however, that several stakeholders shared more general reservations or criticism about the fact Task 2 and Task 3 would not include similar rounds of consultation. Some of them were also critical of the process whereby Annex IX was established, and the delegated act process itself. These remarks were transmitted to the European Commission separately.

As anticipated by the Consortium, several feedstocks appeared controversial, with a significant number of stakeholders supporting their inclusion in Annex IX and a significant number of stakeholders being opposed to that perspective. Opponents were either civil society organisations concerned about direct and indirect environmental impacts of an increased use of certain feedstocks, or other commercial sectors using the same feedstocks and concerned about decreased availability and consequent price increases. We believe that the detailed assessments conducted in Task 2 and Task 3 have allowed the consortium to draw solid conclusions regarding the conformity of new feedstocks with EU RED II Article 28 and potential fraud risks, although it is anticipated that lobbies will keep arguing in favour of their economic interests regardless.

Given the success of the stakeholder consultation and the large number of stakeholder contributions to be processed and analysed, the resources spent by the Consortium in Task 1 were significantly higher than initially budgeted. The resulting shortlist was also larger than what had been initially anticipated. Therefore, the Consortium, in consultation with DG ENER, endeavoured to optimise resources in Task 2 and Task 3, while ensuring that the outcomes were in line with DG ENER's expectation in terms of depth, clarity and quality.

Finally, the timeline for Task 1 was extended by about three months to accommodate the additional workload after the first round of consultation and additional delays due to the Covid-19 crisis.

8. TASK 2 – DETAILED FEEDSTOCK ASSESSMENT

8.1. OBJECTIVES

Task 2 consisted of the detailed assessment of each feedstock in the short list (Task 1) against the criteria described in Article 28(6) of EU RED II, with the objective to evaluate their eligibility for inclusion in Annex IX - Part A or B. Some of the feedstock names were updated in Task 2 to better reflect their characteristics.

8.2. METHODOLOGY

8.2.1. Introduction

Shortlisted feedstocks in Task 1 underwent a thorough assessment against the eligibility criteria described in EU RED II Article 28. Figure 4 provides an overview of the approach adopted for conducting the assessments. It should be noted that, following an initial request from DG ENER, all shortlisted feedstocks were evaluated against all criteria, which means that a complete evaluation has been performed.

To the extent possible, feedstock assessments rely on independent and verifiable sources, which support the analysis and conclusions regarding potential eligibility in Annex IX. However, several feedstocks analysed in this study are currently not documented through technical reports or market data, due to the fact they are produced in limited amounts or were processed as biofuel/biogas feedstocks in the recent years only. Direct inputs from stakeholders involved in the public consultation organised in Task 1 and/or contacted directly were therefore used in some of the assessments, primarily for technical descriptions. Some stakeholder inputs were also used to support the assessments of environmental impacts, markets, and land demand, as long as they could be independently verified by the Consortium.

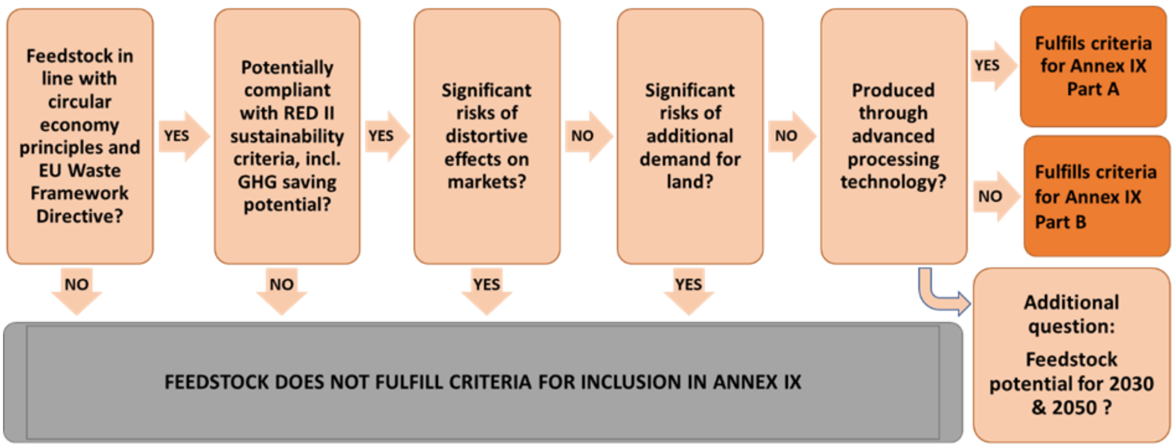

Figure 4: Overview of the evaluation process implemented in Task 2.

Sections 8.2.2 to 8.2.8 describe the different steps followed for the feedstock assessments in Task 2. Section 8.3 provides summaries of the conclusions regarding compliance of shortlisted feedstocks with EU RED II Article 28 criteria.

Note: The complete feedstock assessments can be found in Annex E – Individual Feedstock Evaluations in the following order:

Table 7: List of individual feedstock assessments in Task 2

	Feedstock name
1	Bakery and confectionery residues and waste
2	Drink production residues and waste
3	Fruit / vegetable residues and waste (except tails, leaves, stalks and husks)
4	Potato/beet pulp
5	Starchy effluents (up to 20% dry content)
6	Dry starch from corn fractionation (formerly 'Corn processing residues')
7	Dextrose ultrafiltration retentate, hydrol and raffinate from sugar refining (formerly 'Sugar extraction residues and waste' or 'Sugars (fructose, dextrose) refining residues')
8	Final Molasses (formerly 'Molasses')
9	Vinasse
10	Alcoholic distillery residues and waste
11	Brewers' spent grain (formerly 'Spent grains')
12	Whey permeate
13	Olive oil extraction residues (formerly 'Olive pomace and derivatives')
14	Oil palm mesocarp fibre oil ('PPF oil') (formerly 'Palm mesocarp oil')
15	Raw methanol from kraft pulping (formerly 'Raw methanol from wood pulp production')
16	Cover and intermediate crops (formerly 'Grain, starch, sugar, oil, beans and meals derived from rotation crops, cover crops and catch crops')
17	Biomass from degraded/polluted land (Non-lignocellulosic/non-cellulosic)
18	Damaged crops unfit for human and animal consumption (Formerly 'Damaged crops')
19	Category 3 Animal fats (formerly 'Animal fats Cat 3')
20	Category 2 and 3 Animal by-products (not fats) (formerly 'Animal residues (non-fat) Cat 2-3')
21	Municipal wastewater and derivatives (other than sludge) (formerly 'Municipal wastewater and derivatives (non-sludge)')
22	Soapstock and derivatives
23	Brown grease

24	Fatty acid distillates
25	Technical corn oil (formerly 'Various oils from ethanol production')
26	Distillers' dried grain with solubles (DDGS) (formerly 'Distillers' grain and solubles (DGS)')
27	High oleic sunflower oil extraction residues (formerly 'Residues from oleochemical processing of high oleic sunflower oil')
28	Other biowaste
29	Sea algae
30	Cyanobacteria

Note: Following discussion and validation by DG ENER, 'Biomass from fallow land (Non-lignocellulosic/non-cellulosic)' and 'Biomass harvested from mixture meadow (Non-lignocellulosic/non-cellulosic)' were initially shortlisted as feedstocks but these were eventually removed from the Task 2 assessment list after concluding that they could be considered as being already covered in Annex IX.

8.2.2. Technical description

Each of the feedstock assessment documents begin with an introductory section that includes sub-sections on **feedstock description**, **production process(es)**, and **possible uses** of the feedstock. A flow chart showing an example production process was added to illustrate the supply chain stage(s) where feedstocks are generated.

8.2.3. Circular economy and waste hierarchy (Subtask 2.1)

This assessment aimed to evaluate whether the use of a feedstock to produce biofuel/biogas was in line with the circular economy principles and the waste hierarchy. The EU approach to the circular economy primarily relies on the need to reduce waste and prolong the material use of products as much as possible before being preferentially recycled. Energy recovery or disposal should only be considered when these options are not possible (European Parliament, 2016). The Waste Framework Directive sets the basic concepts and definitions related to waste management. Furthermore, it defines a hierarchy of actions or steps related to waste, in which energy recovery is preceded by the prevention, reuse and recycling of waste.

The overall approach adopted for this assessment consisted of three steps, as summarised in **Figure 5** below:

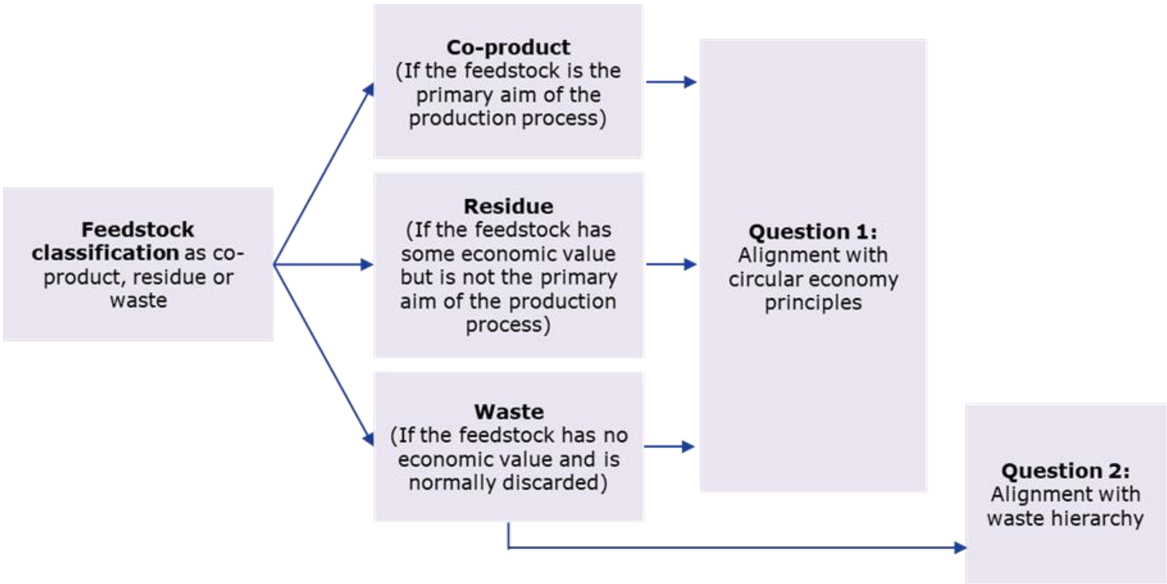

Figure 5: Overall approach for the circular economy and waste hierarchy assessment

The nature of feedstock was determined as co-product, residue or waste.

1. Alignment of the feedstock was assessed against circular economy principles.

2. Alignment of the feedstock (waste only) was assessed against the waste hierarchy.

Classification as co-product, waste or residue

The distinction between co-products, residues and waste is important, as it entails significant differences in feedstock compliance with specific EU RED II criteria. For instance, processing residues or waste are not required to comply with land-use related criteria and the calculation of their greenhouse gas savings only starts at the first collection point.

It is therefore important to carefully assess the nature of each feedstock. Under the EU RED II, co-products may be distinguished from residues based on whether the material is considered a primary aim of the production process and whether the process has been modified to produce it. The EU RED II does not provide a detailed specification of when production of a material should be considered a primary aim, and therefore the consortium developed an indicator to inform the assessment based on the relative economic value of the material compared to other co-products (e.g. palm fatty acid distillates vs refined palm oil) using their respective yields and market prices. When this relative economic value was above 10% of the economic value of the main product or the sum of other co-products, this is taken as evidence in support of considering the feedstock material as a **co-product** as well. The notion of whether the production process has been deliberately modified (or optimised) to increase the economic value of the material, produce a larger quantity or another quality of material was not used as a primary criterion in this process, given that no formal definition of what constitutes a deliberate modification or optimisation exists. For a number of feedstocks (PFADs, DDGS, molasses and animal fats) where the status of the material as a primary aim of production might be contentious, the economic value evaluation was complemented by additional considerations over the primary aim of the process (See individual feedstock assessments), from which the material is generated.

Feedstocks with a relative economic value above 10%, but which were not evaluated as being one of the primary aims of the process, could therefore be considered as **residues**, similarly to those with a relative economic value below 10%. Feedstock with no economic value, which would normally be discarded, were considered as **wastes**. It was suggested that the approach and criteria for the determination of co-products, residues and wastes is further developed and clarified by the European Commission in the near future.

Circular economy principles

Alignment of co-products, residues or wastes with EU circular economy principles was assessed by answering and documenting the following questions:

- Does the feedstock have non-energy (re)uses at commercial scale that could extend its life or sequester carbon for longer (material or chemicals)? *Notes: 1) food/feed/cosmetic uses were not considered as extending feedstock life or sequester carbon longer; 2) the simultaneous production of energy and chemicals in a biorefinery setup (if documented) was considered as being in line with circular economy principles.*

- Does its use as biofuel/biogas feedstock contribute to nutrient recovery?

- Does its use as biofuel/biogas feedstock contribute to a more efficient use of resources by avoiding primary material extraction?

- Does its use as biofuel/biogas feedstock contribute to reducing waste generation, especially food waste (e.g. by avoiding the feedstock to be discarded and require further end-of-life treatment)?

Waste hierarchy

In addition, alignment of wastes with the waste hierarchy, as defined in the EU Waste Directive was assessed by answering and documenting the following questions:

- Could the use of this feedstock contribute to increasing waste?

- Can this feedstock be potentially reused?

- Can this feedstock be potentially recycled?

The implication of the answers to these questions are summarised in a 'conclusions' sub-section.

The waste hierarchy section was only relevant to those feedstocks that were identified as wastes. For those feedstocks that were identified as residues or as a co-product, it was not necessary to consider alignment with the waste hierarchy.

8.2.4. Sustainability criteria (Subtask 2.2)

The sub-task on sustainability criteria was broken down into three areas of evaluation, which reflect the eligibility criteria laid out in EU RED II Article 28 for inclusion of biofuel/biogas feedstock in Annex IX:

1. The first area of the evaluation looked at the **Union sustainability criteria**, as referred to in Article 28 (6) (b) and described in detail in Article 29(2) to (7). It should be noted that Article 29 (2) is relevant only for wastes and residues derived from agricultural land, Article 29 (3) to (5) are relevant only for primary

agricultural biomass (including biomass from degraded lands, damaged crops and intermediate crops). Paragraphs (6) and (7) lay down criteria for bioenergy from forest biomass which are not applicable to any of the short-listed feedstocks.

2. The second area of evaluation looked at the potential for delivering **greenhouse gas emissions savings** (Article 28 (6) (d)) compared to fossil fuels based on a life-cycle assessment of emissions. The GHG emission savings threshold for new installations requires at least 65% GHG savings, as listed in Article 29 (10). In order to assess potential GHG savings of shortlisted feedstocks, the following hierarchy of options was implemented:

- Use a GHG saving default value for the considered feedstock and production pathway (or for an equivalent feedstock/process, which can be used as a proxy), as found in Part A or B of Annex V for biofuels and bioliquids and in Part A of Annex VI for biogas used for transport. The default value for greenhouse gas emissions savings available for this feedstock/proxy was used, as long as it is produced with no net GHG emissions from land-use change.

- If such a default value was not available, the consortium used disaggregated default values for biofuels and bioliquids (available in Part D and E of Annex V) and for biogas for transport (available in Part C of Annex VI) to calculate GHG savings for this feedstock considering appropriate allocation of impacts.

- In cases good estimates could not be obtained using disaggregated default values in EU RED II, publicly available literature was used for GHG emissions data.

3. The third area of evaluation looked at the need to **avoid negative impacts on the environment and biodiversity** (Article 28 (6) (e)).

Beyond compulsory criteria on land-use and GHG savings, EU RED II includes recommendations for biofuel/biogas feedstocks to consider other environmental criteria. Those are primarily related to feedstock cultivation (land-use and land management). Given that feedstocks matching the food/feed crop definition were de facto excluded from the short list in Task 1 and that waste and processing residues are exempted from complying with land-use criteria under EU RED II, the additional environmental criteria related to land-use and land management were only applied to the non-food/feed crops and a limited number of agricultural residues reviewed in this study. Similarly, indirect impacts from diverting residues and/or waste and direct impacts from processing feedstocks (such as water consumption or air pollution) were not considered.

Relevant land-use and land management practices considered in this assessment include tillage, sowing, crop management, pest management, fertilisation and harvesting.

The selection of additional environmental criteria for feedstock assessments was conducted, based on a literature review on direct adverse effects of agricultural land management on soil, ground water, surface water, air and biodiversity.

For relevant feedstocks, potential risks from land-use and land management practices to soil, water, air and biodiversity were evaluated as low, medium or high.

Other significant risks of negative environmental impacts associated with use of these feedstocks were noted where relevant.

8.2.5. Market effects and 2030/2050 potential (Subtask 2.3)

The aim of Subtask 2.3 was to evaluate whether an increased use of each feedstock included in the short list may bring about market distortions, thus potentially triggering negative indirect environmental or (socio)economic impacts. The potential supply and availability of feedstocks in 2030 and 2050 was also evaluated.

Several sources were used for this assessment. Priority was given to statistical databases (EU Agricultural Outlook, 2019-2030, Eurostat, FAOSTAT, World Bank), followed by public reports (from Government, international organisations, NGOs and technical groups), academic literature and stakeholder inputs from Task 1 consultation and direct interviews.

Evaluation of potential market distortions

Potential market distortions were evaluated both a global and local levels by comparing current feedstock supply to current demand from biofuel/biogas and non-energy sectors (e.g. food, feed, paper, oleochemicals):

- If supply significantly exceeds demand, an increased use of feedstock for biofuel/biogas production has a low risk of triggering market distortions.
- If current supply and demand are comparable but feedstock supply is elastic, an increased use of feedstock for biofuel/biogas production has a moderate risk of triggering market distortions (e.g. price increases), thus possibly leading other sectors to use different feedstocks.
- If current supply and demand are comparable but feedstock supply is rigid, an increased use of feedstock for biofuel/biogas production has a high risk of triggering market distortions (e.g. price increases), thus possibly leading other sectors to use different feedstocks.
- If demand significantly exceeds supply, any increase in the use of feedstock for biofuel/biogas production has a high risk of triggering or aggravating market distortions (e.g. price increases), thus possibly leading other sectors to use different feedstocks.

Feedstock supply elasticity reflects the possibility of increasing feedstock production or imports as a result of an increasing demand. As an example, the supply of feedstocks produced as a primary aim of crop cultivation is elastic, whereas the supply of residues or waste generated from an existing supply chain is generally considered rigid, i.e. the amounts of residues or waste generated vary according to the demand in the existing supply chain, but not to the demand from the biofuel/biogas sectors (although in some cases the supply of a residue that requires additional extraction or separation may be elastic in the sense that the rate of extraction/separation may be increased).

The evaluation of market distortions was conducted using the following steps:

1. Reviewing the Task 1 report as well as reviewing stakeholder input gathered about the feedstock

2a. Identification of current supply and demand of the feedstock through literature search

2b. Qualitatively assessing if supply of the feedstock is rigid or elastic

2c. Assessing if the feedstock can be traded to, or from, the EU

3a. Identifying current uses of feedstock and assessing potential of the feedstock being substituted with other materials due to increased biofuel demand

3b. Indicating whether these substitutions could have potential negative environmental (excluding land use)

The resulting risk of market distortion was characterised as low, low-medium, medium, medium-high or high.

Evaluation of 2030/2050 feedstock potential

Future feedstock supply and demand was extrapolated by using available forecast of growth in the production and/or utilisation of feedstocks. While 2030 forecasts are often available in technical reports and literature, based on robustly assessed growth projections, 2050 forecasts are less common and reliable. Therefore, evaluations of the 2050 potential should be regarded with caution.

The evaluation involved:

1a. Forecasting production potential in 2030 and 2050 based on existing forecasts of main product

1b. If 1a was not feasible, then we built our own production potential forecast using proxy data such as GDP, industry market size, etc. or extrapolated historical growth

2. Considering current uses and their expected growth to 2030 and 2050

3. Assessing the available potential for biofuel production considering the other uses of the feedstock and the elasticity of the supply.

The focus of the assessment was on the EU potential. Insights into the global potential were also provided, where relevant.

For some feedstocks like cover and intermediate crops, landscape care biomass, municipal wastewater and derivatives, cyanobacteria and sea algae, quantitatively assessing 2030/2050 potentials was either considered not to be as relevant or was found to be very challenging. Instead the Consortium relied on forecasts, where existing, or otherwise provided a qualitative assessment of the future supply potential.

Following preliminary feedback from DG ENER, the 2030/2050 biomass potentials were converted into a biofuel/biogas potential, using the following conversion factors from the GREET tool:

- Sugar to ethanol: 0.455 kg fuel/kg feedstock
- Starchy material to ethanol: 0.339 kg fuel/kg feedstock
- Vegetable oil to FAME:0.994 kg fuel/kg feedstock
- Vegetable oil to HVO: 0.897 kg fuel/kg feedstock
- Biowaste to biogas: 0.19 kg fuel/kg feedstock
- Waste FOGs to FAME: 0.909 kg fuel/kg feedstock
- Waste FOGs to HVO: 0.852 kg fuel/kg feedstock

- Agricultural/Forestry lignocellulosic feedstock to ethanol: 0.254 kg fuel/kg feedstock

These conversion ratios assume standard feedstock moisture content and composition. Feedstocks with significantly higher moisture and/or unconvertible material contents would require adjusted yields.

8.2.6. Additional demand for land (Subtask 2.4)

This subtask continues from Subtask 2.3 (Market effects), as additional demand for land is directly correlated with market effects, which may trigger additional demand for the main feedstock considered or for other products used as substitute by other sectors in competition with biofuel/biogas production.

Two types of land demand were considered in this assessment:

- The direct land demand for feedstocks grown on land (e.g. crops); and

- The indirect land demand in producing the likely substitute materials for the feedstock. We considered the likely substitute materials identified in Subtask 2.3 and assessed the risk that increased production of these materials will have for additional demand for land. Table 9 describes possible substitute materials and categorize them as low, low-medium, medium, and high risk for additional demand for land.

Modelling results from the GLOBIOM ILUC model (Valin et al., 2015; and Biggs et al., 2016, which is used for soymeal) represent the most recent modelling work on indirect land use change from biofuels production commissioned by the European Commission. While other modelling work using the GLOBIOM ILUC model has been conducted since 2015, Valin et al. (2015) remains the most recent ILUC analysis that addresses a large number of materials specifically for the EU context. These results are originally given as total land use change (in million hectares) from increased demand for biofuel from various feedstocks. For the purpose of this assessment, these were normalised to evaluate land-use change provoked by additional feedstock demand, which is expressed in hectares of global land expansion per tonne feedstock in the final column in Table 8. This does not take into account differences in energy content between substitutes; energy content is not always the most relevant metric for material use in existing uses, for example soap-making. Co-products are taken into account in these results taken from Valin et al., (2015).

Table 8 : Global land use change from additional demand for biofuel from various feedstocks from Valin et al. (2015) and Biggs et al. (2016)

Crop	Additional demand for feedstock (million tonnes)	Global total land use change (Mha)	Global land use change (hectares/tonne)
Wheat	16	1.7	0.11
Maize	14.2	0.95	0.07
Barley	16	1.9	0.12
Sugar beet	58	0.32	0.01
Sugarcane	69	0.6	0.01

Silage maize	41.4	0.59	0.01
Sunflower oil	3.5	1.5	0.43
Palm oil	3.5	1	0.29
Rapeseed oil	3.5	1.9	0.54
Soybean oil	3.5	1.8	0.51
Perennial grasses	13.1	0.92	0.07
Short rotation coppice	13.1	1.2	0.09
Soy meal	15.6	1.0	0.06

In this study, risks of additional land demand were categorised as follows:

- Low risk substitute: no land use change expected.
- Medium-low risk substitute: global land use change < 0.02 ha/t.
- Medium risk substitute: global land use change > 0.02 ha/t and < 0.20 ha/t.
- High risk substitute: global land use change > 0.20 ha/t.

Table 9: Categorisation of risk of additional demand for land for various substitute materials

Substitute materials	Substitute risk level
Palm oil Soybean oil Sunflower oil Rapeseed oil Meat	**High**
Wheat Maize Barley Soymeal Perennial grasses Short-rotation coppice	**Medium**

Sugarbeet Sugarcane Silage maize	**Medium-low**
No market distortion or no substitute Aquatic materials (e.g. algae) Wastes and residues with substantial elastic supply (e.g. corn stover)	**Low**

For context, we can consider how these thresholds compare with the land efficiency of crops. The threshold we have set for medium-low risk substitutes, equivalent to 50 tonnes of material per additional hectare of land demand, represents a higher level of implied land-efficiency than expected for the most productive cellulosic energy cropping systems. The threshold we have set for medium risk substitutes, equivalent to 5 tonnes of material per additional hectare of land demand, represents an implied land efficiency at least as high as a (relatively) high yielding food cropping system. The high risk threshold we have defined therefore represents an implied land efficiency comparable or worse than might be expected for a generic food-crop to biofuel system. Note that these risk levels relate only to land use, these risk categories are not linked to expected land use change *emissions* values. In particular, these risk categories do not take into account the share of land expansion that is onto high carbon stock land.

The overall risk of additional demand for land considers both the risk level of the substitute material and the risk of market distortion, as follows:

Table 10: Characterisation of overall risk of additional land demand

Market Distortion Risk	Substitute Risk	Overall Risk of Additional Land Demand
Low / Low Medium	Low/Low-Medium	Low
	Medium	Low-Medium
	Medium-High /High	Medium
Medium	Low/Low-Medium	Low-Medium
	Medium	Medium
	Medium-High /High	Medium-High
Medium-High / High	Low/Low-Medium	Medium
	Medium	Medium-High
	Medium-High /High	High

8.2.7. Processing technologies (Subtask 2.5)

EU RED II Article 28(6) states that feedstocks processed into biofuels, or biogas via advanced technologies shall be added to Part A of Annex IX whereas feedstocks processed via mature technologies shall be added to Part B of Annex IX. Subtask 2.5 therefore evaluated whether biofuel or biogas production technologies should be considered as mature or advanced. The following approach was applied:

1. The process steps and the technologies used to convert feedstocks into biofuels/biogas were determined, based on the Technical Description (See Section 8.2.2). Additional sources of information include available literature, technical reports, Task 1 consultations and internal resources from the Consortium partners.

2. Whenever a feedstock can be processed via either an advanced or a mature technology, the mature technology was used for the assessment. However, if an advanced technology was required (e.g. pretreatment) ahead of the conversion into biofuel/biogas via a mature technology, the whole process would be considered as advanced.

3. Processing technologies were assessed as mature or advanced, based on their Technology Readiness Level/TRL or Commercial Readiness Level/CRL, using the scale described in **Table 11**. TRL of 9 and CRL above 5 are considered mature. The TRL/CRL of all processing technologies considered in this assessment are described in Annex C – Evaluation of feedstock processing technologies.

Table 11: TRL/CRL scales used for the technology assessment

<table>
<tr><th>TRL</th><th></th><th>CRL</th><th></th></tr>
<tr><td>1</td><td>Basic principles observed</td><td>n/a</td><td></td></tr>
<tr><td>2</td><td>Technology concept formulated</td><td rowspan="6">1</td><td rowspan="6">Hypothetical commercial proposition</td></tr>
<tr><td>3</td><td>Experimental proof of concept</td></tr>
<tr><td>4</td><td>Technology validated in lab</td></tr>
<tr><td>5</td><td>Technology validated in relevant environment</td></tr>
<tr><td>6</td><td>Technology demonstrated in relevant environment</td></tr>
<tr><td>7</td><td>System prototype demonstration in operational environment</td></tr>
<tr><td>8</td><td>System complete and qualified</td><td>2</td><td>Commercial trial, small-scale</td></tr>
<tr><td rowspan="3">9</td><td rowspan="3">Actual system proven in operational environment</td><td>3</td><td>Commercial scale-up</td></tr>
<tr><td>4</td><td>Multiple commercial applications</td></tr>
<tr><td>5</td><td>Market competition driving widespread development</td></tr>
</table>

		6	Bankable asset class

8.2.8. Conclusions

Each feedstock assessment included a final section, in which every step in the assessment was summarised in a dedicated table. Section 8.3 includes all the conclusion tables from the feedstock assessments.

8.3. RESULTS – SUMMARY OF FEEDSTOCK ASSESSMENTS

The summary tables for each feedstock category are presented in the following sub-sections. Scoring criteria are used to characterise the estimated level of risk for evaluated feedstocks to fail to comply with EU RED II Article 28(6) eligibility criteria.

Table 12 : Scoring criteria

Colour	Scoring	Definition
	No concern	The evaluation did not reveal any significant concern about this feedstock (Low risk).
	Some concern	The evaluation identified limited conditions under which some concerns may exist, i.e. using this feedstock for biofuel production could be in contradiction with this criterion (Low-medium or medium risk).
	Significant concern	The evaluation reveals that using this feedstock for biofuel production would be in contradiction with this criterion in most circumstances (Medium-high or high risk).
	Not applicable	This criterion is not applicable to the feedstock.

The full feedstock assessments undertaken in Task 2 are available in Annex E.

8.3.1. Bakery and Confectionary Residues and Waste

Table 13: Summary of evaluation results for bakery and confectionary residues and waste

	Evaluation Result	Rationale
Circular economy and waste hierarchy	Some concern	No commercial uses exist, which can extend product life and sequester carbon for longer than energy uses. Therefore, using bakery/confectionery residues and wastes for biogas/biofuel does neither contribute to, nor contravene circular economy principles or contravene the waste hierarchy. Under which circumstances could this feedstock be problematic? Using feedstocks which could be used for food/feed purposes would not contravene

		circular economy principles, but would not be aligned with the waste hierarchy. How to mitigate this concern? New policy developments would be required to ensure that food residues that could be locally used for food/feed purposes are not used for biofuel production whenever supply is limited. For instance, evaluating whether such use is logistically and economically viable could be added by EU-approved voluntary schemes to the scope of compliance verified by assurance providers (modalities to be further discussed).
Union sustainability criteria	Not applicable	These criteria are **not applicable** to bakery and confectionery residues and waste, as this feedstock is neither primary agricultural biomass or agricultural field residue or forest biomass. The feedstock is classified as a process residue or waste.
Sustainability GHG	No concern	To be eligible with the 65% minimum GHG saving threshold, operators producing **biomethane** from bakery and confectionery residues and waste should ensure that the resulting digestate is maintained in a closed infrastructure and off-gas combustion is applied. To be eligible with the 65% minimum GHG saving threshold, operators producing **bioethanol** from bakery and confectionery residues and waste should not use lignite as process energy. How to mitigate this concern? Failure to meet the minimum GHG savings will be efficiently addressed throughout the certification process by an EU-approved voluntary or national scheme.
Sustainability Others	Not applicable	Bakery/Confectionery residues and waste do not require dedicated land cultivation and therefore these criteria are **not applicable**.

Market distortion	Some concern	Bakery and confectionery residues and waste are currently used as animal feed and have a rigid supply. Therefore, diverting these from feed to energy production has a **risk** of having distortive effect on the animal feed market. However, as it is estimated that 75-90% is available; therefore, this risk is considered as **low.** <u>Under which circumstances could this feedstock be problematic?</u> An incentive to decrease food waste and increase the use of bakery and confectionery residues/waste for food/feed purposes could increase the risk of local competition with energy uses and create local market distortions. However, the inclusion of bakery and confectionery residues in Annex IX could also prevent an increase in food/feed uses at local level. <u>How to mitigate this concern?</u> Inclusion in Annex IXB (See below) would limit the amount of feedstock being used for biofuel/biogas production. Auditors should check that facilities are producing an expected ratio of main product (e.g. bread, dough, wafers, etc.) to other materials. The auditor should have access to historical data to be able to determine that the ratio of process streams has not materially changed over time. New policy developments would also be required to evaluate local markets and demonstrate that no local demand exists from the feed sector and/or that available supply largely exceeds the demand from the feed sector.
2030/2050 Potential	2030: 16.1-19.3 million tonnes (i.e. 5.46-6.5 million tonnes of ethanol or 3.1-3.7 million tonnes of biogas), based on current food waste at processing and wholesale/retail 2050: 16.1-19.3 million tonnes (i.e. 5.46-6.5 million tonnes of ethanol or 3.1-3.7 million tonnes of biogas),	No specific data could be found for the 2030 and 2050 production of bakery and confectionery residues and waste. Current food waste at processing and wholesale/retail was used as proxy. Production levels are expected to remain comparable to the current levels.

	based on current food waste at processing and wholesale/retail	
Land demand	Some concern	Should market distortions occur, substituting bakery/confectionery waste and residues would pose a medium risk for additional demand for land for cereals. The overall risk is considered **low-medium**. How to mitigate this concern? See "Market distortion"
Processing Technologies	Mature (biogas) Mature (bioethanol)	The conversion technologies of bakery and confectionery residues and waste into biogas or bioethanol are considered to be **mature**, due to high TRL (9) and CRL (5).

8.3.2. Drink production residues and waste

Table 14: Summary of evaluation results for drink production residues and waste

	Evaluation Result	Rationale
Circular economy and waste hierarchy	No concern	No commercial uses exist that can extend product life and sequester carbon for longer than energy uses. Furthermore, using citrus peel and pulp residue for biofuel/biogas production contributes to a circular economy, since it produces digestate which can be applied to soil contributing to nutrient recovery.
Union Sustainability criteria	Not applicable	These criteria do not apply to drink production residues because they are process residues therefore this feedstock is neither of the following: a primary agricultural biomass, an agricultural field residue, or a forest biomass.
Sustainability GHG	No concern	<u>Under which circumstances could this feedstock be problematic?</u> To comply with GHG savings criteria, the technology option of close digestate, off-gas combustion would need to be applied for the production of biogas from drinks production residues. The reference used for biofuel production returned GHG savings that would comply

		with this criteria. How to mitigate this concern? Failure to meet the minimum GHG savings will be efficiently addressed throughout the certification process by an EU-approved voluntary or national scheme.
Sustainability Others	Not applicable	Drink production residues are process residues. These criteria are **not applicable** as this feedstock has no land impact.
Market distortion	Some concern	There is a large supply of drink residues available with limited application in healthcare products and composting. Under which circumstances could this feedstock be problematic? Diverting drink residues from animal feed to biofuel/biogas production would be at **medium risk of market distortion.** How to mitigate this concern? Inclusion in Annex IXB (see below) would limit the amount of feedstock being used for biogas production. Auditors should check that facilities are producing an expected ratio of main product (e.g. fruit juice) to other materials. The auditor should have access to historical data to be able to determine that the ratio of process streams has not materially changed over time. New policy developments would also be required to evaluate local markets and demonstrate that no local demand exists from the feed sector and/or that available supply largely exceeds the demand from the feed sector.
2030/2050 Potential	2030: 6.5 million tonnes [i.e. 1.2 million tonnes of biogas] 2050: 8.5 million tonnes [i.e. 1.6 million tonnes of biogas]	EU citrus production estimated to be 11.4 million tonnes. Assuming 50% by weight waste and an average increase in fruit availability of 1.3% citrus pulp and peel residues would reach 6.5 million tonnes in the EU by 2030. Applying the same 1.3% annual increase would estimate 8.5 million tonnes of

		citrus pulp and peel residues available by 2050. However, there may be less feedstock available due to climate change affecting production yields.
Land demand	Some concern	Under which circumstances could this feedstock be problematic? There would be **medium risk** on additional demand for land if the cereal crops such as wheat, corn or barley displaced the use of drink residues in animal feed. How to mitigate this concern? See "Market distortion"
Processing Technologies	Mature (biogas)	Anaerobic digestion can be used to convert drink production residues to biogas which is considered a **mature processing technology**.

8.3.3. Fruit and vegetable residues and waste

Table 15: Summary of evaluation results for fruit and vegetable residues and waste

	Evaluation Result	Rationale
Circular economy and waste hierarchy	No concern	No commercial uses exist that can extend product life and sequester carbon for longer than energy uses. Utilising fruit and vegetable residues for biogas/biofuel production contributes to a circular economy because it reduces the generation of waste and can contribute to nutrient recovery.
Union Sustainability criteria	Not applicable	These criteria do not apply to this feedstock because they are process residues, therefore this feedstock is neither of the following: a primary agricultural biomass, an agricultural field residue, or a forest biomass.
Sustainability GHG	No concern	Under which circumstances could this feedstock be problematic? To comply with GHG savings criteria, the technology option of close digestate, off-gas combustion would need to be applied for the production of biogas from fruit and vegetable residues. The reference used for biofuel production

		returned GHG savings that would comply with this criteria. <u>How to mitigate this concern?</u> Failure to meet the minimum GHG savings will be efficiently addressed throughout the certification process by an EU-approved voluntary or national scheme.
Sustainability Others	Not applicable	The fruit and vegetable residues are derived from the processing of fruits and vegetables into food items, therefore these criteria are **not applicable** as this feedstock has no land impact.
Market distortion	Some concern	There is a large supply of fruit and vegetable residues with limited application in healthcare products and composting. <u>Under which circumstances could this feedstock be problematic?</u> There would be **medium risk of market distortion** if this feedstock was diverted away from use in animal feed. <u>How to mitigate this concern?</u> Inclusion in Annex IXB (see below) would limit the amount of feedstock being used for biogas production. Auditors should check that facilities are producing an expected ratio of main product (e.g. fruit, vegetables) to other materials. The auditor should have access to historical data to be able to determine that the ratio of process streams has not materially changed over time. New policy developments would also be required to evaluate local markets and demonstrate that no local demand exists from the feed sector and/or that available supply largely exceeds the demand from the feed sector.
2030/2050 Potential	2030: 490 million tonnes [i.e. 93.1 million tonnes of biogas] 2050: 638 million tonnes [i.e. 121 million tonnes of biogas]	An estimated 490 million tonnes of fruit and vegetable residues could be available in 2030 considering the increasing population and changes in consumer behaviour. There may potentially be less feedstock available moving to 2050 due to the

		effects of climate change on crop production. However, mitigation measures may suppress these impacts, and an increasing population is likely to result in increased demand.
Land demand	Some concern	Under which circumstances could this feedstock be problematic? There would be **medium risk** on additional demand for land if fruit and vegetable residues were displaced by cereal crops such as wheat, corn or barley in animal feed. How to mitigate this concern? See "Market distortion"
Processing Technologies	Mature (biogas)	Anaerobic digestion can be used to convert fruit and vegetable residues to biogas which is considered a **mature processing technology**.

8.3.4. Potato and sugar beet pulp

Table 16: Summary of evaluation results for potato and sugar beet pulp

	Evaluation Result	Rationale
Circular economy and waste hierarchy	No concern	No commercial uses exist that can extend product life and sequester carbon for longer than energy uses. Diverting these feedstocks to energy uses would reduce waste generation.
Union Sustainability criteria	No concern	Under which circumstances could this feedstock be problematic? Expansion of sugar beet has been observed since the abolition of sugar quotas in the EU. How to mitigate this concern? Failure to meet the Union sustainability criteria will be efficiently addressed throughout the certification process by an EU-approved voluntary or national scheme.
Sustainability	No concern	Sugar beet pulp ethanol would likely meet a minimum of 65% GHG emission

GHG		savings.
Sustainability Others	Some concern (sugar beet pulp)	Under which circumstances could this feedstock be problematic? Sugar beet carries high soil erosion risk (water and wind). Potential compaction risks. Risks due to application of application of herbicides and fungicides and nitrogen fertiliser. Potato pulp is considered to be a residue (from processing) and the requirements do not apply. How to mitigate this concern? Whereas some EU-approved voluntary schemes have additional environmental requirements, which could potentially mitigate the identified concerns, new policy instruments would be required to address these consistently and systematically.
	Not applicable (potato pulp)	
Market distortion	Significant concern	Sugar beet pulp and potato pulp are already widely used in non-energy applications, in particular as animal feed. How to mitigate this concern? This feedstock has been assessed as potentially appropriate for inclusion in Annex IXB. The contribution of Annex IXB feedstocks to national RED transport targets is capped at 1.7% of transport energy. Inclusion under this cap would limit the amount of feedstock likely to be used for biofuel/biogas production and thus mitigate against the most market distortive outcomes, but would not fully prevent indirect impacts.
2030/2050 Potential	Sugar beet pulp: 2030 (global): 13.7 million tonnes (i.e. 4.6 million tonnes of ethanol or 3 million tonnes of biogas) 2050 (global): 15.9 million tonnes (i.e. 5.4 million tonnes of ethanol or 2.6 million	The evaluation concluded that there is a potential of approximately 13.7 million tonnes of sugar beet pulp in 2030. This can increase to a potential of 15.9 million tonnes in 2050. An estimated 5 million tonnes of potato pulp may be available in 2030 and 2050. However, given that almost all of

	tonnes of biogas) Potato pulp: 2030 (global): 5 million tonnes (i.e. 1.7 million tonnes of ethanol or 1 million tonnes of biogas) 2050 (global): 5 million tonnes (i.e. 1.7 million tonnes of ethanol or 1 million tonnes of biogas)	available supply is currently used in non-energy applications, particularly by the animal feed industry, **there is no available potential for the bioenergy market.**
Land demand	Some concern	Sugar beet pulp and potato pulp used as animal feed would most likely be substituted with cereal grains such as maize or barley. This would pose a medium risk for additional demand for land. The overall risk is considered **medium-high**. How to mitigate this concern? See "Market distortion".
Processing Technologies	Mature (biogas) Advanced (bioethanol)	Commercial demonstration of using sugar beet pulp for biogas identified. Potato pulp may be less suitable for anaerobic digestion due to inefficient performance. No commercial demonstration of using either sugar beet pulp or potato pulp for bioethanol production could be identified.

8.3.5. Starchy effluents (formerly "Starchy effluents (up to 20% dry content)")

Table 17: Summary of evaluation results for starchy effluents

	Evaluation Result	Rationale
Circular economy and waste hierarchy	No concern (starch-containing wastewaters)	Using **starch-containing wastewaters** for biogas/biofuel does neither contribute to, nor contravene circular economy principles or contravene the waste hierarchy. Under which circumstances could this feedstock be problematic? Using feedstocks which could be used for

	Some concern (corn steep water and corn steep liquor)	feed purposes would not contravene circular economy principles, but would not be aligned with the waste hierarchy. Using **corn steep water** and **corn steep liquor** for biogas/biofuel is not considered to be in line with circular economy principles as the latter can be used in antibiotics production which can ensure a significantly longer life time and/or carbon sequestration than energy uses. Furthermore, using these feedstocks for biogas/biofuel would not be aligned with the waste hierarchy when their re-use as feed is technically/ economically possible. **Note**: Corn steep water is processed in an evaporator where soluble solids are concentrated by evaporating part of the water resulting in the production of corn steep liquor. How to mitigate this concern? See "Market distortion"
Union Sustainability criteria	Not applicable	These criteria are **not applicable** to starchy effluents as this feedstock is neither primary agricultural biomass or agricultural field residue or forest biomass. Starchy effluents are process residues/ waste.
Sustainability GHG	No concern	GHG savings range between 52 and 95% from using starchy effluents for **bioethanol** production. Under which circumstances could this feedstock be problematic? The process fuel used in the bioethanol production plant will determine whether the feedstock pathway is compliant with the GHG savings criteria. To be eligible with the 65% minimum GHG saving threshold, operators producing **biomethane** from starchy effluents should ensure that the resulting digestate is maintained in a closed infrastructure and off-gas combustion is applied. How to mitigate this concern? Failure to meet the minimum GHG savings will be efficiently addressed throughout the certification process by an

		EU-approved voluntary or national scheme.
Sustainability Others	Not applicable	Starchy effluents are process residues/ waste. These criteria are **not applicable** as this feedstock has no land impact.
Market distortion	Some concern	<u>Under which circumstances could this feedstock be problematic?</u> Given existing use of **starch-containing wastewaters** and **corn steep liquor** in the production of animal feed, adding this feedstock to Annex IX could have a distortive effect on the animal feed market. However, we are unable to ascertain the level of risk as we are not able to determine how much of these materials are currently used for feed versus biofuel production. <u>How to mitigate this concern?</u> Inclusion in Annex IXB (See below) would limit the amount of feedstock being used for biofuel/biogas production. Auditors should check that facilities are producing an expected ratio of main product (food-grade starch, ethanol and gluten feed) to other materials. The auditor should have access to historical data to be able to determine that the ratio of process streams has not materially changed over time. New policy developments would also be required to evaluate local markets and demonstrate that no local demand exists from the food/feed sector and/or that available supply largely exceeds the demand from the food/feed sector. Furthermore, market distortion associated with the use of **starch-**

		containing wastewaters for biogas/biofuel production may be limited in areas where feed demand is low. This is because this feedstock degrades rapidly and has to be used locally.
2030/2050 Potential	2030: Waste corn starch slurry: 20 million tonnes (global) (i.e. 7.1 million tonnes of ethanol or 4 million tonnes of biogas) Corn steep water: Unknown Corn steep liquor: Unknown 2050: Waste corn starch slurry: 45 million tonnes (global) (i.e. 15.5 million tonnes of ethanol or 8.7 million tonnes of biogas) Corn steep water: Unknown Corn steep liquor: Unknown	No specific data could be found for the production levels of starchy effluents in 2030 or 2050. The **waste corn starch slurry** *(a subset of starch-containing wastewaters)* estimates are based on volumes of the feedstock generated per tonne of corn starch produced and projections for corn starch production in 2030 and 2050. Volumes of **corn steep water** and **corn steep liquor** produced are anticipated to increase in 2030 and 2050 as these are linked with starch and bioethanol production which are expected to rise.
Land demand	Some concern	The use of **starch-containing wastewaters** and **corn steep liquor** for biogas/biofuel may divert this feedstock from animal feed, and farmers may then seek alternate feed mix containing **cereals like corn and soybean meal**. How to mitigate this concern? See "Market distortion"
Processing Technologies	Mature (biogas)	Biogas production via anaerobic digestion of starchy effluents is at high TRL (9) and CRL (5).

8.3.6. Dry starch from corn fractionation (formerly "corn processing residues")

Table 18: Summary of evaluation results for dry starch from corn fractionation

	Evaluation Result	Rationale

Circular economy and waste hierarchy	Some concern	Corn starch can be used as platform chemical in a biorefinery setup, thus producing simultaneously chemicals and energy products. <u>Under which circumstances could this feedstock be problematic?</u> Utilising dry starch for biofuel production is not in line with circular economy principles if it competes with uses that extend product life and sequester carbon for longer than energy uses. <u>How to mitigate this concern?</u> Feedstock would fall under the food/feed crop cap, which would limit the amount of feedstock being used for biofuel production.
Union sustainability criteria	No concern	Corn cultivation is generally on land that has been in agricultural use prior to 2008.
Sustainability GHG	No concern	On the basis of EU RED II default values for corn ethanol, only plants using forestry residues for process energy would pass the minimum GHG saving thresholds. Producers using actual values may demonstrate higher GHG savings (up to 80%). <u>How to mitigate this concern?</u> Failure to meet the minimum GHG savings will be efficiently addressed throughout the certification process by an EU-approved voluntary or national scheme.
Sustainability Others	Significant concern	Potential high risk for water resources, soil erosion and crop diversity concerning corn cultivation. <u>How to mitigate this concern?</u> Whereas some EU-approved voluntary schemes have additional environmental requirements, which could potentially mitigate the identified concerns, new policy instruments would be required to address these consistently and systematically.
Market distortion	Some concern	All available corn and corn starch is currently being used. Corn and corn dry

		starch supplies are elastic <u>Under which circumstances could this feedstock be problematic?</u> An increased use of dry corn starch for isobutanol/ethanol (via dry fractionation) at the expense of other food/pharmaceutical/paper, feed or corn ethanol from dry milling without additional corn production would lead to market distortions. <u>How to mitigate this concern?</u> Feedstock would fall under the food/feed crop cap, which would limit the amount of feedstock being used for biofuel production.
2030/2050 Potential	2030: 2.1 million tonnes (EU), i.e. 0.71 million tonnes ethanol; 40.3 million tonnes (world), i.e. 13.7 million tonnes. 2050: 2.9 million tonnes (EU), i.e. 0.98 million tonnes ; 55.2 million tonnes (world), i.e. 18.7 million tonnes.	Corn production globally is projected to reach 1.3 billion tonnes in 2030 with EU production accounting for 68.0 million tonnes. Applying the same increase projected from 2020 to 2030, starch production would reach 40.3 million tonnes globally in 2030 and, 55.2 million tonnes globally in 2050.
Land demand	Some concern	Diverting dry starch away from other uses would likely require substitute materials. <u>Under which circumstances could this feedstock be problematic?</u> In case market distortions are observed, substitute materials such as corn and cereals are evaluated to have a **medium risk** on additional demand for land. In cases where corn starch is supplied through expanded corn production, this would directly cause additional demand for land, also with a **medium** risk. <u>How to mitigate this concern?</u> Feedstock would fall under the food/feed crop cap, which would limit the amount of feedstock being used for biofuel

		production.
Processing Technologies	Mature (biofuel)	Fermentation of dry starch to produce biofuel has been used for the development of dry fractionation technology. This technology is claimed to be used at commercial scale. Therefore, it is considered to be a **mature processing technology**.

8.3.7. Dextrose ultrafiltration retentate, hydrol and raffinate from sugar refining (formerly "Sugars (fructose, dextrose) refining residues")

Table 19: Summary of evaluation results for dextrose ultrafiltration retentate, hydrol and raffinate from sugar refining

	Evaluation Result	Rationale
Circular economy and waste hierarchy	No concern	Using **dextrose ultrafiltration retentate, hydrol** and **raffinate** generated during sugar refining for biofuel does neither contribute to, nor contravene circular economy principles or contravene the waste hierarchy when their re-use as food/feed, including as yeast, is not technically/ economically possible. Under which circumstances could this feedstock be problematic? Using feedstocks which could be used for food/feed purposes would not contravene circular economy principles, but would not be aligned with the waste hierarchy.
Union Sustainability criteria	Not applicable	These criteria are **not applicable** to dextrose ultrafiltration retentate, hydrol and raffinate generated during sugar refining as this feedstock is neither primary agricultural biomass or agricultural field residue or forest biomass. They are process residues/ wastes.

Sustainability GHG	No concern	GHG savings range from 52-95% from using dextrose ultrafiltration retentate, hydrol and raffinate generated during sugar refining for **bioethanol** production. <u>Under which circumstances could this feedstock be problematic?</u> The GHG threshold is not met if we consider lignite as process fuel in CHP plant in the bioethanol production plant. <u>How to mitigate this concern?</u> Whereas some EU-approved voluntary schemes have additional environmental requirements, which could potentially mitigate the identified concerns, new policy instruments would be required to address these consistently and systematically.
Sustainability Others	Not applicable	Dextrose ultrafiltration retentate, hydrol and raffinate generated during sugar refining are process residues/ wastes. These criteria are **not applicable** as this feedstock has no land impact.
Market distortion	No concern (dextrose ultrafiltration retentate)	Adding **dextrose ultrafiltration retentate** to Annex IX should not have a distortive effect on any market given the lack of evidence of existing non-energy uses of this feedstock.
	Some concern (hydrol and raffinate)	<u>Under which circumstances could this feedstock be problematic?</u> Given existing use of **hydrol** and **raffinate** in the production of HFCS and dextrose, adding this feedstock to Annex IX could have a low to medium distortive effect on the HFCS and dextrose market. <u>How to mitigate this concern?</u> Inclusion in Annex IXB (See below) would limit the amount of feedstock being used for biofuel/biogas production. Auditors should check that facilities are producing an expected ratio of main product (e.g. glucose, fructose, dextrose) to other materials. The auditor should have access to historical data to be able

		to determine that the ratio of process streams has not materially changed over time. New policy developments would also be required to demonstrate that available supply largely exceeds the demand from the starch-based sugar refining sector.
2030/2050 Potential	2030: Dextrose ultrafiltration retentate: 3.3 million tonnes (global) (i.e. 1.5 million tonnes of ethanol) Raffinate: 5.8 million tonnes (i.e. 2.6 million tonnes of ethanol) Hydrol: Unknown 2050: Dextrose ultrafiltration retentate: 4 million tonnes (i.e. 1.8 million tonnes of ethanol) Raffinate: 7.1 million tonnes (i.e. 3.2 million tonnes of ethanol) Hydrol: Unknown	Production is anticipated to increase as starch production is expected to rise.
Land demand	No concern (dextrose ultrafiltration retentate)	**Dextrose ultrafiltration retentate** does not have any other existing uses and so it's unlikely that it will have an impact on any other resource. The risk of additional demand for land is therefore in the **lowrisk category**.
	Some concern (hydrol and raffinate)	The use of **hydrol** and **raffinate** for biofuel may divert this feedstock from HFCS and fructose production, which will need to be substituted with wheat and corn starch. The risk of additional demand for land for these substitutes would fall in the **medium risk category**. How to mitigate this concern? See "Market distortion"

Processing Technologies	Mature (bioethanol)	Standard fermentation and distillation process (TRL 9, CRL 5) is required for conversion of this feedstock into bioethanol.

8.3.8. Final molasses

Table 20: Summary of evaluation results for final molasses

	Evaluation Result	
Circular economy and waste hierarchy	No concern	There are some chemical/materials applications for final molasses but these use relatively small volumes. No largescale commercial uses were identified that would extend product life and sequester carbon for longer than energy uses. Increased production of biofuels from final molasses could reduce availability for other uses, but does not directly contradict circular economy principles.
Union Sustainability criteria	No concern	For sugarcane final molasses (i.e. molasses produced from the third refining stage) in particular there is some risk of sugarcane expansion into highly biodiverse or high carbon stock areas if demand increases. For sugarbeet final molasses the risk is considered low. How to mitigate this concern? Failure to meet the Union sustainability criteria will be efficiently addressed throughout the certification process by an EU-approved voluntary or national scheme.
Sustainability GHG	No concern	Lifecycle analyses of ethanol from final molasses suggest that GHG emissions are likely to be below the EU RED II threshold.
Sustainability Others	Significant concern	As a co-product of sugar production, final molasses is associated with several potential negative environmental impacts from land management. For example, both sugarcane and sugarbeet culture are identified in previous work for the Commission as requiring high fertiliser and pesticide inputs.

		How to mitigate this concern? Whereas some EU-approved voluntary schemes have additional environmental requirements, which could potentially mitigate the identified concerns, new policy instruments would be required to address these consistently and systematically.
Market distortion	Significant concern	As final molasses is a fully utilised resource, increased use for bioenergy would result in displacement from other applications leading to market distortions. If displaced from the animal feed market final molasses would need to be replaced by other energy feeds. How to mitigate this concern? By considering molasses covered under the definition of food/feed crop, they would fall under the corresponding food/feed crop cap, which would limit the amount of final molasses being used for biofuel production.
2030/2050 Potential	2030: 7 million tonnes [2.0 million tonnes ethanol] (EU); 76 million tonnes [22 million tonnes ethanol] (global) 2050 : 8 million tonnes [2.3 million tonnes ethanol] (EU) ; 96 million tonnes [28 million tonnes ethanol] (global)	Final molasses production can be expected to scale with total sugar production, which is forecast to increase approximately linearly to 2050.
Land demand	Some concern	Under which circumstances could this feedstock be problematic? The materials that are identified as likely to replace final molasses in existing applications (additional production of wheat, barley and sugar beet) are identified as medium-low land risk substitutes. The overall risk of additional demand for land is thus **medium-high**. How to mitigate this concern? Land demand risk could in principle be mitigated by requiring low ILUC-risk certification for final molasses.
Processing Technologies	Mature	Ethanol production from final molasses is a well established technology.

8.3.9. Vinasse

Table 21: Summary of evaluation results for vinasse (incl. thin stillage)

	Evaluation Result	**Rationale**
Circular economy and waste hierarchy	No concern	Production of biogas from these resources may compete with feed use, but this does not contradict circular economy principles.
Union Sustainability criteria	Not applicable	The feedstocks are process residues and thus the mandatory requirements do not apply.
Sustainability GHG	No concern	It is expected that biogas from **vinasse** or **thin stillage** would be able to meet the minimum GHG saving criteria.
Sustainability Others	No concern	In the sugar cane industry, increased biogas production from **vinasse** could reduce application for fertirrigation. As fertirrigation is currently associated with soil degradation where done on a long-term basis, this may deliver net environmental benefits. Given that imports of **vinasse** or biogas from Brazil are not considered likely to be driven by REDII, these impacts may not be realised in the REDII context.
Market distortion	Some concern	<u>Under which circumstances could this feedstock be problematic?</u> Diversion of vinasse and thin stillage from animal feed markets is likely in Europe, and these would need to be replaced in diets with alternative feeds. These are likely to include soybean meal and cereals. The overall market distortion risk is considered **medium**. <u>How to mitigate this concern?</u> This concern could be mitigated if the feedstock definition was narrowed to exclude **thin stillage** and sugarbeet **vinasse**, and include only sugarcane **vinasse.**
2030/2050 Potential	2030 (EU): 6 billion litres **vinasse** [20,000 tonnes methane] and 60 billion litres **thin stillage** [1.2 million tonnes methane]. 2050 (EU): limited	Production of these feedstocks will be dependent on rates of ethanol production which are quite uncertain. There is also some uncertainty around precise yields of **vinasse** and **thin stillage** per litre of ethanol output.

	potential Imports: potential considered limited due to cost of transport.	
Land demand	Some concern	Under which circumstances could this feedstock be problematic? Diversion of vinasse and thin stillage from existing feed markets would be likely to lead to increased demand for meals and cereals for livestock feed which are considered medium land demand risk substitutes. The overall land demand risk for final molasses is considered **medium**. How to mitigate this concern? As with the market distortion risk, this concern could be mitigated if the feedstock definition was narrowed to exclude **thin stillage** and sugarbeet **vinasse**, and include only sugarcane **vinasse.**
Processing Technologies	Mature	Biogas production is considered the likely pathway for bioenergy from these feedstocks, and anaerobic digestion technologies for biogas production are mature.

8.3.10. Alcoholic distillery residues and wastes

Table 22: Summary of evaluation results for alcoholic distillery residues and wastes

	Evaluation Result	Rationale
Circular economy and waste hierarchy	No concern	No commercial uses exist that could extend product life and sequester carbon for longer than energy uses. Therefore, using this feedstock for biofuel does neither contribute to, nor contravene circular economy principles or the waste hierarchy.
Union sustainability criteria	Not applicable	This feedstock is a process residue. These criteria are **not applicable** as this feedstock is neither primary agricultural biomass nor agricultural field residue nor forest biomass.

Sustainability GHG	No concern	The evaluation did not reveal any significant concern for this feedstock meeting GHG savings criteria.
Sustainability Others	Not applicable	This feedstock is a process residue. These criteria are **not applicable** as this feedstock has no land impact.
Market distortion	Some concern	Under which circumstances could this feedstock be problematic? Given that fusel oils currently find use as solvent in industry and have a rigid supply, its use for biofuel could have **distortive effect** on these low grade chemical applications. However, as it is estimated that much surplus is available than currently utilized this effect is expected to be **low**. How to mitigate this concern? Inclusion in Annex IXB (see below) would limit the amount of feedstock being used for biofuel production. Auditors should check that facilities are producing an expected ratio of main product (alcoholic beverages or neutral alcohol for industrial applications) to distillery residues and wastes. The auditor should have access to historical data to be able to determine that the ratio of process streams has not materially changed over time. New policy developments would also be required to evaluate that available supply largely exceeds the demand from the chemicals sector.
2030/2050 Potential	2030 (global): 0.6 billion tonnes (i.e. 0.18 billion litres ethanol) 2050 (global): 1.5 billion tonnes (i.e. 0.45 billion litres ethanol)	The evaluation concluded that there is a potential of approximately **0.6 billion litres in 2030**. This can increase to a potential of **1.5 billion litres in 2050**.
Land demand	Some concern	Under which circumstances could this feedstock be problematic? There is a low risk of market distortion and the need for the production of substitute materials. If a diversion occurs from chemical uses, the ethanol can be substituted with ethanol produced from sugar and starch crops. These

		substitutes would fall in the medium/medium-low risk category. Overall, this feedstock has a **low-medium** risk for additional demand for land. How to mitigate this concern? See "Market distortion"
Processing Technologies	Mature (heads and tails) Advanced (fusel oils)	Heads and tails can be directly processed into ethanol. Fusel oils require advanced pre-treatments before being processed into biofuels.

8.3.11. Brewers' Spent Grain

Table 23: Summary of evaluation results for brewers' spent grain

	Evaluation Result	Rationale
Circular economy and waste hierarchy	No concern	No commercial uses exist, which can extend product life and sequester carbon for longer than energy uses. Therefore, using Brewers' Spent Grain (BSG) for biogas/biofuel biofuel/biogas does neither contribute to, nor contravene circular economy principles or the waste hierarchy.
Union sustainability criteria	Not applicable	BSG is a process residue. These criteria are **not applicable** as this feedstock is neither primary agricultural biomass nor agricultural field residue nor forest biomass.
Sustainability GHG	No concern	<u>Under which circumstances could this feedstock be problematic?</u> To be eligible, the technology option of closed digestate, off-gas combustion should be applied for producing biomethane. <u>How to mitigate this concern?</u> Failure to meet the minimum GHG savings will be efficiently addressed throughout the certification process by an EU-approved voluntary or national scheme.
Sustainability Others	Not applicable	BSG is a process residue. These criteria are **not applicable** as this feedstock has no land impact.

Market distortion	Some concern	Under which circumstances could this feedstock be problematic? Given that BSG has currently use as animal feed and has a rigid supply, diverting BSG from feed to energy production has a **risk** of having distortive effect on the animal feed market. However, as it is estimated that much more surplus is available than is currently utilised for feed this effect could be **low**. How to mitigate this concern? Inclusion in Annex IXB (see below) would limit the amount of feedstock being used for biogas production. Auditors should check that facilities are producing an expected ratio of main product (beer) to other materials. The auditor should have access to historical data to be able to determine that the ratio of process streams has not materially changed over time. New policy developments would also be required to evaluate local markets and demonstrate that no local demand exists from the feed sector and/or that available supply largely exceeds the demand from the feed sector.
2030/2050 Potential	2030: 51 million tonnes (i.e. 9.7 million tonnes biogas) 2050: 42 million tonnes (i.e. 8 million tonnes biogas)	The evaluation concluded that there is a potential of approximately **51 million tonnes** of BSG in **2030**. This may decrease to a potential of **42 million tonnes** in **2050**.
Land demand	Some concern	Under which circumstances could this feedstock be problematic? The use of BSG for biogas/biofuel may divert this feedstock from animal feed. However, there is **a low risk for this market distortion** and the need for the production of substitute materials. If the diversion were to occur, the farmers may then seek substitute materials such as grains and oil meals. These substitutes would fall in the medium risk category. Overall, this feedstock has a **low-medium risk** for additional demand for land. How to mitigate this concern?

		See "Market distortion"
Processing Technologies	Mature (biogas)	Conversion of BSG into biomethane can be done using anaerobic digestion technology and biogas upgrading technology. These are both **mature processing technologies**.

8.3.12. Whey permeate

Table 24: Summary of evaluation results for whey permeate

	Evaluation Result	Rationale
Circular economy and waste hierarchy	No concern	Using whey permeate for biogas/biofuel does neither contribute to, nor contravene circular economy principles or contravene the waste hierarchy. Use of whey permeate for producing PLA, pharmaceuticals or biosurfactants is not at commercial scale. Under which circumstances could this feedstock be problematic? Using feedstocks which could be used for food/feed purposes would not contravene circular economy principles, but would not be aligned with the waste hierarchy.
Union Sustainability criteria	Not applicable	These criteria are **not applicable** to whey permeate as this feedstock is neither primary agricultural biomass or agricultural field residue or forest biomass. Whey permeate is a process residue/ waste.
Sustainability GHG	No concern	To be eligible with the 65% minimum GHG saving threshold, operators producing **biomethane** from whey permeate should ensure that the resulting digestate is maintained in a closed infrastructure and off-gas combustion is applied. How to mitigate this concern? Failure to meet the minimum GHG savings will be efficiently addressed throughout the certification process by an EU-approved voluntary or national

		scheme. Analysis by Meo Carbon in Germany shows that Carbery **bioethanol** derived from whey permeate can provide 87% savings and is in compliance with the GHG savings criteria of REDII for new installations i.e. at least 65% GHG savings.
Sustainability Others	Not applicable	Whey permeate is a process residue/ waste. These criteria are **not applicable** as this feedstock has no land impact.
Market distortion	Some concern (dry whey permeate) No concern (liquid whey permeate)	<u>Under which circumstances could this feedstock be problematic?</u> Dry whey permeate is currently used as animal feed and is increasingly being used as bulking agent in food products. These markets could be distorted if whey permeate were to be diverted for biofuels production. <u>How to mitigate this concern?</u> Inclusion in Annex IXB (See below) would limit the amount of feedstock being used for biofuel/biogas production. Auditors should check that facilities are producing an expected ratio of main product (whey permeate concentrates) to other materials. The auditor should have access to historical data to be able to determine that the ratio of process streams has not materially changed over time. New policy developments would also be required to evaluate local markets and demonstrate that no local demand exists from the food/feed sector and/or that available supply largely exceeds the demand from the food/feed sector. Large volumes of liquid whey permeate are currently discarded and so the use of this feedstock for biofuels production should have limited market distortion effect.
2030/2050 Potential	2030: Liquid whey permeate: 29 million tonnes (Global) (i.e. 13.1 million tonnes of ethanol or 5.5	The **theoretical potential of raw liquid whey permeate and whey permeate powder** that can be produced in the EU and globally in 2030 and 2050 has been estimated. This is based on the volumes of milk that are

	million tonnes of biogas); 19 million tonnes (Europe) (i.e. 8.8 million tonnes of ethanol or 3.7 million tonnes of biogas) Whey permeate powder: 1.7 million tonnes (Global); 1.2 million tonnes (Europe - theoretical potential); 0.14 million tonnes (Europe – stakeholder projection) 2050: Liquid whey permeate: 48 million tonnes (Global) (i.e. 21.8 million tonnes of ethanol or 9.1 million tonnes of biogas); 23 million tonnes (Europe) (i.e. 10.3 million tonnes of ethanol or 4.3 million tonnes of biogas) Whey permeate powder: 3 million tonnes (Global); 1.4 million tonnes (Europe)	estimated to be used in cheese processing, as well as industry conversion factors.
Land demand	Some concern	Substituting whey permeate in animal feed would pose a **low-medium risk** for additional demand for land for soy meal and/or feed barley. Substituting whey permeate in food products would pose a **medium risk** for additional demand for land to produce skimmed milk powder. <u>How to mitigate this concern?</u> See "Market distortion"
Processing Technologies	Mature (biogas/ biomethane)	Biogas production via anaerobic digestion of whey permeate, followed by upgrading to biomethane is at high TRL (9) and CRL (5).

8.3.13. Olive oil extraction residues

Table 25: Summary of evaluation results for olive oil extraction residues

	Evaluation Result	Rationale

Circular economy and waste hierarchy	No concern	No demonstrated commercial use of olive pomace for material/chemical purposes that could ensure a significantly longer life time and/or carbon sequestration than energy uses.
Union Sustainability criteria	Not applicable	These criteria are **not applicable** to olive pomace, as this feedstock is neither primary agricultural biomass or agricultural field residue or forest biomass. Olive pomace is a process residue.
Sustainability GHG	No concern	To be eligible with the 65% minimum GHG saving threshold, operators producing **biogas/biomethane** from olive pomace should ensure that the resulting digestate is maintained in a closed infrastructure and off-gas combustion is applied. How to mitigate this concern? Failure to meet the minimum GHG savings will be efficiently addressed throughout the certification process by an EU-approved voluntary or national scheme.
Sustainability Others	Not applicable	Olive pomace does not require dedicated land cultivation and therefore have no land management impact.
Market distortion	No concern (de-oiled pomace)	Stakeholders consulted in Task 1 report stated that all available amounts of olive pomace are currently being used, thus leaving no extra supply available if biofuel use was to increase. Under which circumstances could this feedstock be problematic?
	Significant concern (pomace with oil)	A **medium risk** of market distortions could be observed if the use of olive pomace to produce biogas increases without any decrease in the demand from other sectors (food, chemicals, feed, fertilisers). This trend would be further amplified if inclusion in Annex IX was to make pomace oil extraction for biodiesel production economically attractive. How to mitigate this concern? An inclusion in Annex IX limited to de-oiled olive pomace would mitigate the risk of market distortion.

2030/2050 Potential	2030: 15.9 million tonnes (World), i.e. 3 million tonnes of biogas; 11 million tonnes, i.e. 2.1 million tonnes of biogas (EU) 2050: up to 18.1 million tonnes, i.e. 3.4 million tonnes of biogas (World); 11 million tonnes, i.e. 2.1 million tonnes of biogas (EU)	Documented olive production growth through 2027. Estimates for 2050 are based on EU and world population growth scenarios.
Land demand	No concern (de-oiled pomace) Significant concern (pomace with oil)	A risk exists that non-energy uses (e.g. food or feed) may be negatively impacted by an increase in biogas/biodiesel uses of olive pomace (with oil). In such case, olive pomace oil would likely be substituted by oilseeds, which are at high risk of creating additional land demand. <u>Under which circumstances could this feedstock be problematic?</u> Additional land demand subsequent to market distortions could be observed if biogas use of olive pomace increases without any decrease in the demand from other sectors (food, chemicals, feed, fertilisers). This trend would be further amplified if inclusion in Annex IX was to make pomace oil extraction for biodiesel production economically attractive. Being substituted by vegetable oils or meal, pomace would therefore poses a **medium to medium-high risk** of land demand. <u>How to mitigate this concern?</u> An inclusion in Annex IX limited to de-oiled olive pomace would mitigate the risk of additional land use.
Processing Technologies	Mature (Biogas/ biomethane)	The conversion technologies of olive pomace into biogas/biomethane are considered to be **mature**, due to high TRL (9) and CRL (5).

8.3.14. Oil palm mesocarp fibre oil ('PPF oil')

Table 26: Summary of evaluation results for oil palm mesocarp fibre oil

	Evaluation Result	Rationale

Circular economy and waste hierarchy	No concern	PPF oil is a resource that is largely under-utilised, increasing extraction could avoid some primary resource use and would be consistent with circular economy principles.
Union Sustainability criteria	Not applicable	The criteria are not relevant for a process residue.
Sustainability GHG	No concern	It is anticipated that biofuels from PPF oil would be able to meet the GHG emissions threshold of the EU RED II.
Sustainability Others	No concern	No negative environmental impact is anticipated.
Market distortion	Some concern	Under which circumstances could this feedstock be problematic? Increased use of PPF oil for biofuels for the EU market could displace material that is already being extracted from its current uses (either to be mixed back into the crude palm oil supply or supplied primarily for applications in food or feed). As extraction is not understood to be normal practice, however, increased demand would be expected to be met primarily by increased deployment of extraction technologies. The market distortion risk is therefore considered low-medium. How to mitigate this concern? There is no simple way to fully avoid diversion of currently extracted material.
2030/2050 Potential	2030: 1.2-2.4 million tonnes PPF oil (1.2-2.4 million tonnes biodiesel) 2050: 1.6-3.3 million tonnes PPF oil (1.6-3.3 million tonnes biodiesel)	The overall potential can be expected to scale with total palm oil production, although this could change if novel palm pressing technologies allowed increased oil recovery at the initial pressing.
Land demand	Some concern	Under which circumstances could this feedstock be problematic? There is a low-medium risk of market distortion and the need for the production of substitute materials if PPF oil is used for biofuel production. The substitute material is palm oil, which carries a high risk of additional demand for land. Overall, PPF oil has a medium risk for additional demand

		for land. How to mitigate this concern? As with market distortion, there is no simple way to fully avoid diversion of currently extracted material and the associated land demand impact.
Processing Technologies	Mature	The technology for solvent extraction of PPF oil is mature, and the processing technologies to turn that oil into FAME or HVO are also mature.

8.3.15. Raw methanol from kraft pulping

Table 27: Summary of evaluation results for raw methanol from kraft pulping

	Evaluation Result	Rationale
Circular economy	No concern	No contradiction was identified between increased purification of raw methanol for biofuel applications and the circular economy principles. No commercial uses exist that can extend product life and sequester carbon for longer than energy uses.
Union Sustainability criteria	Not applicable	As a process residue the Union sustainability criteria are not applicable.
Sustainability GHG	No concern	It is anticipated that biofuel from this feedstock would meet the GHG criteria.
Sustainability Others	No concern	Use of this feedstock has no land impact, and is not associated with any other environmental concerns.
Market distortion	No concern	Raw methanol may be utilised more efficiently after purification, but displacement from existing energy recovery applications is likely to result in replacement by fossil fuel such as natural gas and fuel oil at most mills This would reduce the potential for net climate benefits from increasing upgrading of raw methanol for transport biofuel.
2030/2050 Potential	2030: 300,000 tonnes methanol (EU); 1.4 million tonnes methanol (outside EU) 2050 : 300,000 tonnes	It is assumed that the EU pulp industry remains at a more or less constant output while pulp output in the rest of the world grows at 1.2% per annum. Generation of methanol will be sensitive to total demand for pulp products, to tree types and pulp

	methanol (EU); 1.8 million tonnes methanol (outside EU).	types being produced and to any changes in the fraction of global pulp production using the kraft process.
Land demand	No concern	No significant impact on land use is expected.
Processing Technologies	Likely considered mature, but further investigation may be appropriate.	One commercial example of raw methanol purification appears to have been operational since 2012, with the first documented EU example becoming operational in 2020. Further investigation would be required to confirm whether this technology should be considered to be at TRL 8 or 9.

8.3.16. Cover and intermediate crops

Table 28: Summary of evaluation results for cover and intermediate crops

	Evaluation Result	Rationale
Circular economy and waste hierarchy	No concern	No commercial uses exist that can extend product life and sequester carbon for longer than energy uses. Therefore, using cover and intermediate crops for biogas/biofuel does neither contribute to, nor contravene circular economy principles.
Union sustainability criteria	No concern	Under which circumstances could this feedstock be problematic? It is possible that the production of cover and intermediate crops could occur on land with high biodiversity value or high carbon stocks, or without management plans in place to address soil carbon. How to mitigate this concern? Failure to meet the Union sustainability criteria will be efficiently addressed throughout the certification process by an EU-approved voluntary or national scheme.
Sustainability GHG	No concern	Under which circumstances could this feedstock be problematic? Biofuels and biogas produced from cover and intermediate crops can, but do not necessarily, comply with the GHG reduction criteria in the EU RED II. For example, production processes with

		high direct emissions such as use of coal as process fuel would likely not comply with the GHG reduction criteria. How to mitigate this concern? Failure to meet the minimum GHG savings will be efficiently addressed throughout the certification process by an EU-approved voluntary or national scheme.
Sustainability Others	No concern	Under which circumstances could this feedstock be problematic? Cover and intermediate crops could potentially be grown on high carbon stock or highly biodiverse land and their production could potentially cause significant GHG emissions, similar to any crop-based biomass, but compliance with EU RED II sustainability criteria through voluntary scheme certification should in principle prevent this. In addition, cover and intermediate crops could potentially worsen water scarcity if grown in arid regions, and water quality if grown with added fertilizer and pesticides. How to mitigate this concern? Whereas some EU-approved voluntary schemes have additional environmental requirements, which could potentially mitigate the identified concerns, new policy instruments would be required to address these consistently and systematically.
Market distortion	Significant concern	Under which circumstances could this feedstock be problematic? While cover and intermediate crops in the EU are typically grown for environmental reasons and usually not harvested, globally most of these crops appear to be cash crops supplying commodity markets. Their use in biofuel would likely cause significant market distortion, similar to all food-based biofuels. How to mitigate this concern? Negative market and land use impacts could be mitigated by adding specific criteria to EU-approved voluntary schemes that ensure that the risk of indirect land-use change from feedstock production and

		utilisation remains low. This feedstock has been assessed as potentially appropriate for inclusion in Annex IXB. The contribution of Annex IXB feedstocks to national RED transport targets is capped at 1.7% of transport energy. Inclusion under this cap would limit the amount of feedstock likely to be used for biofuel/biogas production and thus mitigate against the most market distortive outcomes, but would not fully prevent indirect impacts.
2030/2050 Potential	No projection possible	The potential supply of cover and intermediate crops globally is likely quite large (likely much larger than 77 million tonnes per year) and increasing, but there is not enough data available to make quantitative estimates or projections.
Land demand	Significant concern	<u>Under which circumstances could this feedstock be problematic?</u> The use of cover and intermediate crops for biofuel production globally will likely divert cereals and soybeans from other uses, leading to increased production of cereals and soybeans and a high risk of additional demand for land. <u>How to mitigate this concern?</u> Negative market and land use impacts could be mitigated by adding specific criteria to EU-approved voluntary schemes that ensure that the risk of indirect land-use change from feedstock production and utilisation remains low. This feedstock has been assessed as potentially appropriate for inclusion in Annex IXB. The contribution of Annex IXB feedstocks to national RED transport targets is capped at 1.7% of transport energy. Inclusion under this cap would limit the amount of feedstock likely to be used for biofuel/biogas production and thus mitigate against the most market distortive outcomes, but would not fully prevent indirect impacts.
Processing Technologies	Mature	Cover and intermediate crops globally tend to be major food and feed crops and can be processed into biofuel or biogas using mature technologies, such as ethanol fermentation, transesterification, hydrotreating of vegetable oil, and

	anaerobic digestion.

8.3.17. Biomass from degraded and polluted lands

Table 29: Summary of evaluation results for biomass from degraded and polluted lands

	Evaluation Result	Additional remarks
Circular economy and waste hierarchy	No concern	Using biomass from degraded or polluted lands does neither contribute to, nor contravene circular economy principles or the waste hierarchy.
Sustainability Union criteria	No concern	In most cases for crops grown on degraded lands monitoring and management plans are not necessarily in place, this provides some small risk. <u>Under which circumstances could this feedstock be problematic?</u> It is possible that the production of biomass from degraded or polluted lands could occur on land with high biodiversity value or high carbon stocks, or without management plans in place to address soil carbon. <u>How to mitigate this concern?</u> Failure to meet the Union sustainability criteria will be efficiently addressed throughout the certification process by an EU-approved voluntary or national scheme.
Sustainability GHG	No concern (co-products)	Biomass from degraded or polluted land may be converted through various processes, thus leading to a wide range of GHG savings. <u>Under which circumstances could this feedstock be problematic?</u> Production processes with high direct emissions such as use of coal/lignite as process fuel would likely not comply with the GHG reduction criteria. <u>How to mitigate this concern?</u> Failure to meet the Union minimum GHG

		savings will be efficiently addressed throughout the certification process by an EU-approved voluntary or national scheme.
	No concern (waste)	When considered as waste, biomass from degraded or polluted land will likely exceed the minimum 65% GHG savings.
Sustainability Others	No concern	It can be assumed that the use of degraded or polluted lands will generally aim at stabilising or improving on land degradation or pollution, thus reducing the risk of environmental impacts. <u>Under which circumstances could this feedstock be problematic?</u> A risk exists that land degradation or pollution requires adjustments in cultivation practices (e.g. additional nutrients or water use), which could result in causing or aggravating existing degradation or pollution. <u>How to mitigate this concern?</u> Whereas some EU-approved voluntary schemes have additional environmental requirements, which could potentially mitigate the identified concerns, new policy instruments would be required to address these consistently and systematically.
Market distortion	No concern	The difficulty to formerly and consistently identify degraded or polluted lands poses some concern as non-degraded or non-polluted lands could be unduly considered as such and diverted from other productions. The risk is considered low because the assumption here is that the focus is on land that is truly degraded or polluted according to an EU approved certification system <u>How to mitigate this concern?</u> For degraded lands, feedstock should be certified by EU-approved voluntary schemes as coming from a formally identified and identified degraded land. For polluted lands, new policy developments would be required to establish and consistently implement clear pollution threshold and polluted

		land identification process.
2030/2050 Potential	Unknown	A realistic estimate cannot be made.
Land demand	No concern (low ILUC only)	Whenever only degraded or polluted lands, which were not used before, or which primarily aim at stabilisation or bioremediation (certified as such in an EU-approved certification scheme), are used to produce biomass for energy purposes, the risk of additional land demand can be considered low.
Processing Technologies	Mature	The technologies to convert the different crops grown on degraded or polluted lands to biomethane or liquid biofuels are considered to be Mature.

8.3.18. Damaged crops (unfit for human and animal consumption)

Table 30: Summary of evaluation results for damaged crops unfit for human and animal consumption

	Evaluation Result	Rationale
Circular economy and waste hierarchy	No concern	The conversion of damaged crops into a material/chemical is still in experimental phase and no commercially proven use was found in literature. **Therefore, the use of damaged crops unfit for human and animal consumption for biofuel/biogas is in line with CE.**
Union Sustainability criteria	No concern	<u>Under which circumstances could this feedstock be problematic?</u> Damaged crops can come from land where impacts on soil quality and soil carbon are not per definition monitored. <u>How to mitigate this concern?</u> Failure to meet the Union sustainability criteria will be efficiently addressed throughout the certification process by an EU-approved voluntary or national scheme.

Sustainability GHG	No concern (coproduct)	The mitigation potential calculation depends on whether damaged crops are seen as co-product (crop) or as vegetal waste. If considered as a co-product, the GHG emission savings in most routes are likely to be met. <u>Under which circumstances could this feedstock be problematic?</u> If cultivation emissions need to be allocated to the damaged crops, considering the EU RED II default values, biofuels and biogas produced from damaged crops can, but do not necessarily, comply with the GHG reduction criteria of 65%. How to mitigate this concern? Failure to meet the Union minimum GHG savings will be efficiently addressed throughout the certification process by an EU-approved voluntary or national scheme.
	No concern (waste)	If considered as a waste, the GHG emission savings in most routes are likely to be met.
Sustainability Others	No concern	Impacts on the environment depend on the type of crop and cultivation practices. <u>Under which circumstances could this feedstock be problematic?</u> Tillage practices, use of agricultural inputs and harvesting practices may cause negative impacts on the environment. <u>How to mitigate this concern?</u> Whereas some EU-approved voluntary schemes have additional environmental requirements, which could potentially mitigate the identified concerns, new policy instruments would be required to address these consistently and systematically.
Market distortion	No concern	No competition between energy and other uses is envisioned for damaged crops.
2030/2050 Potential	2030 (global) : 224 million tonnes (i.e. 43 million tonnes of biomethane or 191 million tonnes of HVO),	No specific data could be found for the damaged crops to biomethane or HVO route. Current biowaste/food waste was

	based on biowaste/food waste. 2050 (global) : 301 million tonnes (i.e. 57 million tonnes of biomethane or 256 million tonnes of HVO), based on biowaste/food waste.	used as proxy for conversion to biofuel.
Land demand	No concern	A market for damaged crops unfit for human and animal consumption is non existent. In the future one can expect that the commercial development of using biomass from damaged crops can develop. Should this happen, this can decrease the demand for land suitable for food production.
Processing Technologies	Mature (biomethane, bioethanol, biodiesel, HVO)	Damaged crops can be processed into biomethane or biofuels (ethanol, biodiesel, HVO) using mature technologies.

8.3.19. Category 3 Animal fats

Table 31: Summary of evaluation results for Category 3 animal fats

	Evaluation Result	Rationale
Circular economy and waste hierarchy	No concern	No commercial uses exist that can extend product life and sequester carbon for longer than energy uses. Therefore, using Category 3 animal fats for biofuel/biogas production does neither contribute to, nor contravene circular economy principles. Use in biogas production would contribute to nutrient recovery although it is not understood to be a very suitable substrate.
Union sustainability criteria	Not applicable	These criteria are **not applicable** to Category 3 animal fats as this feedstock is neither primary agricultural biomass or agricultural field residue or forest biomass.
Sustainability GHG	No concern	Category 3 animals fats should realise GHG emission savings of around 80%.
Sustainability Others	Not applicable	This criteria is **not applicable** to Category 3 animal fats if this feedstock is categorised as a residue (from processing).

Market distortion	Significant concern	Most Category 3 animals fats are used for food/feed and are considered to have a rigid supply. Increased demand is likely to result in substitution with either palm oil or rapeseed oil in the food and feed sector. Palm oil is likely to be the substitute for use in the oleochemicals. <u>How to mitigate this concern?</u> Inclusion in Annex IXB (see below) would limit the amount of feedstock being used for FAME/HVO production. The contribution of Annex IXB feedstocks to national RED transport targets is capped at 1.7% of transport energy. Inclusion under this cap would limit the amount of feedstock likely to be used for biodiesel production and thus mitigate against the most market distortive outcomes, but would not fully prevent indirect impacts.
2030/2050 Potential	2030 (EU) : 3.1-3.3 million tonnes (2.8-3 million tonnes FAME, 2.6-2.8 million tonnes HVO) 2050 (EU) : 3.0-3.2 million tonnes (2.7-2.9 million tonnes FAME, 2.6-2.7 million tonnes HVO)	The current EU supply of Category 3 animal fats is estimated to be around **3.2-3.4 million tonnes**. However, supply is expected to decrease by around 2% in the period to 2050 in-line with reduced meat consumption, with a further decrease expected to 2050. **Significant volumes (700 thousand tonnes in 2019)** are already used in biofuels.
Land demand	Significant concern	The use of additional Category 3 animal fats for biofuel will divert this material from other existing uses, leading to additional demand for palm or rapeseed oil. The risk of additional demand for land for substitute materials has been assessed in previous studies and on that basis, the majority of Category 3 substitutes (palm and rapeseed) would fall in the **high risk category**. <u>How to mitigate this concern?</u> See market distortion.
Processing Technologies	Mature (FAME/HVO)	Biodiesel production from Category 3 animals fats is already commercially practised and both transesterification (FAME) and hydrotreating (HVO) are considered **mature technologies**.

8.3.20. Category 2 and 3 Animal by-products (not fats)

Table 32: Summary of evaluation results for Category 2-3 animal by-products (not fats)

	Evaluation Result	Rationale
Circular economy and waste hierarchy	No concern	No commercial uses exist that can extend product life and sequester carbon for longer than energy uses. Therefore, using Category 2 and 3 ABP (not fats) for biofuel/biogas production does neither contribute to, nor contravene circular economy principles. Use in biogas production would contribute to nutrient recovery although it is not understood to be a very suitable substrate.
Union sustainability criteria	Not applicable	These criteria are **not applicable** to Category 2 and 3 ABP (not fats) as this feedstock is neither primary agricultural biomass or agricultural field residue or forest biomass.
Sustainability GHG	No concern	Category 2 and 3 ABP (not fats) should realise GHG emission savings of around 80%.
Sustainability Others	Not applicable	This criteria is **not applicable** to Category 2 and 3 ABP (not fats) if this feedstock is categorised as a residue (from processing).
Market distortion	Category 3: Significant concern Category 2: Some concern	Category 2 and 3 ABP (not fats) are considered to have a rigid supply. Increased demand is likely to result in substitution with soy meal in the food and feed sector (this risk is primarily for Category 3 material since use of Category 2 material is restricted). **Use for biofuel production may be possible under specific conditions, for example** if fats can be separated from the edible proteins prior to conversion to biofuel, without compromising the nutritional quality of the material (for example by "washing out" the fats using an alkaline hydroxide solution). Alternatively, it has been proposed to apply an **innovative rendering method** (for Category 2 material), which produces both a fat fraction and a slurry fraction which can be used for biogas production.

		Synthetic fertilisers would likely replace use as fertiliser, unless the material is used to produce biogas (as proposed for Category 2 material), in which case the digestate can be alternatively applied as fertiliser.
2030/2050 Potential	2030 (EU): 5.2-5.6 million tonnes (no reliable data for FAME, 0.1 million tonnes of biogas – assuming 100% innovative rendering method for Category 2 applied) 2050 (EU): 4.9-5.3 million tonnes (no reliable data for FAME, 0.1 million tonnes of biogas – assuming 100% innovative rendering method for Category 2 applied)	The current supply of Category 2 and 3 ABP (not fats) in Europe is around **5.3-5.7 million tonnes (of which around 95% corresponds to Category 3)**. This is expected to decrease by around 2% in the period to 2030 in-line with reduced meat consumption, with a further decrease expected to 2050.
Land demand	Category 3: Significant concern Category 2: Some concern	The use of additional Category 2 and 3 ABP (not fats) for biofuel or biogas will divert this material from other existing food or feed uses, leading to additional demand for soy (this risk is primarily for Category 3 material). The risk of additional demand for land for substitute materials has been assessed in previous studies (Biggs, 2016) and on that basis, this would fall in the **medium risk category**. The overall risk is considered **medium-high**. <u>How to mitigate this concern?</u> See market distortion.
Processing Technologies	Advanced (biofuels produced using oil extracted from poultry feather meal) Mature (biogas)	Biodiesel production from Category 2 and 3 ABP (not fats) is already commercially practised, but only one specific example has been identified in Pakistan. The overall process is considered to be an **advanced technology**[8]. Category 2 and 3 ABP (not fats) have been proposed by several stakeholders as candidate feedstocks for anaerobic digestion, which can be considered to be a **mature technology**. However, we have not identified widespread examples of

[8] Note that biofuel produced from Category 2 ABP (fat) would be counted under Annex IX Part B. See section 8.3.19 for an assessment of the eligibility of biofuel produced from Category 3 ABP (fat).

		commercial application in Europe.

8.3.21. Municipal wastewater and derivatives (other than sludge)

Table 33: Summary of evaluation results for municipal wastewater and derivatives (other than sludge)

	Evaluation Result	**Rationale**
Circular economy and waste hierarchy	No concern	Using this feedstock contributes to the circular economy through biogas which produces a digestate, thus resulting in nutrient recovery and recycling. The use of this feedstock is in line with the waste hierarchy since it has restricted uses outside of energy applications. Initiatives such as preventing the FOG material entering the sewer system in the first instance, through the use of grease traps, should be prioritised though.
Union Sustainability criteria	Not applicable	These criteria are **not applicable** to Municipal wastewater and derivatives (other than sludge) as this feedstock is neither primary agricultural biomass or agricultural field residue or forest biomass.
Sustainability GHG	No concern	Municipal wastewater and derivatives (other than sludge) for biofuel production should realise GHG emission savings of around 80%. Municipal wastewater and derivatives (other than sludge) for biogas is expected to realise around 80% GHG emission savings if the digestate is stored in a closed tank and the off-gas is combusted. <u>How to mitigate this concern?</u> Failure to meet the minimum GHG savings will be efficiently addressed throughout the certification process by an EU-approved voluntary or national scheme.
Sustainability Others	Not applicable	This criteria is **not applicable** to Municipal wastewater and derivatives (other than sludge) as this feedstock is a waste.
Market distortion	No concern	Municipal wastewater and derivatives (other than sludge) are considered to have a rigid supply. However, the risk of market distortion is extremely low given that there are very limited uses for this feedstock

		outside of energy.
2030/2050 Potential	2030: No data 2050: No data	No estimates of either the current or future potential of FOG potential in the wastewater system could be identified in the literature.
Land demand	No concern	The use of Municipal wastewater and derivatives (other than sludge) has a **low risk category** of land use change.
Processing Technologies	Mature (biodiesel) Mature (biogas <30% concentration) Advanced (biogas >30% concentration)	Biodiesel production from Municipal wastewater and derivatives (other than sludge, e.g. fatberg collected from sewers) is commercially practised, but only on a limited scale and restricted to transesterification. This is considered a **mature technology**. The processing of Municipal wastewater and derivatives (other than sludge) into biogas can be considered to be a **mature technology in co-digestion applications at a concentration of up to 30%** of the total substrate dry mass. **At higher concentrations** the technology could be considered as an **advanced technology**.

8.3.22. Soapstock and derivatives

Table 34: Summary of evaluation results for soapstock and derivatives

	Evaluation Result	Rationale
Circular economy and waste hierarchy	No concern	No commercial uses exist that can extend product life and sequester carbon for longer than energy uses. Using soapstock and derivatives for biogas/biofuel does neither contribute to, nor contravene circular economy principles or the waste hierarchy.
Union Sustainability criteria	Not applicable	Sustainability Union criteria do not apply because soapstock and derivatives is a process residue.
Sustainability GHG	No concern	Biofuel and biogas produced from soapstock and derivatives would likely meet the GHG criteria of EU RED II.

Sustainability Others	Not applicable	Other sustainability impacts do not apply because soapstock and derivatives is a process residue with no land management impact.
Market distortion	Significant concern	Soapstock and derivatives appear to be mostly or entirely used in livestock feed and oleochemicals. Diverting this feedstock to biofuel production would likely cause high risk of market distortion. How to mitigate this concern? This feedstock has been assessed as potentially appropriate for inclusion in Annex IXB. The contribution of Annex IXB feedstocks to national RED transport targets is capped at 1.7% of transport energy. Inclusion under this cap would limit the amount of feedstock likely to be used for biofuel/biogas production and thus mitigate against the most market distortive outcomes, but would not fully prevent indirect impacts.
2030/2050 Potential	2030: 13 million tonnes soapstock (6 million tonnes biodiesel or 5 million tonnes HVO) 2050: 18 million tonnes soapstock (8 million tonnes biodiesel or 7 million tonnes HVO)	Soapstock and derivatives production will likely grow with the growing vegetable oil market.
Land demand	Significant concern	The diversion of soapstock and derivatives from existing uses to biofuel production would likely cause increased production of medium and high risk substitutes, including barley, maize, and vegetable oils such as palm oil and soy oil, with an overall high risk of increased demand for land. How to mitigate this concern? This feedstock has been assessed as potentially appropriate for inclusion in Annex IXB. The contribution of Annex IXB feedstocks to national RED transport targets is capped at 1.7% of transport energy. Inclusion under this cap would limit the amount of feedstock likely to be used for biofuel/biogas production and thus mitigate against the most market distortive outcomes, but would not fully prevent indirect impacts.

Processing Technologies	Mature	Soapstock and derivatives can be processed into biodiesel and biogas using mature technologies.

8.3.23. Brown grease

Table 35: Summary of evaluation results for brown grease

	Evaluation Result	**Rationale**
Circular economy and waste hierarchy	No concern	No commercial uses exist that can extend product life and sequester carbon for longer than energy uses. Therefore, using brown grease for biogas/biofuel does neither contribute to, nor contravene circular economy principles or the waste hierarchy. Production of lubricants, other chemicals, and biopolymers are alternatives to energy production which can extend the lifetime of the feedstock. However, feedstock pretreatment costs make the overall production process very expensive, and therefore commercially unattractive.
Union sustainability criteria	Not applicable	These criteria are **not applicable** to brown grease as this feedstock is neither primary agricultural biomass or agricultural field residue or forest biomass. Brown grease is a process residue or waste.
Sustainability GHG	No concern	Considering GHG savings in the range of 84% to over 90%, biodiesel using brown grease would be in compliance with the GHG savings criteria for new installations i.e. at least 65% GHG savings. <u>Under which circumstances could this feedstock be problematic?</u> To be eligible with the 65% minimum GHG saving threshold, operators producing **biogas/biomethane** from brown grease should ensure that the resulting digestate is maintained in a closed infrastructure and off-gas combustion is applied. <u>How to mitigate this concern?</u> Failure to meet the minimum GHG savings will be efficiently addressed throughout the certification process by an EU-approved voluntary or national scheme.

Sustainability Others	Not applicable	Brown grease is a residue or waste. These criteria are **not applicable** as this feedstock has no land impact.
Market distortion	No concern	Given limited existing non-energy uses, adding brown grease to Annex IX should not have a distortive effect on any market.
2030/2050 Potential	2030: EU: 2.3 million tonnes (i.e. 2 million tonnes of biodiesel or 0.43 million tonnes of biogas); US: 1.6 million tonnes (theoretical potential) (i.e. 1.4 million tonnes of biodiesel or 0.3 million tonnes of biogas) 2050: EU: 2.2 million tonnes (i.e. 1.9 million tonnes of biodiesel or 0.41 million tonnes of biogas); US: 1.7 million tonnes (theoretical potential) (i.e. 1.5 million tonnes of biodiesel or 0.33 million tonnes of biogas)	Additional supply potential will exist in other regions.
Land demand	No concern	It seems unlikely that the use of brown grease as a biofuel feedstock will have an impact on any other resource and is therefore considered a **low risk**, that is, no land use change is expected.
Processing Technologies	Mature (biogas/ biomethane) Mature (biodiesel)	The conversion technologies of brown grease into biogas or biodiesel are considered to be mature, due to high TRL (9) and CRL (5).

8.3.24. Palm fatty acid distillate (PFAD) (Fatty acid distillates[9])

Table 36: Summary of evaluation results for fatty acid distillates

	Evaluation Result	Rationale

[9] Fatty acid distillates (FAD) are produced during the physical refining of vegetable oils. The use of Palm fatty acid distillate (PFAD) for bioenergy applications has received greated interest to date and is therefore the subject of this analysis.

Circular economy and waste hierarchy	Some concern	<u>Under which circumstances could this feedstock be problematic?</u> PFAD does have possible non-energy uses (e.g. feedstock for oleochemical industry) which would extend the life of PFAD and sequester the carbon for longer compared to its use as a biofuel. <u>How to mitigate this concern?</u> Concerns could potentially be mitigated if feedstock is used in a biorefinery setup where both biofuels and feedstocks for the oleochemical industry could be produced.
Union Sustainability criteria	Not applicable	Not relevant if PFAD is considered to be a residue from processing.
Sustainability GHG	No concern	The GHG savings criteria for new installations require at least 65% GHG savings might not be met if the oil mill has open effluent ponds. In the case that there is methane capture at the mill, the GHG criteria will likely be met. <u>How to mitigate this concern?</u> Failure to meet the minimum GHG savings will be efficiently addressed throughout the certification process by an EU-approved voluntary or national scheme.
Sustainability Others	Not applicable	If this feedstock is categorised as a process residue, these criteria are **not applicable**.
Market distortion	Significant concern	Given that Palm Fatty Acid Distillates (PFAD) has current uses in several industries and has a rigid supply, diverting PFAD from these industries to biofuel production has a **high risk** of having distortive effect on these industries. <u>How to mitigate this concern?</u> This feedstock has been assessed as potentially appropriate for inclusion in Annex IXB. The contribution of Annex IXB feedstocks to national RED transport targets is capped at 1.7% of transport energy. Inclusion under this cap would limit the amount of feedstock likely to be used for biofuel production and thus

		mitigate against the most market distortive outcomes, but would not fully prevent indirect impacts.
2030/2050 Potential	2030: 4.4 million tonnes (3.8 million tonnes HVO) 2050: 5.7-7.4 million tonnes (4.9-6.3 million tonnes HVO)	The evaluation concluded that there is a potential of approximately **4.4 million tonnes** of **PFAD** in **2030**. This could increase to a potential of **5.7-7.4 million tonnes of PFAD in 2050**.
Land demand	Significant concern	The use of PFAD for biofuel will divert this material from other existing uses, and the operators of those uses may then seek substitute materials such as palm or soy oil. The risk of additional demand for land for substitute materials has been assessed in previous studies and on that basis, the majority of PFAD substitutes (palm and soy) would fall in the **high risk category**. The overall risk of additional demand for land is high. <u>How to mitigate this concern?</u> See market distortion.
Processing Technologies	Mature	Biodiesel production from PFAD is already commercially practised and both transesterification and hydrotreating are considered **mature technologies**.

8.3.25. Technical corn oil

Table 37: Summary of evaluation results for technical corn oil

	Evaluation Result	Rationale
Circular economy and waste hierarchy	No concern	Increased extraction and use of technical corn oil (TCO) for bioenergy purposes does not contradict circular economy principles, nor does it actively contribute to them.
Union Sustainability criteria	Not applicable	These criteria are not applicable to TCO as this feedstock is neither primary agricultural biomass or agricultural field residue or forest biomass.

Sustainability GHG	No concern	Default GHG emissions values for similar feedstocks meet the criteria.
Sustainability Others	No concern	No other significant environmental impact anticipated.
Market distortion	Significant concern	TCO is a resource that would otherwise be fully utilised, primarily in animal feed either directly or as a constituent of DGS. The feed value of TCO would therefore need to be replaced if diverted to biofuel/biogas use.
2030/2050 Potential	2030: 320,000 tonnes [320,000 tonnes biodiesel] (EU); 1.7 million tonnes [1.7 million tonnes biodiesel] (U.S.) 2050: limited	Assumes corn ethanol production rates more or less constant to 2030 and then reduced significantly by 2050.
Land demand	Significant concern	TCO displaced from existing markets is likely to be replaced with vegetable oils, while additional extraction of TCO from distillers' grains is likely to be compensated by additional cereals. These are materials with a high and medium land use change risk respectively. The overall risk of additional demand for land is therefore considered high.
Processing Technologies	Mature	TCO may be processed with mature biodiesel and renewable diesel production technologies.

8.3.26. Distillers' dried grain with solubles (DDGS)

Table 38: Summary of evaluation results for DDGS

	Evaluation Result	Rationale
Circular economy and waste hierarchy	No concern	No commercial uses exist that can extend product life and sequester carbon for longer than energy uses. Therefore, using DDGS for biofuel/biogas production does neither contribute to, nor contravene circular economy principles.
Union Sustainability	No concern	Maize is generally cultivated on land that has been in agricultural production since

criteria		before 2008.
Sustainability GHG	No concern	Under which circumstances could this feedstock be problematic? The GHG savings depends on the fuel used in processing. Natural gas would likely meet the criteria whereas lignite may not. How to mitigate this concern? Failure to meet the minimum GHG savings will be efficiently addressed throughout the certification process by an EU-approved voluntary or national scheme.
Sustainability Others	Some concern	Under which circumstances could this feedstock be problematic? Several risks exist, including high risk for biodiversity and soil erosion. How to mitigate this concern? Whereas some EU-approved voluntary schemes have additional environmental requirements, which could potentially mitigate the identified concerns, new policy instruments would be required to address these consistently and systematically.
Market distortion	Significant concern	Use of DDGS as animal feed is very well-established globally (North America, Europe, South East Asia). This market is likely to be significantly distorted if the feedstock was instead diverted to biofuel/biogas production. How to mitigate this concern? Feedstock would fall under the food/feed crop cap, which would limit the amount of feedstock being used for biofuel/biogas production.
2030/2050 Potential	2030: 92 million tonnes (31 million tonnes ethanol or 17.5 million tonnes biogas) 2050: 127 million tonnes (43 million tonnes ethanol or 24 million tonnes biogas)	The evaluation concluded that there is a potential supply of approximately **92 million tonnes** of DDGS in **2030 and 127 million tonnes in 2050.**
Land demand	Significant concern	Under which circumstances could this

		feedstock be problematic? DDGS would be substituted by soy meal and maize meal, medium-risk materials. There is overall a **medium-high risk** for additional demand for land. How to mitigate this concern? See market distortion.
Processing Technologies	Advanced	The conversion of DDGS to biofuel or biogas has not been demonstrated at commercial scale.

8.3.27. High oleic sunflower oil extraction residues

Table 39: Summary of evaluation results for high oleic sunflower oil extraction residues

	Evaluation Result	Rationale
Circular economy and waste hierarchy	Some concern	No commercial uses exist that can extend product life and sequester carbon for longer than energy uses. Using high oleic sunflower oil extraction residues for HVO production is in line with circular economy principles. Under which circumstances could this feedstock be problematic? PSK-Keto and FAV are processing residues generated in large volumes through the conversion of high oleic sunflower oil into pelargonic and azelaic acids, which are used as chemical precursors. The use of a food crop (high oleic sunflower) for non-food purposes can be seen as problematic from a food security perspective. How to mitigate this concern? This concern relates to the business model of pelargonic and azelaic production out of biomass. EU bio-based economy policies should ensure that the use of biomass does not present any risk to food security.
Union Sustainability criteria	Not applicable	These criteria are **not applicable** to high oleic sunflower oil extraction residues, as this feedstock is neither primary agricultural biomass or agricultural field residue or forest biomass. This feedstock is

		a process residue.
Sustainability GHG	No concern	GHG savings estimates are largely above the most stringent minimum GHG saving threshold (65%) applied to installations starting operations after January 1, 2021.
Sustainability Others	Not applicable	High oleic sunflower oil extraction residues do not require dedicated land cultivation and therefore have no land management impact.
Market distortion	No concern	High oleic sunflower oil extraction residues (PSK-Keto and FAV) are currently not distributed via an established market, rather among business partners. Non-energy uses are currently very limited.
2030/2050 Potential	2030 (Global): 28,400 tonnes (PSK-Keto), i.e. 24,200 tonnes of HVO; 44,200 tonnes (FAV), i.e. 37,200 tonnes of HVO. 2050 (Global): undetermined	No specific data could be found for the 2030 and 2050 production of high oleic sunflower oil extraction residues. 2030 are based on 2021-2026 growth estimates for pelargonic acid markets, assuming that all operators use similar processes as Matrica.
Land demand	No concern	Competition with non-energy uses appears unlikely. Therefore, the risk for additional demand for land is **low**.
Processing Technologies	Mature (HVO)	The conversion technologies of high oleic sunflower oil extraction residues into HVO or FAME are considered to be **mature**, due to high TRL (9) and CRL (3).

8.3.28. Other biowaste

The feedstock "other biowaste" studied in this report concern biowaste that is not already covered in Annex IX and refer to food and kitchen waste from restaurants, caterers and retail premises that are similar in nature to household waste and are separately collected.

Table 40: Summary of evaluation results for other biowaste

	Evaluation Result	Rationale
Circular economy and waste hierarchy	No concern	Using biowaste for biogas/biofuel does neither contribute to, nor contravene circular economy principles or the waste hierarchy.

Union sustainability criteria	Not applicable	Biowaste is waste. These criteria are **not applicable** as this feedstock is neither primary agricultural biomass nor agricultural field residue nor forest biomass.
Sustainability GHG	No concern	Under which circumstances could this feedstock be problematic? To be eligible, the technology option of close digestate, off-gas combustion should be applied for producing biogas. How to mitigate this concern? Failure to meet the minimum GHG savings will be efficiently addressed throughout the certification process by an EU-approved voluntary or national scheme.
Sustainability Others	Not applicable	Biowaste is waste. These criteria are **not applicable** as this feedstock has no land impact.
Market distortion	No concern	Biowaste has a rigid supply. Redirecting biowaste from composting to anaerobic digestion is **not expected to create a distortive effect on market**.
2030/2050 Potential	2030 & 2050: 9-15 million tonnes (i.e. 1.7-2.9 million tonnes biogas)	The evaluation concluded that there is a potential of approximately **9-15 million tonnes** of "other biowaste" available in **2030 and 2050**.
Land demand	No concern	The use of biowaste for biogas/biofuel pose no risk of additional demand for land.
Processing Technologies	Mature (biogas)	Conversion of biowaste into biomethane can be done using anaerobic digestion technology and biogas upgrading technology. These are **mature processing technologies**.

8.3.29. Sea algae

Table 41: Summary of evaluation results for sea algae

	Evaluation Result	Rationale
Circular economy and waste hierarchy	No concern	Sea algae could help contribute to a more circular economy with a biorefinery approach in which energy, fertiliser, and other products can displace fossil equivalents and use the primary material

		of sea algae efficiently.
Union Sustainability criteria	Not applicable	These criteria are **not applicable** to sea algae as this feedstock is neither primary agricultural biomass or agricultural field residue or forest biomass.
Sustainability GHG	No concern	Under which circumstances could this feedstock be problematic? Very high level GHG estimates for sea algae fuels suggest that the threshold may not be met. However, these estimates are based on experimental data and are not robust enough upon which to draw conclusions. How to mitigate this concern? Failure to meet the minimum GHG savings will be efficiently addressed throughout the certification process by an EU-approved voluntary or national scheme.
Sustainability Others	Some concern	Under which circumstances could this feedstock be problematic? Several sustainability impacts on marine ecosystems would need to be investigated for large scale production. The main concerns are facilitation of disease, alteration of population genetics and wider alterations to the local physiochemical environment. How to mitigate this concern? Whereas some EU-approved voluntary schemes have additional environmental requirements, which could potentially mitigate the identified concerns, new policy instruments would be required to address these consistently and systematically.
Market distortion	No concern	Sea algae is considered to have an elastic supply thus will have little interference with the markets of existing applications such as for human food consumption.
2030/2050 Potential	Variable	The potential for sea algae depends on the demand and economics of producing biofuels and biogas that drive this demand. Technical potentials are very high (1 billion tonnes per year over an area of 10 billion

		hectares), but the economic and sustainable potentials would be lower.
Land demand	Not applicable	By definition, sea algae is not land based so does not cause concern for increased land demand.
Processing Technologies	Advanced (biofuels and biogas)	Although some parts of biofuel and biogas production use conventional technologies, there are few examples of large-scale production specifically with sea algae. Biofuel or biogas production from sea algae should thus be categorised as an advanced technology.

8.3.30. Cyanobacteria

Table 42: Summary of evaluation results for cyanobacteria

	Evaluation Result	Rationale
Circular economy and waste hierarchy	No concern	No commercial uses exist that can extend product life and sequester carbon for longer than energy uses. Therefore, using cyanobacteria for biogas/biofuel does neither contribute to, nor contravene circular economy principles or the waste hierarchy.
Union Sustainability criteria	No concern	Sustainability Union criteria do not apply because cyanobacteria is aquatic and unlikely to be produced on agricultural land.
Sustainability GHG	No concern	Biofuel and biogas produced from cyanobacteria could have high GHG emissions. <u>How to mitigate this concern?</u> Failure to meet the minimum GHG savings will be efficiently addressed throughout the certification process by an EU-approved voluntary or national scheme.

Sustainability Others	No concern	Cyanobacteria cultivation is not very likely to cause negative sustainability impacts. <u>Under which circumstances could this feedstock be problematic?</u> Cyanobacteria could potentially be invasive, depending on what species are grown in what locations, and could potentially worsen air quality by emitting NO_x. <u>How to mitigate this concern?</u> Whereas some EU-approved voluntary schemes have additional environmental requirements, which could potentially mitigate the identified concerns, new policy instruments would be required to address these consistently and systematically.
Market distortion	No concern	It is unlikely that biofuel and biogas demand would divert cyanobacteria from its existing high-value uses or otherwise impact existing markets.
2030/2050 Potential	Very low	At present, there does not appear to be any cyanobacteria available for economically viable biofuel or biogas production, and this status does not seem likely to change.
Land demand	No concern	Cyanobacteria are aquatic and not likely to be grown on agricultural or other high-value land. Because the risk of market distortion is low, there is no concern of an indirect increase on land demand.
Processing Technologies	Mature	Cyanobacteria can be processed into ethanol, biogas, and biodiesel using mature technologies.

8.4. CONCLUSIONS

The project consortium successfully conducted 30 feedstock assessments against EU RED II Article 28 criteria. The results, which are summarised in the previous section, provided a comprehensive overview of potential risks in relation to their potential inclusion in Annex IX.

The decision to suggest feedstocks for inclusion was made challenging by the fact that EU RED II does not specify how the different criteria listed in Article 28 should be used in the decision to include additional feedstocks in Annex IX.

Some of the risks identified in this assessment, in line with Article 28, can be efficiently captured by an independent audit as part of the certification process by an EU-approved voluntary scheme. This is the case for the Union sustainability criteria and GHG savings. On the contrary, a lack of alignment with circular economy principles, market distortions and additional land demand would not be addressed by such independent audit. Some concerns may, however, be mitigated by further defining feedstock specificities (e.g. in the case of de-oiled pomace) and other existing policy mechanisms such as the inclusion in Annex IX - Part B or a characterisation as a co-product from a food/feed crop, which would make feedstock capped. Risks that cannot be captured by a RED compliance audit or existing policy mechanisms may therefore require the development of new policy instruments, such as the implementing act on voluntary schemes.

Seven of the assessed feedstocks were marked as no concern for any of the criteria used for the assessment, which cannot be addressed by EU-approved voluntary schemes: **Raw methanol from kraft pulping, Biomass from degraded/polluted lands (if appropriately evaluated as low ILUC), Damaged crops (unfit for human or animal consumption), Municipal wastewater and derivatives (other than sludge), Brown grease, Other biowaste and Cyanobacteria.**

Some feedstocks raised significant concerns over one or more of the criteria: **Cover and intermediate crops, Animal by-products category 2-3 (not fats), Animal fats category 3, Dry starch from corn fractionation, Fatty acid distillates, Molasses, Potato/beet pulp, Soapstock and derivatives, Technical corn oil, and DDGS.**

Numerous feedstocks were only marked with "some concerns", where the overall level of risk might be considered acceptable or where a risk would only materialise in certain conditions. In several cases, existing policy instruments (inclusion in Annex IXB or food/feed cap) or further specification of the feedstock type could mitigate the identified concerns. This would be the case for **Drink production residues and waste, Fruit and vegetable residues and waste, Vinasse** (by excluding thin stillage and sugarbeet vinasse), **Olive extraction residues** (de-oiled pomace only), **biomass from degraded land** (with a formal validation of the degraded status by an EU-approved voluntary scheme).

The relevance of using the "low ILUC" approach to mitigate risks for cover/intermediate crops and crops produced on degraded or polluted land could be further explored. Direct communication with the Consortium in charge of evaluating the low ILUC certification reveals that the low ILUC approach (additionality) would not apply to the cover and intermediate crops evaluated in this study, whenever these would fall under the food/feed crop definition. However, the use of the low ILUC approach to the identification of degraded lands was deemed relevant in the perspective of the inclusion of such approach by voluntary schemes in the near future.

As mentioned in the methodology, the assessments of shortlisted feedstocks conducted in this project relied on a diverse range of sources with variable levels of robustness and independence. For feedstocks with limited documentation, the assessment primarily relied on direct inputs from stakeholders or documentation for somewhat comparable feedstocks, which were used as proxies.

Finally, it should be noted that only six feedstocks were evaluated as being processed via advanced technologies. Therefore, all of the remaining feedstocks may only be eligible for Annex IX Part B. This is due to the methodological decision to base the assessment of technology on the most widely used feedstock processing pathway and end-use. It could, however, be envisioned that the inclusion of certain feedstocks in Annex IX be conditioned to specific end-uses such as aviation or marine fuels. In principle it would be possible to produce aviation or marine fuels from most of the feedstocks discussed in Task 2, and some of these processes would be considered advanced, for example through ethanol-to-jet processes, or through upgrading of Fischer-Tropsch waxes or pyrolysis oils.

9. TASK 3 - FRAUD RISK AND MITIGATION MEASURES

9.1. SUBTASK 3.1 – REVIEW OF EXISTING FRAUD CASES

This section describes documented cases of fraudulent supply chain and certificate or credit reporting in the EU and US biofuel industries; in order to supplement these cases and learn from experience acquired in other sectors, reported frauds in the forestry sector were also documented. The purpose of this review was to assist in identifying potential weak points in the sustainability certification process and thus potential risks of fraud for Annex IX feedstocks and candidate feedstocks for inclusion in Annex IX, which were shortlisted at the end of subtask 1.

9.1.1. Biofuel fraud cases

Here, we reviewed historical and ongoing cases of fraud in the biofuels industry with a view to understanding weaknesses in current systems that can inform the development of fraud risk indicators used in subtask 3.4 to evaluate fraud risks of existing Annex IX feedstocks and shortlisted feedstocks, as well as recommendations for new measures to reduce fraud risks. These cases have largely centred around the fraudulent creation of credits or certificates for biofuel that did not exist. There are also two cases of soy biodiesel being fraudulently sold as used cooking oil methyl ester (UCOME):

Biodiesel Kampen, Netherlands (2019)

Biodiesel Kampen was a Dutch company that produced and sold biofuel to the Netherlands domestic market. The Netherlands sets annual mandatory obligations to supply renewable energy for transport fuel companies and establishes a compliance and registry system to track renewable energy use in the Dutch transport sector (Dutch Emissions Authority, n.d.a). Renewable energy units, referred to as HBEs and formerly known as bio-tickets, represent 1 gigajoule of renewable energy delivered each. There are three type of HBEs differentiated by the feedstock used to make the fuel (Dutch Emissions Authority, n.d.b). HBE Advanced (HBE-A) is produced from advanced and non-biological renewable feedstock under Annex IX - Part A. HBE Conventional (HBE-C) is produced from agricultural crops. HBE Other (HBE-O) includes electricity or biofuels from Annex IX - Part B or feedstocks that don't fall into the aforementioned categories. Companies must have Proof of Sustainability or Guarantee of Origin to validate the feedstock and HBE type it qualifies under (Dutch Emissions Authority, n.d.c). Feedstocks that fall under Annex IX - Part A and B, HBE-A and HBE-O, are double counted and are therefore more valuable than HBE-C.

Biodiesel Kampen generated HBE-O credits from used cooking oil methyl ester (UCOME). Inspectors from the Human Environment and Transport Inspectorate reported to Dutch Emissions Authority that Biodiesel Kampen had sold more HBEs than permitted i.e. it claimed and sold HBEs for more fuel than was put on the market, which is illegal (Van Oirschot, 2019b). In 2013 and 2014 alone Biodiesel Kampen sold 8 million litres worth of HBEs but produced approximately 7% of that volume of UCOME annually (Van Oirschot, 2019a). The HBEs sold falsely stated that the fuel was on the market, which resulted in a forgery charge. The arrest of the Biodiesel Kampen's CEO Cees Bunchoten occurred in April of 2019. In the following month, May 2019, the facilities certification for producing biodiesel, from the International Sustainability & Carbon Certification (ISCC) was revoked. The Public Prosecution Service was responsible for investigating the criminal charges while the Dutch Emissions Authority performed their own internal investigation of HBE fraud. In August 2019 Biodiesel Kampen's CEO and multiple company accountants were found guilty and awarded prison sentences, community services, and/or given a fine (Van Oirschot, 2019c).

A second criminal investigation is also underway looking into whether the company sold HBE-C biodiesel instead of HBE-O biodiesel in order to benefit from the higher value generated from UCOME as opposed to crop-based biodiesel (Van Oirschot, August 22, 2019). This second crime would have occurred in 2015 and 2016 and relates to between 25-30% of the biodiesel sold during that period, valued at 150 million euros (Naschert, C., 2019). As of February 2020, this second case had not yet been resolved.

Sunoil, Netherlands (2020)

Sunoil is another Dutch biodiesel company reportedly under investigation as of November 2020 (Dekker, 2020). Sunoil purchased the former Biodiesel Kampen facility after that company went bankrupt in 2019 following the arrest and indictment of the Biodiesel Kampen CEO on fraud charges (See above). Sunoil is alleged to have also sold HBE-C biodiesel as HBE-O biodiesel and to have forged Proof of Sustainability or Guarantee of Origin certificates. No information on the volume of fuel falsely sold has been released and it is understood that this investigation is still on-going.

Waste Oil Trade LLC, Sistem Ecologica & Fob Fats, Europe (2020)

The European Anti-Fraud office (OLAF) investigated a case in October 2020 that involved soy biodiesel being claimed as UCOME, and that was tried in the Netherlands (Court of Rotterdam, 2020). Biogra Trading LLC., established in Hong Kong, agreed to purchase UCOME from Sistem Ecologica DOO SRBAC, a Bosnian Company hereafter referred to as Sistem Ecologica. Sistem Ecologica claimed to have imported used cooking oil (UCO) from the U.S. based company Waste Oil Trade LLC and then that this material was exported as UCOME to Belgium.

When the material identified as UCOME entered Belgium an injunction was received by Biogra Trading LLC for the payment of duties that apply to soy biodiesel imported from the U.S. Because soy-based biodiesel, and not UCO or UCOME, is subject to import duties when originating from the U.S., OLAF suspected that fraudulent reporting had been used to avoid these payments. Furthermore, Biogra Trading LLC discovered overlap in the personnel from Waste Oil Trade LLC, Sistem Ecologica, and Fob Fats, a Dutch company Biogra also purchased UCOME from, and alleged that these companies "are all manifestations of one and the same illegal enterprise" (Court of Rotterdam, 2020).

Biogra Trading LLC had the biodiesel sold to them by Sistem Ecologica tested by Saybolt, a petrochemical inspection company. Saybolt reported that, "Based upon the found results, our conclusion is that this most probably is SME (Soya Methyl Ester) and not UCOME (Used Cooking Oil Methyl Ester)". Therefore, Sistem Ecologica and Waste Oil Trade LLC sold Biogra Trading LLC the wrong product, presumably because of the higher value of UCOME due to benefits of inclusion in Annex IX. Additionally, both Sistem Ecologica and Waste Oil Trade LLC have had their third-party sustainability certificates from the International Sustainability & Carbon Certification suspended.

European Anti-Fraud Office 2019 Report

Another biodiesel fraud case investigated by the European Anti-Fraud Office was detailed in their 2019 report (European Anti-Fraud Office, 2019). A Norwegian company exported biodiesel to the EU claiming it was produced from UCO imported from Canada. However, it was discovered that the true country of origin was the U.S. and that the feedstock was soy oil, not UCO, that was subsequently blended with vegetable oil in Canada before being exported to Norway. Over 150,000 tonnes of this oil were imported from Canada without stating the U.S. as the true country of origin to avoid the anti-dumping and associated duties incurred when importing these products from the U.S., in this case €62 million, and to exploit national renewable energy schemes and incentives. The European Anti-Fraud Office also discovered that the Canadian and Norwegian company were both owned and operated by a single Swiss company.

Greenworks Holdings LLC, Pennsylvania/New Jersey, U.S. (2010-2012)

A U.S. example of biodiesel fraud involved used cooking oil (UCO) feedstock and occurred in Pennsylvania and New Jersey. This case involved the production of Renewable Identification Numbers (RINs), which are used as tradeable credits to demonstrate compliance with the Renewable Fuel Standard (RFS). RINs are generated when biofuel is produced and cannot be traded until they are separated from the biofuel when the biofuel is blended into conventional diesel or gasoline.

From 2010 to 2012 Greenworks Holdings LLC claimed to collect UCO from restaurants and cafeteria kitchens to process it into biodiesel and sell this finished fuel and generate RINs which they would subsequently separate from the fuel and sell (Hall, December 22, 2015). They processed some UCO feedstock to remove impurities but did produce biodiesel from it; the substance was thus not eligible for generating RINs because this product was not intended for use as a fuel without further processing (United States District Court for the Eastern District of Pennsylvania, 2015). Therefore, the RINs the company generated and sold were fraudulent because the biodiesel did not exist. Greenworks sold the processed UCO to other renewable fuel producers to process into biodiesel. The company separated and sold the RINs generated to obligated parties under the RFS. The investigation also found that Greenworks Holdings LLC claimed tax credits and U.S. Department of Agriculture subsidies for the biodiesel they claimed to produce. Similar to RIN generation, biofuel tax credits and subsidies are only awarded to producers of the finished fuel (United States District Court for the Eastern District of Pennsylvania, 2015). Greenworks Holdings LLC only processed the feedstock and did not produce a final fuel.

Additionally, the investigation found that Greenworks Holding LLC claimed the wastewater generated as a by-product of the UCO cleaning process as some of the volumes of UCO feedstock that they sold to renewable fuel producers. These transactions actually involved the removal of this wastewater by a third party (United States District Court for the Eastern District of Pennsylvania, 2015). The defendants altered the invoice to appear as an invoice for fuel sold. This forgery was done to deceive government officials.

In addition to the falsified waste-water removal documents, the defendants had additional paper transactions with other biofuel companies that enabled them to falsely inflate the volume of their product (United States District Court for the Eastern District of Pennsylvania, 2015). The defendants used this fraudulent paperwork to generate additional RINs and claim additional policy incentives based on the volumes recorded. For example, in 2010 they received subsidies and other payments for 17.5 million gallons of biodiesel when they produced less than 6 million gallons of cleaned UCO (again, the company did not produce any biodiesel) (Department of Justice: Eastern District of Pennsylvania, 2015).

Chieftain Biofuels, GRC Fuels, Unity Fuels, & Triton Energy, U.S. (2011-2015)

Another U.S. example of biodiesel fraud involved the following parties: GRC fuels in New York, Triton Energy and Gen2 Renewable Diesel LLC (same owners) in Indiana, Unity Fuels in NJ, and New Energy Fuels in Texas which subsequently relocated to

Ohio and was renamed Chieftain Biofuels (United States District Court: Southern District of Ohio Eastern Division, 2017).

The Texas/Ohio based companies produced a low-grade fuel that did not meet the ASTM and EPA standards for biodiesel (United States District Court: Southern District of Ohio Eastern Division, 2017). They then fraudulently generated, separated, and sold RINs making about $15 million in revenue (United States Department of Justice, Office of Public Affairs, August 27, 2015). The Texas based company additionally claimed tax credits worth $7 million (United States Department of Justice, Office of Public Affairs, August 27, 2015). Similar to RINs, the U.S. biodiesel tax credits are only available the biodiesel meeting the ASTM International standards (United States Department of Energy, n.d.). The company was also found guilty of illegal dumping of hazardous by-products.

This low-grade product and accompanying RINs, generated from the Chieftain Biofuels LLC based companies, were then sold to GRC fuels in New York where the physical product was then re-sold to Unity fuels of NJ as feedstock. Unity Fuel then minimally processed the product and sold it back to GRC fuels as recycled vegetable oil blend (RVOB) (United States District Court: Southern District of Ohio Eastern Division, 2017). GRC Fuel then sold this feedstock back to Chieftain or Triton to start the process over again. This cyclic behaviour enabled the parties to generate RINs and claim tax credits for the same quantity of fuel multiple times.

The Indiana based companies Triton Energy LLC and Gen2 Renewable Diesel LLC claimed tax credits and generated RINs worth over $60 million for renewable fuel made from corn oil_and RVOB (United States Department of Justice: Office of Public Affairs, July 18, 2017). The fuel produced was sold for use in "fire starter logs and for asphalt and cement production"; not for transportation end-uses and was thus never eligible for RINs and tax credits (United States Department of Justice: Office of Public Affairs, July 1 2017). Additionally, RINs, corn oil, and RVOB were bought and sold by GRC fuels of NY where the RINs would be re-sold and the fuel sold to Unity Fuels of NJ.

Washakie Renewable Energy, Utah, U.S. (2010-2016)

Lev Dermen, a California based business owner, and Washakie Renewable Energy, run by the Kingston family of Utah, collected more than $1 billion in fraudulent renewable fuel tax credits and RINs from 2010 to 2016 (Department of Justice: Office of Public Affairs, March 16, 2020). According to the plea documents, there was no manipulation or tampering of the physical biofuel itself (United States District Court, District of Utah, Central Division, 2019). Rather, the fraud was perpetrated through the falsification of documents by the Kingston family and Dermen that enabled them to generate and sell RINs and claim the associated renewable fuel tax credits for volumes of biofuel they never possessed or for volumes of biofuel they did possess but claimed multiple times. For the latter case, biofuel was shuffled between various companies to generate and claim additional RINs and tax credits on the same biofuel multiple times. The Kingston family and Lev Dermen used multiple bank accounts to launder the money generated by their fraud and substantiate the movement of biofuel between parties (Department of Justice: Office of Public Affairs, March 16, 2020).

Keystone Biofuels, Pennsylvania, U.S. (2009-2013)

Keystone Biofuel produced and sold soy-based biodiesel they claimed was B100 (Ciccocioppo, April 1, 2008). Their product did not meet the standards outlined in ASTM D6751_for B100 and as a result they deceived their customers as well as generated RINs for fuel that did not conform to the standards. Keystone Biofuel also inflated the volumes of fuel produced to claim additional tax credits and RINs as well as producing false records, fake transactions, and producing false fuel quality test reports to cover up their fraud (United States District Court for the Middle District of Pennsylvania, 2018).

9.1.2. Forestry Fraud Cases

We next looked to fraud cases in the forestry industry to inform our assessment of potential weak points in sustainability certification for existing and potential Annex IX feedstocks.

Lumber Liquidators, Virginia (2010-2015)

One of the largest cases of Forestry Fraud was perpetrated by the American Company Lumber Liquidators. The Environmental Investigation Agency (EIA), an independent watchdog group, published a report in 2013 detailing illegal logging activities in Lumber Liquidators' supply chain. Lumber Liquidators purchased lumber from Suifenhe Xingjia Economic and Trade Company, based in China, since 2007. EIA found that Suifenhe Xingjia Economic and Trade Company in China knowingly established sawmills and harvesting operation in Russia's Far East forests and bribed state officials. EIA found illegal logging in these forests, "the world's last major stands of old-growth temperate hardwood forests, a unique biodiversity-rich ecosystem and home to the last 450 Siberian tigers remaining in the wild" (Environmental Investigation Agency, 2013).

Under the Lacey Act, which bands the trafficking of illegal wildlife including plants and plant products into the U.S., importers must exert "due care" in assessing their own supply chain and take action to ensure that they are excluding illegal wood (Forest Legality Initiative, n.d.). EIA's investigation found that Lumber Liquidators had reportedly visited and toured the illegal mills in Russia with Suifenhe Xingjia Economic and Trade Company (Environmental Investigation Agency, 2013), despite their awareness of the high risk of illegality associated with imports from this region (Department of Justice: Office of Public Affairs, February 1, 2016). In addition to not exerting due care as required by law, Lumber Liquidators utilized harvest permits for other jurisdictions multiple times across their supply chains often exceeding the legal volume limit of those permits. Additionally, Lumber Liquidators falsely reported the specifies and harvest country of the timber on import documents (Department of Justice: Office of Public Affairs, February 1, 2016).

In 2016 Lumber Liquidators was the first felony conviction under the Lacey Act for illegal import of timber and was the largest criminal fine ever under the act (Department of Justice: Office of Public Affairs, February 1, 2016).

Holzindustrie Schweighofer, Austria (2008-present)

The European Union Timber Regulation (EUTR) prohibits illegally harvested timber and wood product from entering the market in any EU country starting in 2013 (Environmental Investigation Agency, n.d.). The EIA released a report in 2015 documenting illegal logging in Romania by multiple European companies before and after the implementation of EUTR. In particular, the Austrian timber company Holzinfustrie Schweighofer was found to be responsible for 40% of total annual softwood production in Romania, much of it illegally sourced (Environmental Investigation Agency, October 2015). This Austrian company retailed across the EU before and after the EUTR was implemented. In total the Romanian National Forest Inventory concluded that between 2009 and 2014, 49% of the timber harvested in Romania was done so illegally, representing 8.8 million m³ timber. The common causes of illegality include illegal clear-cutting, exceeding allowable cutting limits, and abuse of permits for the cutting of diseased or damaged trees. In 2016 the Forest Stewardship Council (FSC), a third-party certification organization, put

Holzindustrie Schweighofer on probation after it found that its supply was not coming from the FSC-certified forest the company claimed it sourced from (Forest Stewardship Council, n.d.). Contrarily, the Program for the Endorsement of Forest Certification (PEFC), an alliance of national forest certification systems, continues to award chain of custody certifications to Holzindustrie Schweighofer (HS Timber Group, n.d.). In 2018 a criminal investigation into Holzindustrie Schweighofe led to raids of their offices by Romanian officials (Business Wire, May 31, 2018).

Charcoal fraud cases

Charcoal and Bamboo fraud cases have been uncovered by the Forest Stewardship council (FSC) and Accreditation Services International (ASI). In 2017 FSC and ASI investigated companies they certified that were involved in charcoal supply chains. They used transaction documentation and sampled charcoal fibrefibres of FSC-certified companies in order to determine whether the material was sourced from non-certified forests or materials (Forest Stewardship Council, 2018a). This investigation resulted in 21 FSC-certified companies losing their certificates either through termination or suspension. FSC has developed a Supply Chain Integrity Project team that is collaborating with the Forests Products lab of the U.S. Forest Service and Thuenen Institute in Germany to continue fibrefibre testing of charcoal sold by FSC-certified companies throughout 2018 and 2019. Additional measures taken by the FSC include enhanced Chain of Custody Standards and mandatory volume reporting on a quarterly basis starting in 2017 (Forest Stewardship Council, 2018a). As a result of these enforcement and compliance measures, FSC and ASI identified and terminated or suspended 63 companies in 2018 and 2019 (Forest Stewardship Council, 2019).

Bamboo fraud cases

FSC and ASI also discovered cases of fraud within bamboo supply chains that resulted in certification terminations and suspensions followed by additional compliance and enforcement measures. In 2017 allegations and a subsequent investigation into B & M Noble Co. dba DuChateau (DuChateau) and Zhejiang Yuhua Timber Co., Ltd., (Yuhua) discovered large volumes of non-certified material falsely being claimed and sold as FSC-certified (Forest Stewardship Council, 2018b). Both companies were suspended from the FSC certification system for 12 months and will need to remedy and fulfil all compliance assessments in order to regain certification. FSC and ASI have since employed Chain of Custody standards, transaction reporting and verification, unannounced onsite audits, and product samplings to reduce non-compliance within bamboo supply chains. FSC has investigated 591 certificate holders and found 22 companies to be making false claims resulting in certificate terminals and suspensions (Forest Stewardship Council, 2018b).

9.1.3. Used Cooking Oil Fraud Concerns

In October 2020, the European Commission published their annual Renewable Energy Progress Report. This document found UCO contributed 18.8% of the total feedstock for biodiesel consumed by the EU in 2018 of which 11% was imported (European Commission, 2020b). This imported UCO predominantly comes from China, Indonesia, Malaysia and the U.S. with smaller amounts originating in Saudi Arabia, Japan, and Russia.

The per capita production of UCO from some of these countries, particularly Malaysia, compared to the volumes exported to the EU and the collection rates achieved in Europe or the USA has raised concerns over the validity of the feedstock. For example, in 2018 Malaysia with a population of 32.4 million (Department of Statistics Malaysia Official Portal, 2019), and exported 26.78 ktoe of UCO to the EU. The per capita volume of UCO collected in Malaysia is 2 to 3 times greater than

Europe’s for 2018. These observations have risen suspicions over the authenticity and origin of this UCO. Specifically, there are suspicions of palm oil (Michalopoulos, S., June 26, 2019), or virgin vegetable oil (Toop et al., 2014) being sold in place of or blended with UCO to take advantage of the higher prices for UCO.

9.1.4. Certification Violations

This section involved reviewing the experience of certification violations with two sustainability certification bodies, the Roundtable on Sustainable Palm Oil (RSPO) and the International Sustainability & Carbon Certification (ISCC), in order to understand potential weakness in current assurance systems and inform recommendations to further strengthen the functioning and monitoring of voluntary schemes.

Roundtable on Sustainable Palm Oil (RSPO)

The certification and oversight body Roundtable on Sustainable Palm Oil (RSPO) was founded in 2004 by palm oil plantation companies and NGOs to provide a standard for production. RSPO focuses on the sustainability of palm oil production, creating metrics for “deforestation, biodiversity loss, and human rights abuses” that companies and countries rely on when making purchasing decisions (Environmental Investigation Agency, 2015). The RSPO has been heavily criticized for laxly enforcing the labor rights, anti-deforestation practices, and community rights and consent necessary to receive certification (Howard, February 9, 2016).

A 2015 report by EIA and Grassroots reviewed the flaws and areas in need of reform within the RSPO standards, procedures, and organizational structure (Environmental Investigation Agency, 2015). An example of certification violations documented in this report occurred in East Kalimantan, Indonesia. First Resources Ltd began operations prior to identifying all land belonging to community members and receiving their consent. In addition to these violations, complaints from community members were deliberately left out of the official documents, which led to EIA filing their own complaint within RSPO’s system. While the EIA complaint remained unresolved, employees of First Resources LTD became members of RSPO’s Complaint Panel, a clear violation of RSPO’s conflict of interest policies.

Additional case studies identified fraudulent behaviour and collusion by the third-party certification bodies and assessors. An example provided in the EIA report involved the company Golden Agri Resources. Violations of RSPO standards by Golden Agri Resources were well documented and publicly available when RSPO certification was provided. This example drew multiple complaints from many different organizations underlining the lack of credibility and trust in the RSPO.

In 2019 EIA and Grassroots published a second report reviewing the progress of the RSPO in the RSPO’s efforts to return credibility to their certification procedures (Environmental Investigation Agency, 2015). However, EIA and Grassroots’ investigation found the internal committee tasked with reforming oversight within RSPO to be “one of the most poorly managed, run and disorganized working groups ever established by the RSPO” with many of its objectives not achieved or partially achieved but with unclear or unmonitored impacts. In particular, the backlog of complaints within the RSPO system remains an institutionalized failure. Case studies in this second report emphasized the inaction taken on case studies from the first EIA and Grassroots report. An example is the dispute between First Resources LTD and Muara Tae community of East Kalimantan Indonesia that remains unresolved.

International Sustainability & Carbon Certification (ISCC)

The International Sustainability & Carbon Certification (ISCC) is a third-party certification scheme for multiple feedstocks and fuels. It has been recognized by the EU Commission for its enforcement of RED and FQD criteria as well as additional sustainability requirements. ISCC certificates are awarded by third-party certification bodies after an auditor verifies that these certification bodies conform to ISCC requirements. ISCC has issued over 29,000 certificates, starting around 2010, of which nearly 8,000 include UCO as a feedstock, including recertifications. Looking at valid certificates for 2020, we observe over roughly 4,000 active and certified unique system users, of which over half handled waste and residue feedstocks, such as UCO. ISCC publishes information on suspended system users (International Sustainability & Carbon Certification (ISCC), (n.d.a) as well as fake (ISCC, n.d.b) or withdrawn certificates (ISCC, n.d.c). Generally, many of these issues involve UCO as a biofuel feedstock.

Suspended system users are companies' ineligible for an ISCC certification for the duration of their suspension. Suspended system users are also not "allowed to handle sustainable material under ISCC as a 'dependent collecting point' or a 'dependent warehouse'" for the duration of their suspension. The length of the suspension depends on the severity of non-compliance and can last from months to years. Non-cooperation with the ISCC Integrity Assessments results in the immediate suspension of a system user. Using ISCC's published statistics, we found that roughly 40 companies were suspended for some duration of time during 2020 and 16 began their suspension in 2020. Of those 16 companies suspended during 2020, 10 handled UCO, 5 handled palm, 4 handled animal products, and 6 handled other food-based feedstocks. This breakdown matches the broader trend we observe for the roughly 40 companies suspended for some duration of 2020: 69% UCO, 17% food-based, and about 21% for palm and animal products each. The most common countries of origin for the suspended members were Spain (7), Malaysia (4), and Ukraine (4).

A fake certificate is a forged document that uses the name and address of a company certified by the ISCC. The ISCC is not aware of who is responsible for fake certificates and states that "a fake certificate has not necessarily been falsified by the stated company itself", i.e. an unknown company falsely claims to be certified by using a forged document. Our understanding of these fake certificates is that they are identity thefts rather than certified companies acting fraudulently. To reduce the risk of fake certificates ISCC publishes all valid certificates and system users on their website for recipients or buyers to verify with. Of the 94 fake certificates discovered by ISCC over time, the most common feedstocks claimed by fake certificates were UCO (32%), palm (11%) and other food-based feedstocks (39%). Although the entity responsible for the forgery is unknown the most common countries claimed as the origin of the biofuel on the fake certificates are Malaysia (11), Ukraine (9), South Africa (7), Turkey (6) and Hungary (6). In 2020, 14 fake certificates were discovered, of which 8 included UCO as a feedstock.

Certificates withdrawn by the ISCC are also listed on their website. The reason for the certificate withdrawal is not explicitly provided for all cases, although audit reports, when available, do illuminate the circumstances for those companies. Audit reports are performed by third parties accredited by ISCC to verify members compliance with ISCC requirements. Audit reports for members who subsequently had their certificate withdrawn revealed that many of these cases of withdrawn certificates were preceded by violations documented in the audit reports. Violations of ISCC mandatory requirements must be resolved before a certificate can be issued while violations of minor requirements do not immediately prevent or revoke certificates (ISCC, 2016a). Investigation of these audit reports revealed that the most common violations were for management systems, mass balancing, traceability or sustainability criteria such as Principle 1: "Protection of land with high biodiversity value or high carbon stock" (ISCC, 2016b). The most common feedstocks from withdrawn certificates are UCO (54%), food-based with 25%, and palm with 12%. The most common countries of origin, out of 154 withdrawn certificates, are Hungary (14), Spain (13), Poland (11) and Slovakia (11). In 2020, 20 certificates were withdrawn, of which 14 included UCO as a feedstock.

In their 2019 annual report ISCC outlined the findings of their Integrity Program, which sets guidelines and standards for audit and certification processes (ISCC, 2020). On-site integrity assessments are random or risk-based audits that assess compliance with specific criteria or with all criteria. In 2019, 66 integrity assessment were performed with 75% performed on system users registered to handle waste/residue materials due to the greater volume of complaints for those "supply chains indicating specific risks of fraud for those types of material". Nearly half (46%) of these integrity assessments on waste/residue supply chains found non-conformities. This is similar to ISCC's reporting that 49% of all integrity assessments completed in 2019 found non-conformities of major and minor severity. Of the integrity assessments finding non-conformities, 66% related to mass balancing and traceability, 24% related to GHG emissions, 6% related to management systems and documents, and 2% to basic data and sustainability criteria, respectively. Additionally, six non-conformities were categorized as critical. ISCC describes critical non-conformities as those posing a significant risk to the integrity of ISCC, including fraud and all intentional violations of ISCC requirements.

The trends of these official findings in 2019 by the ISCC appear to have continued in 2020 based on our analysis of their published certificate information. We also found waste and residue supply chains to make up roughly half of certificates withdrawn and system users suspended as a result of non-conformities, the latter with critical status.

9.2. SUBTASKS 3.2/3.3 – CHARACTERISATION OF FRAUD RISKS AND DEVELOPMENT OF FRAUD RISK INDICATORS

This section describes the fraud risks characterized in Subtask 3.2 and the fraud risk indicators developed in Subtask 3.3. Subtask 3.2 aimed to characterize fraud risks associated with different feedstock types and their supply chain. Documented cases from Subtask 3.1 were combined with other suspected or potential risks identified by the Consortium to define risk categories, which are further detailed in this section. The outcomes of subtasks 3.1 and 3.2 were used to develop fraud risk indicators (Subtask 3.3). The indicators were grouped in the following four main categories: Physical characteristics; supply chain characteristics; feedstock definition characteristics; assurance. These indicators were further used in Subtask 3.4 to assess fraud risks for shortlisted and current Annex IX feedstocks.

9.2.1. Documented fraud cases

Task 3.1 revealed that only a limited number of fraud cases were publicly reported and led to judiciary consequences such as prosecutions. Suspicions exist among assurance providers that more fraud cases may exist. Two types of fraud cases have been identified:

Paper/administrative fraud where a biofuel producer claims and sells more credits than actually exist. This is the most common type of fraud uncovered. This includes creating fake certificates. This is an administrative fraud because there is no real certification process involved. This problem is of course not specific to Annex IX feedstocks.

Feedstock fraud whereby feedstocks that do not qualify for inclusion in Annex IX are reported as waste-based or advanced feedstock. This is less commonly uncovered, although assurance providers and civil society organisations reported potential irregularities when comparing claimed volumes of incentivized biofuel feedstocks (esp. UCO) to actual production/consumption patterns, e.g. adding virgin oil to UCO thereby increasing the double counted volume. This fraud can be profitable even for feedstocks that are more expensive than UCO.

9.2.2. Cases of non-conformity (suspected/non-documented frauds)

To complement documented fraud cases, the consortium also looked at irregularities, which may not lead to a formal case of fraud but could nonetheless reflect systemic weaknesses in the implementation of EU RED II sustainability, traceability and assurance rules. These irregularities may stem from "honest mistakes" or purposeful fraud but are primarily due to loopholes or lack of clarity in how such rules are implemented by economic operators and/or assurance providers. Certification schemes keep track of suspensions due to non-conformity or non-compliance with the scheme; those can lead to suspension or withdrawal of the certificate, which is then registered on public websites. Most common are violations to **mass balance and traceability requirements**. This can lead to incorrect GHG emission values for the supply chain or may cover up other irregularities. There are also grey areas such as cases where deforestation is suspected due to imperfect land use change information between the year 2008 (the reference year) and the current year.

9.2.3. Classes of fraud risk

Based on the above, a distinction was made between elements incentivising fraud (primary risk indicators) and elements that might increase the risk of fraud (secondary risk indicators or amplifiers), which were defined as follows:

- **Primary risk indicators:** Elements incentivising fraud relate to the profit to be gained from fraud. They stem from a combination of policy incentives (e.g. double counting, sub-targets) and market patterns (e.g. feedstock market prices, available supply, etc.) leading to significant profit to be potentially gained from intentionally substituting feedstocks. Primary risk indicators include the physical characteristics of feedstocks and feedstock definition characteristics.

- **Secondary risk indicators (amplifiers):** Elements increasing the risk of fraud relate to the ease of fraud. They are mostly related to the type and complexity of supply chain, size of economic operators, the type of chain-of-custody system used, etc). Secondary risk indicators include supply chain characteristics and assurance.

Primary and secondary risks were combined to evaluate an overall risk score for every feedstock category, noting that secondary risk indicators are not considered relevant/applicable if primary risk indicators are deemed low. The evaluation of the overall fraud risk was done using the following table:

Table 43 : Calculation of overall fraud risk (See also Table 44)

Primary risk indicators	Secondary risk indicators	Overall fraud risk
Both indicators low or low-medium	Not applicable	Low
One or both indicators medium or medium-high	Both low or low-medium	Low-medium

One or both indicators medium or medium-high	One or both indicators medium or medium-high	Medium
One or both indicators medium or medium-high	One or both indicators high	Medium-high
One or both indicators high	Both low or Low-medium	Medium-high
One or both indicators high	One or both indicators medium or medium-high	High
One or both indicators high	One or both indicators high	High

9.2.4. Elements incentivising fraud (Primary risk indicators)

9.2.4.1. Physical characteristics

- **Physico-chemical properties:** This risk relates to cases where an incentive exists (or could exist after addition to Annex IX) to substitute between feedstocks with similar physico-chemical properties, e.g. if a feedstock included in Annex IX is available in limited amounts and sold with a significant price premium and is physically similar to at least one non-Annex IX feedstock. Due to the difficulty of distinguishing feedstocks on the basis of their physico-chemical properties, feedstocks included in Annex IX could therefore be fraudulently substituted by, or mixed, with feedstocks that are not included in Annex IX. This risk is increased where it is difficult for assurance providers to systematically identify the exact physico-chemical nature of feedstocks, either through a visual inspection or via a simple test.

  Distinguishing feedstocks is often more challenging after feedstocks are processed as biofuels; while it could be possible to analyse the type of fatty acid methyl-esters in FAME to identify the feedstock oil(s), it would not be possible to evaluate the nature of feedstock by analysing the composition of ethanol, biogas or FT diesel. This can result in two possible cases of fraud: 1) two distinct species or feedstocks with physico-chemical similarities (e.g. rapeseed and carinata, or crude palm oil and mesocarp fibre oil); or 2) the same species, but grown in different conditions, one benefiting from enhanced support (e.g. produced on degraded land), one not eligible (e.g. cropland).

  Scoring pattern (risk indicators):

  - No identified incentive to substitute feedstock with another feedstock not included in Annex IX = low risk
  - An incentive exists to substitute the feedstock with another physically similar feedstock not included in Annex IX, but the feedstocks can be distinguished by visual/olfactory inspection = medium risk.
  - An incentive exists to substitute the feedstock with another physically similar feedstock not included in Annex IX, and the feedstocks are either indistinguishable or can only be distinguished by chemical testing = high risk.

- **Land properties of feedstock:** This risk relates to whether an incentive exists (or could exist after addition to Annex IX) to fraudulently claim specific land properties (degraded or abandoned) or cultivation practices (intermediate and cover crops). Fraud is made possible by the difficulty in distinguishing feedstocks on the basis of the land they were cultivated on (abandoned or degraded land) or agricultural practices (intermediate and cover crops), once they have been collected and processed. The difficulty of distinguishing identical feedstocks produced from land with different properties is further amplified by the absence, incompleteness or lack of accessibility of historical data on land status, especially for farmers renting their land.

  Scoring pattern (risk indicators):

  - Feedstock is not characterised by land properties or cultivation practices: Not applicable.

  - Feedstock is partly characterised by land properties or cultivation practices but land properties or cultivation practices can be reliably monitored and verified by auditors: medium risk.

  - Feedstock is partly characterised by land properties or cultivation practices but land properties or cultivation practices cannot be reliably monitored and verified by auditors: high risk.

- **Alteration of process or feedstocks:** This risk relates to the possibility for economic operators to purposefully modify a production process to generate higher amounts of residues/wastes at the expense of the main product. This risk also covers fraud related to the purposeful alteration (e.g. degradation, contamination, etc.) of feedstock that is not included in Annex IX to make it visually or chemically similar to a feedstock included in Annex IX. For example, a shipment of corn can be spoiled during sea transport (i.e. by opening the latch during a storm, leading to putrefaction) making the corn unsuitable as feed and qualifying the cargo as waste. But it could still be used for ethanol (or biogas) production. If spoiled corn were included in Annex IX it could make this fraud attractive. The mixing of limited amounts of unincentivized feedstocks into larger amounts of incentivized feedstocks could also fail to be detected by economic operators and/or assurance providers. Scoring pattern (risk indicators):

  - Feedstock is neither a residue nor a waste, and/or is not characterised by its degradation/contamination status: low risk.

  - Feedstock is a residue/waste, but the production process cannot be easily modified to produce more of it (e.g. standard co-product/residue/waste ratio exist); OR the feedstock cannot be easily produced by degradation/contamination of primary material: medium risk.

  - Feedstock is a residue/waste and the production process can be easily modified to produce more of it (no standard co-product/residue/waste exist); OR the feedstock can easily be degraded/contaminated: high risk.

9.2.4.2. Feedstock definition characteristics

- **Feedstock definition across countries:** This risk relates to incompatibility or inconsistency of the definition of feedstocks across countries, which could make the implementation of sustainability/traceability rules by economic operators and/or assurance providers more challenging, e.g. by not knowing the exact nature of feedstocks. Feedstocks with poorly understood definitions, or that may be defined differently in different regions, may be more prone to fraud.

Scoring pattern (risk indicators):

- A globally accepted definition exists: Low risk
- Some countries have a definition for this feedstock: Medium risk
- Feedstock is not defined in any national policy: High risk

- **Feedstock classification (Residue/waste):** This risk relates to the incompatibility or inconsistency of the classification of feedstocks as co-product, residue or waste across countries, which could lead to erroneous scope of compliance and/or audits between countries. For example, if a feedstock is considered as a processing residue by a country, thus requiring GHG calculations to start at the first collection point (e.g. PFAD in Finland), it would not be accepted as EU-compliant in a country where it is considered as a co-product.

  Scoring pattern (risk indicators):

  - Feedstock is not a residue/waste: Not applicable.
  - Feedstock is a residue/waste, which is consistently classified across countries and/or there is no ambiguity about the residue/waste nature of the feedstock: Low risk
  - Feedstock is a residue/waste. Some discrepancies exist in the feedstock classification across countries but there is limited ambiguity about the co-product/residue/waste nature of the feedstock: Medium risk
  - Feedstock is a residue/waste. Feedstock classification varies significantly across countries, or the co-product/residue/waste nature is ambiguous/difficult to define: High risk

- **Cellulose/ non-cellulose ratio:** This risk relates to the difficulty in consistently and accurately define thing amounts of cellulosic/ligno-cellulosic (covered by Annex IX) and non-cellulosic/ligno-cellulosic (not-covered by Annex IX) material in feedstocks. This could increase the probability of feedstock not in Annex IX to be fraudulently processed and transferred as a feedstock included in Annex IX, without the possibility of assurance providers and/or end-users detecting the fraud.

  Scoring pattern (risk indicators):

  - There is a consistent and well documented ratio: Low risk
  - The ratio is well documented, but some variability exists: Medium risk
  - There is no documented ratio or the ratio is highly variable: High risk

  Fuels made from fibre (other non-food cellulosic material) and (q) Other ligno-cellulosic material) are classified under Annex IX A. RED (2018) defines 'non-food cellulosic material' as "feedstock mainly composed of cellulose and hemicellulose and having a lower lignin content than ligno-cellulosic material". Most crops consist of a fibre (ligno)-cellulose) and carbohydrates such a glucose, fructose, sucrose, starch, fructans and other easily converted carbohydrates and other material (lipids, protein, etc.). The word "mainly" can cause problems. The possibility of introducing a cut-off for the cellulosic/lignocellulosic content and count the should be further explored. The question of how to account for the non-cellulosic/lignocellulosic fraction should also be investigated. In the (US) RFS and LCFS, the cellulosic/lignocellulosic to starch ratio is closely monitored for corn ethanol from corn fibre, using an ASTM protocol designed expressly for this purpose (ASTM E3181). The EC could consider a similar EN protocol, especially since some US corn fibre ethanol is likely to enter the EU RED market, so protocols should be harmonized.

9.2.5. Elements enabling fraud (Secondary risk indicators or amplifiers)

9.2.5.1. Supply chain characteristics

- **Trading patterns:** This risk relates to the increased potential for intentional or non-intentional fraud across the supply chain as the number of intermediaries increases and/or for globally traded feedstocks. This is particularly the case where a large number of intermediaries exist, who merely transfer feedstocks or derivatives to the next economic operators without any processing, e.g. aggregators, traders, middlemen, etc. Additional trading steps increase the risk of both intentional and unintentional misreporting as material is transferred between entities. In addition, global trading leads feedstocks and derivatives to cross multiple borders, which increases the risk of incompatibility of the feedstock status and treatment across countries, and losses or misinterpretations of product documentation. This could make the falsification of product nature or origin more difficult to detect.

  Scoring pattern (risk indicators):

  - Feedstock is used on-site by the economic operator: not applicable.
  - Feedstock is sold directly from producer to user, mostly single-sourced and local/within country: low risk.
  - Limited number of feedstock sources and intermediaries and/or feedstock may be sourced from other EU countries: medium risk.
  - Multiple sources, with aggregators and traders selling large amounts and/or feedstock is globally traded: high risk.

- **Rule of law in producing countries:** This risk relates to the difficulty of countries where feedstocks and derivatives are produced or transferred to stringently enforce laws ensuring the traceability of products and transparency of transactions, which may exacerbate the risk of fraud over the nature or origin of feedstocks and derivatives. Countries that rank poorly on indicators such as the World Justice Project Rule of Law Index are less likely to have regulatory oversight to control against fraudulent practices.

  Scoring pattern (risk indicators):

  The rule of law index from the World Justice Project (https://worldjusticeproject.org/rule-of-law-index/global) was used to determine the ranking of the countries in which the feedstock would be typically produced. Countries which represent less than 5% of total imports into the EU were not considered.

  - Country ranked between 1 and 42: Low risk

- Country ranked between 43 and 86: Medium risk
- Country ranked between 87 and 128: High risk

9.2.5.2. Assurance

- **Origin tracking and feedstock segregation:** This risk relates to the difficulty for assurance providers of establishing with certainty the exact origin of feedstocks used for biofuel/biogas production, especially in supply chains with no strict segregation of incentivised/EU-compliant feedstocks. If the first point of auditing is the First Gathering Point (FGP) or other post-source point, there is more potential fraud related to mixing and mislabelling, even if auditors are in theory entitled to verify feedstock sources (e.g. restaurants in the case of UCO). In practice, fraud occurring at waste generation level is difficult to detect for auditors.

  Scoring pattern (risk indicators):

  - Feedstock cultivation/production is included in the scope of compliance (e.g. for co-products): Low risk
  - Feedstock is a residue/waste from single/limited sources and with the ability to trace it back to its origins (e.g. PFAD): Medium risk
  - Feedstock is a residue/waste aggregated from multiple sources with limited tracking of points of origin (e.g. Used Cooking Oil): High risk

- **Understanding of conversion technology:** This risk relates to the difficulty for assurance providers in inspecting product documentation and/or physical conversion operations accurately and exhaustively when technology is not well documented and/or understood. This could lead to errors or deliberate misstatement in the calculation of GHG emissions and/or the mass balance of feedstocks or derivatives.

  Scoring pattern (risk indicators):

  - Typical conversion technologies and yields are documented in international literature, technical reports or standards: Low risk
  - Typical conversion technologies and yields are documented in limited sources (individual company reports): Medium risk
  - Typical conversion technologies and yields are not documented: High risk

- **Competencies of assurance providers:** This risk lies with the difficulty for assurance providers in systematically detecting fraud in relation with the risk indicators mentioned in the previous sections. Novel and less well documented feedstocks and processes may be more difficult to evaluate by auditors. If the feedstock originates from a production system that is not well known, certification bodies and auditors may lack the experience or training to assess compliance, hence a higher risk of missing non-compliances.

  Scoring pattern (risk indicators):

  - Existing training/competence requirements are sufficient to address the identified risks for this feedstock: Low risk

- Limited training/competence may be missing to address the identified risks for this feedstock: Medium risk

- Significant training/competence may be missing to address the identified risks for this feedstock: High risk

9.3. SUBTASK 3.4 – FEEDSTOCK ASSESSMENTS

The following section describes the results of the assessment of both existing Annex IX feedstocks and feedstocks shortlisted in Task 1 against the identified fraud risk indicators[10]. A summary of the risk assessment is provided in Table 44 and additional details are available in Annex F – Subtask 3.4 – Feedstock fraud risk assessment matrices.

Table 44: Summary of risk assessment

Feedstock Category	Feedstocks	Currently in Annex IX?	Primary Risk Indicators		Secondary Risk Indicators (Amplifiers)		Overall Fraud Risk
			Physical characteristics	Feedstock Definition characteristics	Supply Chain characteristics	Assurance	
Agriculture	Intermediate and Cover Crops - Niche or primarily soil-improving cover crops	No	Medium-High risk	Medium-High risk	Low risk	Low-Medium risk	Low-Medium
	Intermediate and Cover Crops - Commodity crops (corn, soy, wheat)	No	High risk	Medium-High risk	Medium risk	Low-Medium risk	High
Forestry	Other ligno-cellulosic material except saw logs and veneer logs	Yes	Medium risk	Medium risk	High risk	Medium risk	Medium -High
Algae/	Algae cultivated on land in ponds or	Yes	Medium risk	Medium risk	Not applicable	High risk	Medium-

[10] Note that feedstocks were grouped by characteristics to facilitate the fraud risk assessment, which ends up with a different grouping than in Task 2.

Feedstock Category	Feedstocks	Currently in Annex IX?	Primary Risk Indicators		Secondary Risk Indicators (Amplifiers)		Overall Fraud Risk
			Physical characteristics	**Feedstock Definition characteristics**	**Supply Chain characteristics**	**Assurance**	
Microbes	photobioreactors						High
	Sea algae	No	Medium risk	Medium risk	Medium-High risk	High risk	Medium-High
	Cyanobacteria	No	Low risk	Medium risk	Medium risk	High risk	Medium-High
Degraded land / Polluted land / Damaged crops	Biomass from degraded lands	No	High risk	Medium-High risk	Low-Medium risk	Medium-High risk	High
	Biomass from polluted lands	No	Medium-High risk	Low-Medium risk	Low-Medium risk	Medium risk	Medium
	Damaged crops	No	Medium-High risk	Medium risk	Low-Medium risk	Medium risk	Medium
Harvesting – Agricultural residues	Straw	Yes	Low risk	Medium risk	Low-Medium risk	Medium risk	Medium
	Other non-food cellulosic material	Yes	Medium-High risk	Medium-High risk	Medium-High risk	Medium risk	Medium

Feedstock Category	Feedstocks	Currently in Annex IX?	Primary Risk Indicators		Secondary Risk Indicators (Amplifiers)		Overall Fraud Risk
			Physical characteristics	Feedstock Definition characteristics	Supply Chain characteristics	Assurance	
Harvesting – Forestry residues	Biomass fraction of wastes and residues from forestry and forest-based industries - black liquor, brown liquor, fibre sludge, lignin and tall oil	Yes	Low risk	Low-Medium risk	Not applicable	Not applicable	Low
	Biomass fraction of wastes and residues from forestry and forest-based industries - bark, branches, pre-commercial thinnings, leaves, needles, tree tops, saw dust, cutter shavings	Yes	Medium risk	Low risk	High risk	Medium risk	Medium-High
Processing residues derived from food/feed	Cereals - Cobs cleaned from kernels of corn	Yes	Low risk	Low risk	Not applicable	Not applicable	Low
	Cereals - Corn dry starch	No	Low risk	Low risk	Not applicable	Not applicable	Low
	Cereals - DDGS	No	Low risk	Low risk	Not applicable	Not applicable	Low

Feedstock Category	Feedstocks	Currently in Annex IX?	Primary Risk Indicators		Secondary Risk Indicators (Amplifiers)		Overall Fraud Risk
			Physical characteristics	Feedstock Definition characteristics	Supply Chain characteristics	Assurance	
	Cereals - Technical corn oil (TCO)	No	Medium risk	Medium risk	Medium risk	Low risk	Medium
	Cereals - Starchy effluents	No	Medium risk	Medium risk	Low risk	Medium-High risk	Medium-High
	Cereals - Dextrose ultrafiltration retentate, hydrol and raffinate from sugar refining	No	Medium risk	High risk	Low risk	Medium-High risk	High
	Fruits and vegetable residues and waste	No	Medium risk	Medium risk	Low risk	Medium risk	Medium
	Nut shells	Yes	Low risk	Low risk	Medium risk	Low-Medium risk	Low
	Husks	Yes	Low risk	Low risk	Low-Medium risk	Low-Medium risk	Low
	Potato pulp	No	Medium risk	Low-Medium risk	Low risk	Medium risk	Medium
	Sugar beet pulp	No	Medium risk	Medium risk	Medium-High risk	Medium risk	Medium
	Sugar - Bagasse	Yes	Medium risk	Low-Medium risk	Medium risk	Medium risk	Medium

Feedstock Category	Feedstocks	Currently in Annex IX?	Primary Risk Indicators		Secondary Risk Indicators (Amplifiers)		Overall Fraud Risk
			Physical characteristics	Feedstock Definition characteristics	Supply Chain characteristics	Assurance	
	Sugar - Final molasses	No	High risk	Low-medium risk	Medium-High risk	Low-Medium risk	High
	Oilseeds - Palm oil mill effluent (POME)	Yes	High risk	Medium risk	Medium-High risk	Medium risk	High
	Oilseeds - Palm mesocarp	No	High risk	Medium risk	Medium-High risk	Medium-High risk	High
	Oilseeds - Empty palm fruit bunches	No	Medium risk	Low-Medium risk	Medium-High risk	Low-Medium risk	Medium
	Oilseeds - Fatty acid distillates (FADs)	No	Medium risk	Medium risk	Medium-High risk	Low-Medium risk	Medium
	Oilseeds - Olive oil extraction residues (de-oiled pomace)	No	Low risk	Low-Medium risk	Not applicable	Not applicable	Low
	Oilseeds - Olive oil extraction residues (non de-oiled pomace)	No	High risk	Low-Medium risk	Low-Medium risk	Low-Medium risk	Medium-high
	Oilseeds - High oleic sunflower oil extraction residues: FAV and PSK-	No	High risk	Medium risk	Low-Medium risk	Medium-High risk	High

Feedstock Category	Feedstocks	Currently in Annex IX?	Primary Risk Indicators		Secondary Risk Indicators (Amplifiers)		Overall Fraud Risk
			Physical characteristics	Feedstock Definition characteristics	Supply Chain characteristics	Assurance	
	Keto						
	Animal by-products (non-fats) – Category 2 and 3	No	Low risk	Low risk	Not applicable	Not applicable	Low
	Animal fats – Category 1, 2 and 3	Yes (cat 1-2) / No (cat 3)	Low risk	Low risk	Not applicable	Not applicable	Low
	Drinks, distillery and brewing products - Grape marc and wine lees	No	Low risk	Medium risk	Medium risk	Low-Medium risk	Medium
	Drinks, distillery and brewing products - Citrus fruit pulp and peels	No	Low risk	Low risk	Not applicable	Not applicable	Low
	Drinks, distillery and brewing products - Distillery heads and tails and fusel oils	No	Medium risk	Low risk	Low-Medium risk	Medium-High risk	Medium

Feedstock Category	Feedstocks	Currently in Annex IX?	Primary Risk Indicators		Secondary Risk Indicators (Amplifiers)		Overall Fraud Risk
			Physical characteristics	Feedstock Definition characteristics	Supply Chain characteristics	Assurance	
	Bakery and Confectionery products	No	Low-Medium risk	Medium-High risk	Low-Medium risk	Medium-High risk	Medium
Processing residues – others	Tall oil pitch	Yes	Low risk	Low risk	Not applicable	Not applicable	Low
	Crude glycerine	Yes	Low risk	Low-Medium risk	Not applicable	Not applicable	Low
	Raw methanol	No	High risk	Low-Medium risk	Low-Medium risk	Medium risk	Medium
	Soapstock and its derivatives	No	Medium risk	Medium risk	Medium risk	High risk	Medium-High
Agriculture waste	Animal manure	Yes	Low risk	Medium risk	Low risk	Low-Medium risk	Low-Medium
Food/feed production waste	Brewers' Spent Grain (BSG)	No	Medium risk	Medium risk	Low-Medium risk	Low-Medium risk	Low-Medium
	Whey Permeate	No	Medium risk	Low risk	Low risk	Low-Medium risk	Low-Medium
Waste –	Vinasse	No	Low-Medium	Medium risk	Low-Medium	Low-Medium	Low-

Feedstock Category	Feedstocks	Currently in Annex IX?	Primary Risk Indicators		Secondary Risk Indicators (Amplifiers)		Overall Fraud Risk
			Physical characteristics	Feedstock Definition characteristics	Supply Chain characteristics	Assurance	
others			risk		risk	risk	Medium
	Thin stillage	No	Low-Medium risk	Medium risk	Low-Medium risk	Low-Medium risk	Low-Medium
	Brown grease	No	Low-Medium risk	Low-Medium risk	Not applicable	Not applicable	Low-Medium
	Used Cooking Oil	Yes	High risk	Low-Medium risk	Medium-High risk	Medium risk	High
Wastewater	Sewage sludge	Yes	Low risk	Low risk	Not applicable	Not applicable	Low
	Municipal wastewater and derivatives (other than sludge)	No	Low risk	Low risk	Not applicable	Not applicable	Low
Solid waste	Biogenic Fraction of Municipal Solid Waste and Biowaste	Yes	Medium risk	Medium risk	Low-Medium risk	Medium risk	Medium

9.3.1. Agriculture

9.3.1.1. Intermediate and Cover Crops

9.3.1.1.1. Definition

Intermediate and Cover Crops are "any crop that is not the primary crop cultivated in a field in a given year and that is grown at a different time than the primary crop." This refers to crops that are grown directly after or before primary crops on the same piece of land, for market and/or to improve soil fertility and prevent soil nutrient loss. A great variety of crops are grown as cover and intermediate crops. This includes legumes (e.g. varieties of clover, vetch, pea, alfalfa, soybean, and other beans), brassicas (rapeseed, carinata, mustard, varieties of radish), grains (oats, rye, winter wheat, spelt, triticale), and others (silage maize, sudangrass, buckwheat, millet, teff).

9.3.1.1.2. Primary Risk Indicators

Feedstock physical characteristics:

While it is quite simple to determine that a given crop is in fact the plant listed in transaction records, it is much more difficult to ascertain whether the crop was indeed an intermediate/cover crop vs primary crop after it is harvested and moved off-farm. Some crops are used much more regularly as cover crops (e.g. vetch, clovers), some are quite interchangeable (e.g. buckwheat, winter wheat), and some are generally primary crops but could easily be used as intermediate (e.g. soybeans or corn grown in subtropical climates in winter). In-depth knowledge of each farming operations' storage records and financial flows are required to make an accurate determination, which may be difficult or impossible in many cases.

Even more challenging is determining whether a cover crop was grown on degraded land vs typical farmland, though unless there is greater incentive for either of those categories, this may not be critically important. There are no known examples of different materials that could be altered to appear as intermediate/cover crops, other than simply other crops as mentioned above. The ease with which unincentivized primary cash crops could be claimed as "intermediate" crops and the financial incentive to do so gives an overall **high risk** related to all intermediate and cover crops' physical characteristics.

Feedstock definition characteristics:

The EU RED II definition of "non-food cellulosic material" describes ley and cover crops as "understood to be temporary, short-term sown pastures comprising grass-legume mixture with a low starch content to obtain fodder for livestock and improve soil fertility for obtaining higher yields of arable main crops." The fact that soil improvement is the primary reason for growing many of these crops means that they could be considered a residue, creating another channel through which to market the crops as benefiting from inclusion in Annex IX and thereby increasing risk. This is also a highly specific definition and does not apply to all cases that agronomists generally refer to as "cover crops." Additionally, "intermediate crops" are not defined by EU RED II, and only briefly referred to in the "food and feed crops"" definition. It may also be very difficult to arrive at a definition that does not indirectly incentivize diversion of crops from food to fuel, thereby causing indirect land use change to meet food crop demand. This is most likely to occur with commodities such as soy and wheat that are generally seen as both primary and food crops. Some crops or parts of crops may be strong candidates for cellulosic conversion, and if they are novel or not previously used for this purpose there could be lack of knowledge of cellulosic content, expected yields, etc. An overall **medium-high feedstock definition risk** applies to all intermediate and cover crops.

9.3.1.1.3. Secondary Risk Indicators (Amplifiers)

Supply chain characteristics:

When standard commodity crops such as soybeans and wheat are used as intermediate/cover crops, risk is inherent to the larger, more complex trading networks in place to move material from field to processing unit. China and Brazil rank 88 and 67 respectively out of 128 on the WJP rule of law index and are known to harvest much more of their intermediate/cover crops than North American and EU countries that often grow them solely for soil benefit. The tropical and subtropical climates present throughout portions of China and Brazil enable the growing of corn and soy in the winter season, and it would be very difficult to determine whether a crop was a primary or intermediate crop in these cases.

In the case of smaller-scale, lesser-known crops that are often contract grown for a specific off taker, or in the case of bulky/wet biomass crops with high transportation costs being fed directly into local conversion units, there is less risk due to fewer exchanges which are easier to audit. Crossing of international borders is also less likely with niche grains, except when those crops are in the process of scale up (e.g. large investments are going into brassica carinata production in South America currently.) Examples of these include clovers, buckwheat, sudangrass, and winter peas. Risk associated with niche or primarily soil-improving cover crops is therefore low, while commodity crops used as intermediate crops carry a **medium risk**.

Assurance:

Widely traded crops of the same type are very likely to be mixed after harvesting and primary processing (cleaning, drying, etc), whether they are considered "intermediate/cover" or not. Mass balance accounting would most likely be used to track which portion qualifies for benefits of inclusion in Annex IX, which is sometimes regarded as riskier than physical segregation. Crops with less multinational trade such as carinata or clover are more likely to go directly to their end use point as a distinct batch when in grain and are less likely to be comingled in the supply chain before being converted to oil or starch. The conversion technologies applied to these crops will generally be very mature and well-understood (FAME, HVO, ethanol, biogas). While assurance providers may be familiar with crops as biofuel feedstocks, they likely lack the expertise to differentiate between primary and intermediate/ cover crops, which creates significant risk in being able to detect when fraud is taking place. Assurance risk for all intermediate and cover crops is assessed as **low-medium**.

9.3.2. Forestry

9.3.2.1. Other ligno-cellulosic material except saw logs and veneer logs

9.3.2.1.1. Definition

Annex IX, list A includes the feedstock: "Other ligno-cellulosic material except saw logs and veneer logs." The REDII defines ligno-cellulosic material as "material composed of lignin, cellulose and hemicellulose, such as biomass sourced from forests, woody energy crops and forest-based industries' residues and wastes" (Directive 2018/2001). Saw logs refers to "roundwood that will be sawn (or chipped) lengthways for the manufacture of sawnwood or railway sleepers (ties)," while veneer logs are specifically the highest quality cuts from high-quality trees that are used for the production of veneer (Directive 2018/2001). Examples of materials that qualify as other ligno-cellulosic material are pulplogs (logs used for the production of pulp, which is then used in paper and other products), fuelwood, construction and demolition waste wood, pre-commercial thinnings, and short-rotation woody energy crops. The use of qualifying other ligno-cellulosic materials includes, but is not limited to pulp, fibre boards, cooking fuel, charcoal, or energy pellets (Directive 2018/2001).

9.3.2.1.2. Primary Risk Indicators

Feedstock physical characteristics:

The physico-chemical properties of other ligno-cellulosic materials are difficult to distinguish from sawlogs or veneer logs. The main factor distinguishing sawlogs and veneer logs from trees qualifying as other ligno-cellulosic material is how the tree is grown and when it is harvested. The same tree species can be grown for sawlogs in one case and for pulplogs in another. Sawlogs and veneer logs are not included in Annex IX. These materials are easily visually distinct from other ligno-cellulosic material such as pulplogs when still in log form due simply to the diameter of logs. However, these materials are indistinguishable, including by chemical testing, after processing such as chipping or pelletizing. Sawlogs and veneer logs are high-quality sources of wood with high economic value, which would discourage economic operators from claiming sawlogs and veneer logs as other ligno-cellulosic material. However increased incentives for qualifying other ligno-cellulosic materials due to inclusion in Annex IX could plausibly result in this outcome. The Feedstock Risk Indicator Assessment for "Biomass fraction of wastes and residues from forestry and forest-based industries, namely, bark, branches, pre-commercial thinnings, leaves, needles, tree tops, saw dust, cutter shavings, black liquor, brown liquor, fibre sludge, lignin and tall oil" presents price data for chipped wood and sawlogs to illustrate that incentives related to inclusion in Annex IX could plausibly, but would not definitely, create a high enough incentive to falsely claim sawlogs and veneer logs as other ligno-cellulosic material, despite the generally higher economic value of sawlogs and veneer logs.

This fraud risk for other ligno-cellulosic material is considered **medium**.

Feedstock definition characteristics:

"Other ligno-cellulosic material" is a term that has regulatory meaning only in the REDII and not outside the EU. Some of the individual feedstocks encompassed by other ligno-cellulosic material are fairly consistently defined globally, however the classification of logs as "pulp logs" versus "saw logs" or "veneer logs" likely varies considerably among operators. The classification of fuelwood, logging or forestry residues, and pre-commercial thinnings can vary between countries (Giuntoli & Searle, 2019), which could contribute to the risk of intentional and unintentional mislabelling, although all the materials in this latter grouping are eligible in Annex IX - Part A.

Some types of other ligno-cellulosic material, such as pulplogs, are generally classified as main products. However, ligno-cellulosic material from construction and demolition are generally regarded as waste. It is likely that varying classifications exist for other types of other ligno-cellulosic material, such as pre-commercial thinnings.

The ratio of lignin, cellulose, and hemicellulose can vary across ligno-cellulosic materials and no threshold or standard has been established by the EU. By dry-weight, ligno-cellulosic material can vary between 15 and 40% lignin, 40 and 60% cellulose, 20 and 35% hemicellulose according to the scientific literature (Rowell, 1984; Zoghlami & Paës, 2019). It is important to note that the same species of tree can be grown for different purposes, so even if a strict cellulose to non-cellulose ratio were established for, e.g. one tree species, that would not help distinguish pulplogs grown using that species from sawlogs grown using the same species.

There is overall a **medium risk** of fraud given the feedstock definition of other lignocellulosic material.

9.3.2.1.3. Secondary Risk Indicators (Amplifiers)

Supply chain characteristics:

Other lignocellulosic material is produced, traded, and consumed globally, including in many countries with weak rule of law. About 30% of global forested area are managed to produce wood and non-wood products, with plantation forests, which are intensely managed for production, representing 3% of global forested area (FAO, 2020a). The 2019 Forest Product Yearbook published by FAO documents that about 711 million m3 of pulp-logs were removed and over 67 million tonnes of wood pulp exported/imported globally in 2019 (FAO, 2021). Similarly, nearly 40 million tonnes of wood pellets were produced and roughly 24 million tonnes were imported, including 10 million tonnes to the EU (FAO, 2021). Materials, such as sawlogs and veneer, were likewise produced and traded at large volumes globally.

The 2020 Global Forest Resource Assessment published by the Forest and Agriculture Organization (FAO) found that of 187 reporting countries, 164 had national forest policies for sustainable management and 94 had traceability systems for wood products that document the origin and movement of all wood products along the supply chain, such as Forest Law Enforcement, Governance and Trade (FLEGT) (FAO, 2020b). The existence of these laws and traceability schemes reduces fraud risk in the countries where they apply.

It is likely that other lignocellulosic material is often traded globally and between multiple intermediaries.

There is overall a **high risk** of fraud given supply chain characteristics of other lignocellulosic material.

Assurance:

Other ligno-cellulosic materials are sometimes but not always segregated in the supply chain. For example, pulplogs may be segregated during trade, but it is likely that qualifying woodchips and wood pellets could be mixed with non-qualifying woodchips and wood pellets. Similarly, wood of different origins and types may be mixed together in the supply chain as "fuelwood." Woodchips, wood pellets, and fuelwood would generally be produced using materials qualifying as "other ligno-cellulosic materials" or other woody materials listed in Annex IX - Part A (such as branches and tree tops), but could potentially include sawlogs and veneer logs. Such non-qualifying material could only be readily distinguished from qualifying material at the harvest site and not after processing.

Existing certification schemes focused on sustainable forest management and chain of custody, including the Forest Stewardship Council (FSC) and the Programme for the Endorsement of Forest Certification (PEFC), have developed some methods, such as fibre testing, to verify the origin of wood. Such methods could be used to reduce the risk of fraud in the REDII. However, even with the use of such certification systems, there are numerous fraud cases involving falsely reporting the chain of custody for wood, as detailed in Task 3.1 of this report. Presumably fibre testing can be used to identify the tree species but not always the geographic origin where that tree was grown. There may be technologies available that can identify geographic origin as well. In addition, other means of committing fraud—such as intentionally degrading sawlogs and veneer logs— would not be determinable using fibre testing.

The technology for converting other ligno-cellulosic material to ethanol via hydrolysis is fairly well understood but still developing and the yields are not standardized. There is less industry experience in producing ethanol from ligno-cellulosic material compared to straw. Other ligno-cellulosic material could also be converted to biofuel using gasification/Fischer-Tropsch or fast pyrolysis, and the yields of these technologies are less well understood.

There is overall a **medium risk** of fraud given assurance characteristics of other ligno-cellulosic material.

9.3.3. Algae/microbes

9.3.3.1. Algae cultivated on land in ponds or photobioreactors

9.3.3.1.1. Definition

If cultivated on land, in ponds or photobioreactors, algae is a feedstock that is already included in Annex Part A. This refers to microalgae that is cultivated on land but excludes cyanobacteria. Although cyanobacteria are referred to as "blue-green algae", they differ biologically from microalgae in that they do not have nuclei or other membrane-bound organelles such as chloroplasts (Nguyen and Hoang, 2016). Ponds are open cultivation systems whereas photobioreactors are closed cultivation systems that are operated at highly controlled conditions (Narala et al., 2016).

9.3.3.1.2. Primary Risk Indicators

Feedstock physical characteristics:

Algae cultivated on land in ponds or photobioreactors has distinctly different physical properties than most land-based biomass and is thus easy to distinguish from other biofuel or biogas feedstocks. There are no other materials similar to microalgae that have an incentive to be altered to appear as microalgae. DNA sequencing could also confirm whether or not a feedstock is a microalgae species. Land-based microalgae is also physically distinct from macroalgae cultivated at sea during the cultivation phase. The risk is therefore low during cultivation. The physical characteristics once processed to oils, however, could be similar to other processed oil feedstocks in terms of aspect, fatty acid composition, etc[11]. The risk is therefore **medium** for processed feedstocks.

Since the production process is geared towards the production of algae only, there is no risk of modifying the process to generate (more) residue/waste.

Risk indicators in relation to land properties (e.g. degraded or abandoned land) are not applicable since the microalgae are grown in ponds or photobioreactors.

Feedstock definition characteristics:

Microalgae is an immature market and there is no yield factor or cellulose to non-cellulose ratio defined for the feedstock, for example. This ambiguity could pose a **medium risk** for fraud.

The risk that microalgae is not uniformly defined across all regions is currently not applicable given that it is not yet traded. Similarly, the risk associated with material classification is not applicable since microalgae is a product.

9.3.3.1.3. Secondary Risk Indicators (Amplifiers)

[11] Other nutriments (e.g. sugar) were not considered here.

Supply chain characteristics:

Algae cultivated on land in ponds or photobioreactors does not currently have a large market nor supply chain. There are only a few commercial producers of microalgal products, which focus on nutritional and personal care markets rather than biofuel markets (Bioenergy International, 2017). **The current supply chains are too small and undeveloped to conclude on the fraud risk.**

Assurance:

Since the conversion of microalgae to biofuels and biogas is still not implemented at commercial scale, some risk would be posed by the inability to accurately audit processing volumes due to lack of generally known conversion and yield ratios for the novel system. There is also little knowledge and experience from assurance providers on the feedstock and its derivatives. The risk is therefore **high**. As mentioned above, there are only a few commercial producers of microalgal products. Thus, knowledge on the supply chains, and whether feedstocks are typically segregated or easily tied to a particular origin is limited.

9.3.3.2. Sea Algae

9.3.3.2.1. Definition

Sea algae, or marine algae, can be divided into two main categories – macroalgae and microalgae. Macroalgae are macroscopic plants, typically referred to as seaweed, while microalgae are microscopic photosynthetic plant-like organisms such as phytoplankton. The cultivation of these types differs in that macroalgae are typically cultured in natural environments while microalgae are typically cultivated on land in photobioreactors or ponds. Wild sea algae can be harvested, but the majority of commercial sea algae cultivation is done through aquaculture (Oilgae, 2010).

Sea algae can be categorised into red, green and brown algae, each of which have slightly different characteristics relevant for biofuel and biogas production, such as sugar content or ideal climatic conditions for growth. Green algae for example have a higher level of cellulose and accessible sugars for fermentation than brown algae, thus is potentially more attractive as a biofuel feedstock (Sustainable Energy Ireland, 2009).

9.3.3.2.2. Primary Risk Indicators

Feedstock physical characteristics:

Sea algae has distinctly different physical properties than most land-based biomass and is thus easy to distinguish from other feedstocks during the cultivation phase. If there were an incentive for sale to the biofuel market rather than food market, sea algae could intentionally be contaminated or degraded, thus made unfit for the food market (currently the primary use of sea algae). The risk is considered to be low to medium given the high price that food grade sea algae commands in existing markets (nutritional and personal care). Most, but perhaps not all, species of sea algae will have different physical and chemical properties. However, if only sea algae from aquaculture were included in Annex IX, it would be physically indistinguishable from wild sea algae. It would also be difficult to distinguish between legally and illegally wild harvested sea algae. Therefore, the overall risk is **medium**.

Since the production process is geared towards the production of sea algae only there is no risk of modifying the process to generate (more) residue/waste.

Risk indicators in relation to land properties (e.g. degraded or abandoned land) are not applicable as sea algae by definition is grown at sea and not on land.

Feedstock definition characteristics:

Sea algae are not currently, but should be, uniformly defined across all jurisdictions to avoid both intentional and accidental fraud that takes advantage of lack of cohesion in universal definition. However, the term sea algae is very generic and refers to a large range of algae species with varying physio-chemical characteristics and end-uses. There is no yield factor defined for the feedstock, for example. This ambiguity could pose a **medium risk** for fraud.

The risk associated with material classification is not applicable since sea algae is a product.

9.3.3.2.3. Secondary Risk Indicators (Amplifiers)

Supply chain characteristics:

Sea algae are a globally traded commodity and more than 30 million tonnes were produced in 2015 (primarily from aquaculture) from more than 50 different countries (FAO, 2018). For application in the food market, there are a large number of intermediaries including the farmers, local collectors and traders, overseas traders, manufacturers and solution providers and distributors (US AID, 2007). These large volumes and relatively long supply chains increase the fraud risk. In -addition, the main producers of cultivated sea algae species are China, Indonesia, Korea and the Philippines (FAO, 2018). These countries have a relatively low rule of law indicator, and rank 88, 59, 17 and 91 out of 128 respectively which could increase fraud risk (World Justice Project, 2021). Therefore, the overall risk is **medium to high risk.**

Assurance:

Since the conversion of sea algae to biofuels and biogas is still not implemented at commercial scale (ETIP Bioenergy, 2019), some risk would be posed by the inability to accurately audit processing volumes due to lack of generally known conversion and yield ratios for the novel system. There is also little knowledge and experience from assurance providers on the feedstock and its derivatives. The overall risk is therefore **high**.

9.3.3.3. Cyanobacteria

9.3.3.3.1. Definition

Cyanobacteria are photosynthetic bacteria. They are the only type of bacteria containing chlorophyll a. They are sometimes called “blue-green algae” because of their colour as well as their similarities with microalgae. Cyanobacteria differ from microalgae in that they do not have nuclei or other membrane-bound organelles such as chloroplasts (Nguyen and Hoang, 2016). Cyanobacteria are highly prevalent in the natural world, however commercial farming of cyanobacteria appears to be uncommon with the exception of spirulina (Arthrospira platensis and Arthrospira maxima) production.

Cyanobacteria can be genetically engineered relatively easily to produce a variety of lipids and other compounds. It is also possible to genetically modify cyanobacteria to excrete compounds such as alkanes or free fatty acids, which could then be made into biofuel or other product.

9.3.3.3.2. Primary Risk Indicators

Feedstock physical characteristics:

Cyanobacteria has distinctly different physical properties than most land-based biomass and is thus easy to distinguish from other feedstocks in the cultivation phase. There is also no apparent incentive to alter a different material to appear as the only current significant commercial application of cyanobacteria is spirulina production for the nutraceuticals, cosmetics, food and beverage, animal feed and other markets (Allied Market Research, n.d.). One could thus conclude that cyanobacteria is more profitable in these markets than the biofuel market, so there is little incentive for fraud. The overall risk of this category is therefore **low**.

Since the production process is geared towards the production of cyanobacteria only there is no risk of modifying the process to generate (more) residue/waste.

Risk indicators in relation to land properties (e.g. degraded or abandoned land) are not applicable since cyanobacteria are grown in photobioreactors.

Feedstock definition characteristics:

Feedstock characteristics for cyanobacteria are not currently defined, but should be uniformly defined across all jurisdictions to avoid both intentional and accidental fraud that takes advantage of lack of cohesion in universal definition. However, cyanobacteria is still in its infancy in terms of commercial biofuel applications and there is no yield factor or cellulose to non-cellulose ratio defined for the feedstock, for example. The compounds extracted from cyanobacteria for spirulina production and components for biofuel production differ. In addition, cyanobacteria can be genetically engineered in an infinite number of ways which can make a harmonised definition more challenging. Overall, there is **medium risk** for this category.

The risk associated with material classification is not applicable since sea algae is a product.

9.3.3.3.3. Secondary Risk Indicators (Amplifiers)

Supply chain characteristics:

The only current significant commercial application of cyanobacteria is spirulina production for the nutraceuticals, cosmetics, food and beverage, animal feed, and other markets (Allied Market Research, n.d.). The market was valued approximately 400 million USD in 2019. There is limited information on the trade and the number of intermediaries in a typical supply chain, but most of the largest spirulina companies are located in China (Meticulous Blog, n.d.). China, ranked at 88 out of 128 in the Rule of Law Index, could present a risk for fraud (World Justice Project). There would be limited incentive however for fraud in the biofuel market as the current markets it is sold to are more profitable. Therefore, the risk is only **medium**.

Assurance:

Since the conversion of cyanobacteria to biofuels and biogas has not yet been commercially implemented, some risk would be posed by the inability to accurately audit processing volumes due to lack of generally known conversion and yield ratios for the novel system. There are potential wide variations in biomass production between different strains as well. Additionally, there is little knowledge and experience from assurance providers on the feedstock and its derivatives, therefore there is a **high risk**.

9.3.4. Degraded and polluted lands

9.3.4.1. Biomass from degraded/polluted lands

9.3.4.1.1. Definition

Polluted and degraded land will be treated as separate subcategories here.

Polluted lands are classified as lands affected either by point source pollution influencing a limited surface area (e.g. former industrial, mining or landfill sites), or affected by diffuse pollution, which usually impacts on a much larger surface.

Lands subject to diffuse pollutions usually do not reach pollution levels that make harvested products reach the thresholds of maximum pollution levels as specified in Reg. 1881/2006 (EC. 2006), thereby making them unsuited for food or feed production. There are however exceptional situations. Point source affected sites are usually contaminated by a limited number of pollutants which are present at high levels, often making the land unsuitable for food or feed production.

Here we define biomass from polluted land as biomass from crops or trees grown with the purpose to either reduce, extract or stabilize the inorganic pollutants to deliver biomass which may be used for non-food purposes only, including biofuels and biogas.

Degraded lands are defined according to Annex V Par.9C of Directive (EU) 2018/2001 (in point 9 of Annex V) for 'severely degraded land'. This is land where the soil for a significant period of time has been affected by soil degradation. This includes, but is not limited to erosion, compaction, salinization, loss of organic matter through excessive nutrient extraction and any other mechanism leading to the loss of porous space crucial for holding and exchanging air and water. As pointed out by IPCC (Olson et al, 2019) accurate data and mapping of degraded lands are currently limited. For this category we focus on non-cellulosic biomass production, meaning crops mainly grown for starch, sugars, fruits, vegetables, or vegetable oil. Biomass consisting mainly of cellulosic/lignocellulosic is covered under Annex IX A.

9.3.4.1.2. Primary Risk Indicators

Feedstock physical characteristics:

<u>Polluted Lands</u>

Crops grown on polluted land will generally be the same crops as grown on non-polluted land (see Task 2). Therefore, it seems likely that it will be difficult to distinguish feedstock from polluted land from feedstock produced on non-polluted land. The feedstock may contain pollutants, though the content of pollutants differs between tissues (as pointed out in Task 2). For example, oils from oilseeds may contain fewer or no pollutants than protein cake.

Pollutants may not carry over into fuels made from feedstock grown on polluted land (biogas, ethanol, biodiesel, etc.). Therefore, it is likely that it will be difficult to distinguish fuels derived from feedstock produced on polluted land from other fuels produced on non-polluted land.

The definition of degraded or polluted lands will differ between countries and classifying land as degraded or polluted may be attractive if inclusion in Annex IX and associated benefits depend on that classification.

There is a **medium to high** fraud risk for biomass from polluted land, based on its physical characteristics.

Degraded Lands

The crops grown on degraded land will be crops similar to normal crops. It will probably be very difficult to distinguish biomass from these crops based on physio-chemical properties from crops grown on normal land. This constitutes a **high fraud risk** if inclusion in Annex IX has a large economic benefit, which it will likely have.

Similarly, the definition of degraded land has to be well established and clear. This may pose an elevated risk for fraud to occur.

Labelling biomass from normal land as biomass from degraded land is possible because physico-chemical properties are likely to be the same.

There is a **medium to high** fraud risk for biomass from degraded land, based on its physical characteristics.

Feedstock definition characteristics:

Polluted Lands

Here we define biomass from polluted land as biomass from crops or trees grown with the purpose to either reduce, extract or stabilize the inorganic pollutants to deliver biomass which may be used for non-food purposes only. The criteria for deciding if biomass from polluted land can be used for food or feed may differ per country (outside of the EU). So the definition of biomass from polluted land may lack uniformity.

As discussed in Task 2 we argue that biomass from crops or trees grown with the purpose to either reduce, extract or stabilize the inorganic pollutants to deliver biomass which may be used for non-food purposes only can be considered as a waste or by-product of this "remediation" activity. The classification of feedstocks from polluted land is not the main issue if it has been established that the land is polluted and the feedstock is not to be used for feed or food.

Feedstocks from polluted land is generally produced using the same crops as on non-polluted land. The resulting fuels can likely not be distinguished from other biofuels.

As the crops grown on polluted land (for remediation) will generally be the same crops already used for biofuels, yield factor issues should be similar to other feedstocks.

There is a **low-medium** fraud risk for biomass from polluted land, based on its feedstock definition characteristics.

Degraded Lands

The definition of degraded lands is key. It may be quite possible that the definition of degraded lands is not unform across regions even within the EU let alone outside the EU. This may open the possibility for fraud. The risk can be considered **medium to high.**

9.3.4.1.3. Secondary Risk Indicators (Amplifiers)

Supply chain characteristics:

Polluted Lands

Feedstocks from polluted lands that are not suited for food or feed will not likely be traded widely because they are likely to be contaminated making them less accepted. However, any biofuel can be produced from feedstocks grown on polluted land and can be traded just like any other fuel. In a book and claim system (credits are traded instead of the fuel itself) this may involve many intermediaries and large volumes.

Many of the polluted lands are situated in countries with a weak rule of law, such as newly independent states of the former Soviet Union. Still, it seems logical that conversion to biofuel will take place locally, as potentially contaminated feedstocks are not likely to be traded widely.

Just as with other feedstocks there is a chance that feedstocks for production of biofuels or the biofuels itself will cross multiple non-EU borders.

There is a **low-medium** fraud risk for biomass from polluted land, based on its supply chain characteristics.

Degraded Lands

Crops grown on degraded land can be normal crops which produce oil seeds or grains or sugar beets or sugar cane or any other product. These products or the fuels produced from these products (i.e. ethanol) can be traded through normal trade channels. In principle these feedstock or fuels can be traded through many intermediaries, though is seems unlikely that a situation will occur as with used cooking oil where a very large number of intermediaries and producers are involved in supplying only one factory. The risk arising from many intermediaries is therefore considered medium to low. The risk arising from global trade and large volumes also seems **low**.

Degraded lands on which biofuel crops are grown also exist in countries with a weak rule of law this can increase the risk of fraud to a higher level. Examples may consist of defining productive lands as degraded or mixing in feedstocks from normal productive land with feedstocks produced on degraded lands. Overall, the risk can be considered **medium**.

Overall, there is a **low-medium** fraud risk for biomass from degraded land, based on its supply chain characteristics.

Assurance:

Polluted Lands

Feedstocks are specifically tied to a particular origin but can be mixed with feedstocks not included in Annex IX in case of fraud as they are generally undistinguishable.

Crops grown on polluted land should generally be the same crops as grown normal land. Conversion technology and typical yield values will be the same. However, applications of residues such as protein cake (in case of oil seeds) and digestate, in case of biogas production, may be different compared to feedstock from non-polluted land (as pointed out in Task 2). This makes the calculation of impacts (GHG) more difficult as the value or application possibilities of the by-products may be different.

Assurance providers may not have specific experience with this feedstock, as it is linked to the definition of polluted land and remediation. Also, the uses of the term "residues" is different from the conventional use of the term.

There is a **medium** fraud risk for biomass from polluted land, based on assurance.

<u>Degraded Lands</u>

As non-cellulosic/non-lignocellulosic feedstocks from degraded land should be similar or the same as crops as grown on normal (non-incentivized) land there is a risk of mislabelling – the origin cannot be tied to a specific location. This increases the risk of fraud.

The conversion process into biofuels of feedstocks originating from degraded land is likely to be similar of the same as for conventional feedstocks. The conversion technology should therefore not pose a specific extra fraud risk.

Assurance providers may have to assess if land qualifies as degraded land. Lack of data may pose a challenge to less experienced assurance providers especially in combination with weak institutions.

There is a **medium-high** fraud risk for biomass from degraded land based, on assurance.

9.3.4.2. Damaged Crops

9.3.4.2.1. Definition

As discussed in Task 2 (Feedstock Evaluation Damaged crops) we define this category as "crops that are damaged because they become affected pre- or post-harvest by pests and pathogens which make their consumption as food or feed a health threat".

Feedstock may also be considered damaged if it contains other contaminants which may not originate from a pest or pathogen. An example is formation of 3-MCPD in the presence of chloride and fats or lipids during processing (Jędrkiewicz et al. 2016), which is not caused by a pathogen or pest. In our definition this type of damaged crop is excluded from this category.

9.3.4.2.2. Primary Risk Indicators

Feedstock physical characteristics:

Damaged crops can be distinguished by the fact that they are affected by pests or pathogens. This can apply to virtually any crop. Methods and norms to determine if a crop or food is contaminated (and unsuited for food or feed) exist (see EC 2006, regulation no 1881/2006) and can therefore be used as a way to distinguish this type of feedstock. In practice this may be difficult to implement. Incentives aimed at reducing food loss can help to reduce intentional spoilage.

The origin of the crop is not relevant. Crops can easily be damaged and become affected by a pest or pathogen when not handled properly, i.e. grains can be stored at humid conditions leading to purification. Crops may be handled such that they become damaged. It is difficult to determine if a crop was damaged on purpose or by some unintended event.

There is a **medium-high** fraud risk for biomass from damaged crops, based on its physical characteristics.

Feedstock definition characteristics:

Damaged crops as defined here, may still be defined differently between countries. Therefore, the classification may be different across countries. Fitness for consumption or use as a feed will differ across countries (outside the EU). This seems a relevant issue not only for imported damaged crops but especially for fuels that are produced outside the EU from damaged crops. Classification systems based on waste classification seem problematic.

There is a **medium** fraud risk for biomass from damaged crops, based on its feedstock definition characteristics.

9.3.4.2.3. Secondary Risk Indicators (Amplifiers)

Supply chain characteristics:

Damaged crops are produced through the same agricultural practices as regular crops but undergo some pre-harvesting or post-harvesting degradation (see Task 2). Damaged crops are generally a result of accidents or unforeseen events at any stage in crop production and trade involving many steps and different entities from farm to consumer. The damaged feedstocks will generally be left in the field or processed as waste later in the production chain if they are also not suitable as feed. The common processing will be composting, land filling or another waste process. Sometimes biogas production is also practiced.

The damaged crop can originate from within the EU or outside the EU where regulations with respect to damaged crops are different. A biofuel processing plant i.e. biogas for transport may supply its feedstocks from many different sources and intermediaries that collect damaged crops.

It seems unlikely that damaged crops are traded globally in large volumes or that they will cross multiple borders. But this cannot be excluded (i.e. if some intermediate products is made from it).

Damaged crops originate in any crop production and distribution chain, not typically in countries with a weak rule of law. Even if in less developed countries typically more crop spoilage occurs.

There is a **low-medium** fraud risk for biomass from damaged crops, based on its supply chain characteristics.

Assurance:

Damaged crops may be generated by accident but can originate all along the chain. They will therefore be handled by many different parties which are not necessarily familiar with assurance systems when the feedstock is handled.

Damaged crops are wide in origin and they can include crops that are not generally converted into a biofuel. Therefore, typical conversions yield into a biofuel is not always evident. Assurance providers will not know typical conversion efficiencies and other relevant data.

There is a **medium** fraud risk for biomass from damaged crops, based on assurance.

9.3.5. Harvesting – Agricultural residues

9.3.5.1. Straw

9.3.5.1.1. Definition

Straw is an agricultural residue generated during the harvest of crops such as wheat, maize, rice, and rapeseed. Composed of the residual stalks, leaves, or stover (in case of maize/corn). If used, straw is mostly applied as animal bedding/litter, animal feed, mushroom production, and providing a number of environmental services such as promotion of soil fertility and erosion prevention (Scarlat et al., 2007). Straw is also used for energy generation, such as in Denmark, and as a building material (Kühner, 2013).

9.3.5.1.2. Primary Risk Indicators

Feedstock physical characteristics:

Straw can be generated from multiple different crops which makes it an inherently heterogenous material. Additionally, straw can encompass many different parts of one crop such as the stover and husk from maize. As a result, straw's appearance comes in many forms. During the baling process straw is collected, chopped, and pressed into more manageable forms, called bales, before being stored or transported (Kühner, 2013). This baling process homogenizes the appearance of straw. Straw has varying chemical compositions that can make distinguishing straw from other materials based on visual or chemical indicators difficult. For example, rice straw is composed of 32-47% cellulose, 19-27% hemicellulose and 5-24% lignin (Binod et al., 2010), wheat straw is composed of 35-39% cellulose, 23-30% hemicellulose, and 12-16% lignin (Furkan et al., 2015), and sugarcane straw is composed of 32.4–44.4 % cellulose, 24.2–30.8 % hemi- celluloses, and 12.0–36.1 % lignin (Costa et al., 2015). In comparison, grasses have a composition of 25-40% cellulose, 25-50% hemicellulose, and 10-30% lignin and bagasse from sugarcane contains 50% cellulose, 25% hemicellulose, and 25% lignin (Pandey et al., 2000). It could thus be possible to alter another material to appear as straw. The similarity between straw and other cellulosic materials such as bagasse and grasses increase the risk of mislabelling and potentially intentional fraud. However, the other materials that could be easily mistaken for straw are generally also included in Annex IX, part A, and so there is no incentive for and little consequence of intentional mislabeling.

There is **low fraud risk** for straw based on its physical characteristics.

Feedstock definition characteristics:

Straw is generally defined uniformly across all regions and therefore has low fraud risk, but there may be exceptions, for example whether corn husks are classified as straw.

The classification of straw as a residue is not uniform across countries. Within the EU the classification of straw as a residue and not a co-product was argued against by different stakeholder groups, such as Copa-Cogeca (Michalopoulos, 2018). In the academic literature, straw is sometimes referred to as a waste, sometimes as a residue, and sometimes as a co-product. Therefore, the classification is ambiguous.

The cellulose to non-cellulose ratio has been estimated in the scientific literature but is variable across qualifying materials. For example, rice straw is composed of 32-47% cellulose, 19-27% hemicellulose and 5-24% lignin (Binod et al., 2010), wheat straw is composed of 35-39% cellulose, 23-30% hemicellulose, and 12-16% lignin (Isikgor & Becer, 2015), and sugarcane straw is composed of 32.4–44.4 % cellulose, 24.2–30.8 % hemi- celluloses, and 12.0–36.1 % lignin (Costa et al.

2015). This increases the risk that another material could be altered to appear as straw because there is not standardized cellulose to non-cellulose ratio. However, any such material would likely already be included in Annex IX Part A. The volume of straw collected, its yield from the production of the crop, depends on the main crop's yield and harvest ratio, which vary considerably.

Overall, there is a **medium risk** of fraud for straw based on its feedstock definition.

9.3.5.1.3. Secondary Risk Indicators (Amplifiers)

Supply chain characteristics:

Straw is produced throughout the world. Cereal crops are one of the world's dominant agricultural products with 2018 production volumes at 2,686 million tonnes and expected to reach 3,053 million tonnes by 2028 (OECD-FAO, 2019). Therefore, straw is produced in many countries with weak rule of law which could increase the risk of fraud.

Straw is traded, including in some cases internationally. According to European Trade Statistics, straw was imported or exported between EU member states and 68 other countries in 2019 (European Commission DG Trade, 2021). Straw traded or sold for use as animal feed or litter is regulated by Annex V of Commission Regulation (EU) No. 136/2004 (European Commission, 2004). The European Commission's Trade Control and Expert System (TRACES) documents and regulates the import and export of straw and other materials intended for use as animal feed. The country of origin must be on the approved list and the proper documentation must accompany the straw and be reported in TRACES (European Commission, 2019a). Straw imported or traded for an end-use other than animal feed does not appear to fall under any other European trade regulations, such as Regulation (EU) 2019/2072, which regulates the trade of plants, plant derived product, or other materials which could transport pests (European Commission, 2019b).

Although straw may be traded globally, given its low bulk density it probably does not typically travel long distances in most cases.

Overall, there is a **medium-low risk** of fraud for straw based on its supply chain characteristics.

Assurance:

Straw is generated during a crops' harvest and is baled when dry enough. Although straw is segregated in the supply chain, its origin cannot easily be tied to a particular location. However, generally any material that could be mistaken for straw is already in Annex IX, part A.

The conversion process for cellulosic ethanol from straw is well understood, but yields are variable depending on the type of straw and the specific conversion process used. Biofuel yields from other advanced technologies, such as gasification/Fischer-Tropsch and fast pyrolysis, are less well understood (Baldino et al., 2019). The lack of standardized biofuel yields increases the risk of fraud.

Assurance providers may lack specific knowledge to distinguish between straw and other cellulosic biomass which increases the risk of fraud; however other types of cellulosic biomass that may be easily confused with straw are generally also included in Annex IX, part A, so there may be limited incentives to deliberately mislabel other biomass as straw.

Overall, there is a **medium risk** of fraud for straw based on its assurance characteristics.

9.3.5.2. Other non-food cellulosic material

9.3.5.2.1. Definition

The REDII defines other non-food cellulosic material as "feedstock mainly composed of cellulose and hemicellulose, and having a lower lignin content than ligno-cellulosic material" and lists the following examples of qualifying materials: "food and feed crop residues, such as straw, stover, husks and shells; grassy energy crops with a low starch content, such as ryegrass, switchgrass, miscanthus, giant cane; cover crops before and after main crops; ley crops; industrial residues, including from food and feed crops after vegetal oils, sugars, starches and protein have been extracted; and material from biowaste, where ley and cover crops are understood to be temporary, short-term sown pastures comprising grass-legume mixture with a low starch content to obtain fodder for livestock and improve soil fertility for obtaining higher yields of arable main crops" (Directive 2018/2001).

9.3.5.2.2. Primary Risk Indicators

Feedstock physical characteristics:

This feedstock overlaps with others in Annex IX. For example, straw, bagasse, palm empty fruit bunches, and corn cobs without kernels are explicitly listed in Annex IX, part A, but also fit the definition of other non-food cellulosic material. This overlap could contribute to confusion about what other non-food cellulosic material is. Other non-food cellulosic materials, which includes cellulosic energy crops and intermediate crops, are extremely heterogenous in appearance and composition which can make it difficult to distinguish between qualifying and non-qualifying materials. For example, some grasses, such as sweet sorghum, have a high sugar and starch content that should make them ineligible to be considered other non-food cellulosic material. However, sweet sorghum is not obviously visually distinct from other sorghum varieties that should qualify as other non-food cellulosic material, which increases fraud risk. Sweet sorghum could be distinguished from eligible non-food cellulosic materials through chemical testing. There could potentially be an incentive to falsely claim sweet sorghum as other non-food cellulosic material. Price data on sweet sorghum is not readily available; a techno-economic analysis estimates it to be roughly 20-30 USD/wet tonne (Amosson et al., 2011), which converts to roughly 60-90 EUR/ton inflation adjusted at 15% moisture (a typical traded moisture content of many crops). For comparison, JRC estimate the cost of producing straw and other agricultural residues to be generally 3-5 EUR/GJ in most EU countries (Riuz et al., 2015), which converts to roughly 60-100 EUR/ton, inflation adjusted. This price range is similar to that of sweet sorghum. With the incentives related to inclusion in Annex IX, it may thus be financially attractive to falsely claim sweet sorghum as other non-food cellulosic material. Generally, other materials that could easily be confused with other non-food cellulosic material, such as straw, are also in Annex IX, part A, and so there is no incentive for fraud.

Other non-food cellulosic material includes some materials leftover after extracting oils, sugars, starches and protein, for example bagasse. At present there does not appear to be a financial incentive to reduce the extraction efficiency of food and feed materials from the cellulosic material, but this could change if incentives increase the value of other non-food cellulosic material considerably. Reduced extraction efficiency of oils, sugars, starches and protein could lead to these materials being mislabeled as other non-food cellulosic material.

Overall, there is a **medium-high risk** of fraud for other non-food cellulosic material based on its feedstock characteristics.

Feedstock definition characteristics:

The term "other non-food cellulosic material" exists only in the REDII and is not a recognized term outside the EU. The term is not precisely defined in the REDII, mainly in that the cellulosic content of qualifying materials is not defined. The REDII definition simply states that this feedstock is "mainly composed of cellulose and hemicellulose." The definition of "cellulosic material" likely varies across countries and other jurisdictions, even where such materials have a clear definition. For example, the United States Environmental Protection Agency, for the purposes of the federal Renewable Fuel Standard program, has established a threshold of 75% for the minimum cellulosic content of materials to be considered as eligible feedstocks for cellulosic biofuel (U.S. EPA, 2014).

Other non-food cellulosic materials include materials that may be considered primary products, co-products, residues, and wastes. It is likely that many of these materials are classified differently in different regions and by different actors. For example, straw and bagasse, which are types of other non-food cellulosic materials, are classified differently by different actors and researchers, as discussed in those sections.

The content of lignin, cellulose, and hemicellulose can vary across cellulosic material. The REDII defines "other non-food cellulosic material" as having a lower lignin content than "ligno-cellulosic material" but it is not clear what this threshold lignin content is. For example, some sources characterize ligno-cellulosic material has having, by dry-weight, 15-40% lignin, 40-60% cellulose, and 20-35% hemi-cellulose (Rowell, 1984; Zoghlami & Paës, 2019), but it is not clear how universal these ranges may be considered. Grasses such as switchgrass, which are not generally referred to as "ligno-cellulosic material," can have lignin contents in this range (Waliszewska et al., 2021; Doczekalska et al., 2020). The ratio of cellulose to non-cellulose will ultimately vary across the heterogenous pool of materials that qualify as other non-food cellulosic material. Risk increases when varieties of a species of plant or type of material have varying ratios of cellulose to non-cellulose without a noticeable difference in appearance. For example, sorghum is a type of grassy crop that comes in multiple varieties with varying cellulose to non-cellulose ratios. Specifically, sweet sorghum has a sugar content of 16-18% and a high starch content that should disqualify it under the REDII's definition of cellulosic material (Li et al., 2018). However other varieties of sorghum, such as energy sorghum or the stalks of grain sorghum, qualify as non-food cellulosic material. The similarities in the appearance of different sorghum varieties represents a source of fraud risk, and this could carry over to other types of crops.

Overall, there is a **medium-high risk** of fraud for other non-food cellulosic material based on its feedstock definition.

9.3.5.2.3. Secondary Risk Indicators (Amplifiers)

Supply chain characteristics:

Some materials that qualify as other non-food cellulosic material are traded globally and in large volumes. Under the harmonized commodity description and coding system, the international classification system for products traded globally, some agricultural residues are included under "Bran, sharps (middlings) and other residues, whether or not in the form of pellets, derived from the sifting, milling, or other working of cereals or of leguminous plants" which includes maize, wheat, and rice. This category includes both cellulosic material (e.g. bran) and non-cellulosic (middlings). In 2019, 100 countries outside the EU imported or exported agricultural residues with an EU member state. The total gross volume traded was over 686 million kg with a value of about 137 million Euro. Within the EU during 2019, all 27 member states imported or exported agricultural residues for a total value of 842 million Euro for over 4 billion kg of residues (European Commission

DG Trade, 2021). Other materials that qualify under this feedstock, such as grass in the form of baled hay or pelletized, do not appear to be traded in large volumes globally. It is unknown whether the materials that are traded globally are typically traded between many intermediaries before reaching their endpoint.

Many of the materials that qualify as Other non-food cellulosic material are produced globally and therefore are produced in many countries with weak rule of law.

Overall, there is a **medium-high risk** of fraud for other non-food cellulosic material based on its supply chain characteristics.

Assurance:

The chain of custody for many of these materials—agricultural residues, grassy energy crops, and cover crops— begin at the farm or at the industrial facility where crops are processed. However, materials are not easy to tie to a particular origin which increases risk. Some types of other non-food cellulosic materials are likely segregated in the supply chain, such as bagasse and straw. It is conceivable that others, such as some types of agricultural processing residues, such as bran, could become mixed in the supply chain, possibly with materials that do not qualify as non-food cellulosic material such as middlings, particularly in supply chains associated with animal feed production.

The conversion process for cellulosic ethanol from various cellulosic materials such as straw is well understood, but yields are variable depending on the type of cellulosic material and the specific conversion process used. Biofuel yields from other advanced technologies, such as gasification/Fischer-Tropsch and fast pyrolysis, are less well understood (Baldino et al., 2019). The lack of standardized biofuel yields increases the risk of fraud.

Some other non-food cellulosic materials, such as straw and bagasse, are likely to be familiar to assurance providers. However, other non-food cellulosic material is such a broad category that it almost certainly includes many materials assurance providers are not familiar with.

Overall, there is a **medium risk** of fraud for other non-food cellulosic material based on its assurance characteristics.

9.3.6. Harvesting – Forestry residues

9.3.6.1. Biomass fraction of wastes and residues from forestry and forest-based industries[12]

9.3.6.1.1. Definition

The biomass fraction of wastes and residues from forestry and forest-based industries (namely, bark, branches, pre-commercial thinnings, leaves, needles, tree tops, saw dust, cutter shavings, black liquor, brown liquor, fibre sludge, lignin and tall oil), henceforth abbreviated as BiFraWaRF for brevity, is a somewhat broad category of materials associated with both cultivation and processing of wood. Most of the named residues/wastes in this category have quite clear definitions emerging from biology, chemistry, commercial considerations or the associated processes.

[12] Namely, bark, branches, pre-commercial thinnings, leaves, needles, tree tops, saw dust, cutter shavings, black liquor, brown liquor, fibre sludge, lignin and tall oil

Bark, branches, leaves and needles from forestry have clear biological definitions (cf. Gschwantner et al., 2009).

Pre-commercial thinning (PCT) is undertaken on tree plantations before trees have reached a saleable size and involves removing some trees in order to optimise conditions for growth of those that remain. Precise practices will vary be location and by the types of tree being produced. For example, in relation to Swedish coniferous forestry Fällman (2005) notes that PCT is normally undertaken with trees at a height from 2-4 metres with a view to reducing the number of stems to 2000-3000 per hectare, and that additional PCT may be performed after the first thinning if considered necessary.

Tree tops (or stem tops) refers to the thinner part of the tree stem at the top of the tree. Gschwantner et al., 2009) note that there is some inconsistency in the definition of stem tops in European growing stock inventory definitions, with over-bark threshold diameters ranging from 5 to 7.5 cm.

Saw dust and cutter shavings are residues produced at sawmills and in other wood working.

Black liquor and brown liquor are spent cooking liquor from the kraft (sulphate) and sulphite pulping processes respectively.

Fibre sludge refers to solid residue recovered from used water streams in the pulping process (Chakraborty et al., 2019; Scott et al., 1995). Characteristics of fibre sludge vary depending on origin, for instance between kraft and mechanical pulping and between pulping of wood and of paper recycling.

Lignin is one of the chemical constituents of wood, alongside cellulose and hemicellulose. Generically lignin could refer to that compound in any wood-based product, but in the context of wastes and residues lignin may also refer specifically to high-concentration lignin removed from paper pulp in order to improve paper properties, for instance lignin precipitated from black liquor from the kraft pulping process (Bajpai, 2018).

Tall oil is extracted from black liquor produced in the kraft pulping process (via crude sulphate soap separation).

9.3.6.1.2. Primary Risk Indicators

Feedstock physical characteristics:

BiFraWaRF covers a large range of forestry related materials, which may be subdivided into harvest residues (bark, branches, leaves and needles, PCT and tree tops), woody processing residues (sawdust and cutter shavings) and other processing residues (black and brown liquor, fibre sludge, lignin).

Harvest residues are physically distinctive prior to processing, but chipping or pelletising branches, PCT or tree tops, could produce material that was difficult or impossible to distinguish from chipped or pelletised primary wood, saw logs or veneer logs. Similarly, woody processing residues are visually distinct from primary wood but could be generated purposefully by additional processing of timber grade wood, and chipped or pelletised offcuts would be indistinguishable from chopped or pelletised saw logs.

As saw and veneer logs are not included in Annex IX, this creates a risk of an incentive for mislabelling in the supply chain that would be difficult or impossible to detect later in the supply chain. This incentive is offset, however, by the generally higher price achievable by saw and veneer logs on the market for non-energy applications. Fraud is only likely to occur if the additional value of support for fuels from Annex IX feedstocks is greater than the existing price differential between wood for energy and non-energy applications.

In order to explore whether a fraud risk may emerge, UN Comtrade (2020) data for the value of different wood imports to the EU may be taken as a proxy for the value of wood in different categories.

For the period 2018-20, the average reported values for imported fuel in the categories:

- "Wood; for fuel, in chips or particles, coniferous, whether or not agglomerated" has an average value reported as 45 € per tonne;
- "Wood; for fuel, in chips or particles, non-coniferous, whether or not agglomerated" has an average value reported as 88 € per tonne.
- These are generally well below average values reported for imported wood from saw logs, for example:
- "Wood; coniferous species, of pine (Pinus spp.), sawn or chipped lengthwise, sliced or peeled, whether or not planed, sanded or finger-jointed, of a thickness exceeding 6mm" has an average value reported of 230 € per tonne;
- "Wood; of birch (Betula spp.), sawn or chipped lengthwise, sliced or peeled, of a thickness exceeding 6mm, whether or not planed, sanded or finger-jointed" has an average value reported as 180 € per tonne.

It should be noted though that there is considerable variation between reported prices for different types of wood, and also in reported prices within each wood category for imports from different countries.

While these price differentials are currently large enough to provide a clear incentive against using saw logs for bioenergy except in quite particular circumstances (e.g. for very low quality wood or wood that is difficult to bring to a non-energy market for logistical reasons), it is not out of the question that the value of cellulosic biofuels from Annex IX feedstock could make it appealing to use some saw logs for energy purposes. If inclusion in Annex IX is assumed to deliver an added value of 50 €cent per litre of fuel supplied, and given an indicative yield of 300 litres of biofuel per dry tonne of wood, the value of mislabelling woody material as meeting the Annex IX requirements could be of the order of 150 € per tonne of feedstock.[13] If additional biomass demand under the EU RED II results in a significant narrowing of the value differential between fuel wood and saw logs, it may become appealing in some circumstances to mislabel wood from saw logs for use as biofuel feedstock. This fraud risk for harvest and processing residues is considered **medium**.

The other residues have quite distinct physical characteristics, and it would not be readily possible to produce excess black or brown liquor, lignin or fibre sludge except by pulping additional wood. **This fraud risk is considered low.**

it would not be readily possible to produce excess black or brown liquor, lignin or fibre sludge except by pulping additional wood, which would not be financially attractive even with significant value from Annex IX status. This risk is considered medium. Production of forest residues could be increased by classing larger fractions of the tree as a tree top, or potentially be change of management

[13] Yield based on energetic conversion efficiency range of 46-51% given for wood to syndiesel in the JEC well-to-wheels study version 4, 50 €cent per litre additional value assumption is informed by consideration value of compliance credits under current RED implementations.

practices to prioritise total growth over stem growth. Production of forest industry residues could in principle be increased relatively easily by de-optimising timber handling or using thicker saw blades (increased saw dust generation) but as noted above this may not be financially attractive. **This risk is considered medium.**

Feedstock definition characteristics:

Details of the definitions of some BiFraWaRF materials vary between countries and regions – for example, as noted above, the definition given for tree tops varies across European countries. Whenever the feedstock refers to a specific harvesting/processing practice rather than a specific product, there may be substantive differences in the use of terminology between regions – for example, what might be considered late pre-commercial thinning in one context could be considered first commercial thinning in another (characterisation as 'pre-commercial' may also be affected by changes to forest product prices) (Huuskonen & Hynynen, 2006). In general though the underlying distinction between primary products (saw logs, veneer logs and pulp wood) and other materials output by forest industries is widely applicable.

The BiFraWaRF category primarily includes feedstocks that are considered as residues in this study as they are materials that are not normally considered the primary aim of production in the forestry and forest-based industries. Some low value materials such as fibre sludge, bark, leaves and needles might also be considered as wastes by some stakeholders/in some regions if they are disposed of without energy recovery (for instance by leaving leaves and needles on site).

The application of the distinction between 'residues' and 'co-products' may also be inconsistent under existing regulatory frameworks. For example, tall oil and brown liquor are characterised as co-products under the UK RTFO (UK Department for Transport, 2021) despite being listed as wastes or residues in EU RED II.

While some inconsistencies in application of feedstock definitions exist within the BiFraWaRF category, these relate to distinguishing between BiFraWaRF materials rather than to distinguishing BiFraWaRF from saw and/or veneer logs. The fraud risk associated with these definitional issues is therefore considered **low**.

9.3.6.1.3. Secondary Risk Indicators (Amplifiers)

Supply chain characteristics:

Woody BiFraWaRF materials may be traded internationally, in particular as (a component of) wood pellets. In principle leaves and needles may also be pelletised (Kala & Subbarao, 2017) and could then be transported, although this is not understood to be a standard practice currently.

Black and brown liquors are unlikely to be taken far from the associated mills as process chemicals can be reclaimed from them, but materials extracted from liquors (such as tall oil) may be transported internationally. Given the large range in sizes of forestry and forest products sites, there is considerable potential for intermediaries and aggregators to act in these supply chains.

BiFraWaRF materials are produced in all countries with any significant amount of forestry or forests, which is to say that BiFraWaRF materials are produced in significant quantities in most countries (cf. United Nations Food and Agriculture Organization, 2021).

Table **45** shows the rule of law rankings for the countries identified as having the largest output of forest products in FAOstat data for 2019. Potential sources of BiFraWaRF include countries at all risk levels from **low to high**.

Table 45 : Rule of law ranking for major BiFraWaRE producers

Country	Rule of law ranking
China	88
United States	21
Russian Federation	94
Canada	9
Brazil	67
Germany	6
Sweden	4
Indonesia	59
Finland	3

Assurance:

The various materials falling under BiFraWaRF would generally be segregated from primary wood products in the supply chain pending further processing due to their quite different physical characteristics, but the woody materials could be intermingled with non-residual material if chipped or pelleted. This fraud risk is considered **medium**.

Several, but not all, of the technologies for producing biofuels/biogas from BiFraWaRF are fairly well characterised, albeit generally without reference to extensive data from actual commercial operations. The EU RED II includes default LCA values for several pathways based on waste wood (Fischer-Tropsch drop-in fuels, DME, methanol) and for gasification and methanol production from black liquor. HVO renewable diesel production from tall oil and lignocellulosic ethanol production from woody materials have no default GHG emission values in the EU RED II but are well characterised in the broader literature. Biofuel production processes for non-woody materials (leaves, needles, brown liquor, fibre sludge, lignin) are not included in the EU RED II default pathways and are not generally well characterised in the literature. Auditors may therefore struggle to assess the credibility of process data for some of these materials and processes. This fraud risk is considered **medium**.

Assurance providers are likely to be used to working with forestry and forest industries, but may not be used to evaluating the implementation of chain-of-custody rules for many of the specific waste/residues falling under BiFraWaRF. This fraud risk is considered **medium**.

9.3.7. Processing residues derived from food/feed

9.3.7.1. Cereals

9.3.7.1.1. Definition

This category includes the following feedstocks:

- Cobs cleaned from kernels of corn
- Starchy effluents (formerly "Starch effluents up to 20% dry matter content")

This category includes various effluents from the milling and processing of starchy crops such as corn and wheat into food/feed or ethanol, namely:

  - Starch-containing wastewaters, which are generated out of the wet and dry milling of corn/wheat to produce ethanol/starch.
  - Waste starch slurry, which is defined by the United Kingdom (RTFO) as a mixture of starch and water arising from the wet milling of wheat or corn with dry matter content not exceeding 20% (as measured at the point of separation in the production process) and total suspended solid particles larger than 5 microns in diameter not exceeding 10% (as measured by a filter with a standardized perforation of 5 micrometer). We consider waste starch slurry to be a subset of starch containing wastewaters.
  - Steep water, which is produced during the steeping stage of the wet milling process used to produce corn and wheat starch.
  - Corn steep liquor, which is formed by the evaporation of steep water until it reaches a 40-60% solid content (incl. proteins, amino acids, minerals, vitamins, reducing sugars, organic acids and elemental nutrients).

- Dry starch from corn fractionation (formerly "Corn processing residues")

Dry fractionation of corn is an alternative to conventional dry milling and wet milling. Starch is a polymer composed of repeated glucose units, which is commonly found in vegetable and animals. Corn dry starch is a white, odourless and tasteless powder used as a staple ingredient worldwide.

- Dextrose ultrafiltration retentate, hydrol and raffinate from sugar refining

(formerly "Sugars (fructose, dextrose) refining residues")

This feedstock includes residues from the processing of corn and wheat to produce sugars such as glucose, fructose or dextrose and derivatives (e.g. sweeteners). These include:

  - Retentates from ultrafiltration and retention steps, which is composed of sugars, proteins, fats and impurities.
  - Hydrol, also known as corn sugar molasses, which is also considered to have about the same composition as that of blackstrap molasses, i.e. 83.2% total soluble solids, 17.8% reducing sugars, 32.1% sucrose, 49.9% total sugars, 10.25% ash, 0.54% calcium, 0.28% sodium, 2.89% potassium.
  - Raffinate, which is a side stream of high fructose corn syrup production and contains more than 85% of dextrose and less than 10% of fructose.

- Technical corn oil (formerly "Various oils from ethanol production")

Technical corn oil is defined here as oil extracted from corn (maize) distillers dried grain with solubles after fermentation. It is also sometimes referred to as distillers' corn oil. Oil extracted from corn prior to fermentation is here referred to as 'crude corn oil'. Unlike crude corn oil, technical corn oil is not considered fit for human consumption and only has non-food applications.

- Distillers dried grain with solubles (DDGS)

DDGS is a material that arises from bioethanol production. It represents the non-fermented fraction of grains and is composed of crude proteins (26-33%), fat (9-14%), fibre, vitamins and minerals, and in some cases, very small quantities of residual starch. The composition of DDGS varies depending on the process of ethanol production, the batch of production and more importantly the grain it is derived from. DDGS can be produced from maize, wheat and barley ethanol fermentation. Corn is the most abundantly used feedstock for bioethanol production globally, and therefore corn DDGS will be the specific focus of this analysis. Technical corn oil is frequently removed from DDGS, especially in the US (Kerr and Shurson, 2013) and traded separately from "reduced-oil DDGS".

9.3.7.1.2. Primary Risk Indicators

Feedstock physical characteristics:

The feedstocks in this category have different physical characteristics, with variable associated risks:

- Cobs cleaned from kernels of corn, dry starch, and DDGS are easily identified through a visual observation. **This fraud risk is considered to be low.**

- An incentive could exist for operators to mix TCO with another non-incentivised vegetable oil, since vegetable oils are miscible, and TCO cannot be visually distinguished from other vegetable oils. Commercial labs offer fatty acid composition testing via gas chromatography and mass spectrometry, which are well-understood technologies and could allow the intentional mixing of TCO with other vegetable oils to be detected**.** It is assumed that the maximum amount of TCO is already being extracted from DDGS, hence no risk of modifying the process to extract more TCO. **This fraud risk is considered to be medium.**

- Starchy effluents and dextrose ultrafiltration retentate, hydrol and raffinate from sugar refining are liquid streams with variable concentrations in starch, proteins and other components, which are generally increased by removing water through evaporation. This would make possible to purposefully modify their content in starch, sugars or other nutrients at the expense of the main product. **This fraud risk is considered to be medium.**

For all feedstocks in this category, risk indicators in relation to land properties (e.g. degraded or abandoned land) are not applicable. The **risk of intentionally altering another material to look like any residue from cereal processing appears low,** due to their visual characteristic (corn cobs, dry starch, DDGS) or low value (starch effluents, dextrose ultrafiltration retentate, hydrol and raffinate from sugar refining), with the exception of TCO, which could be visually confused with another vegetable oil altered on purpose (**medium risk**).

Feedstock definition characteristics:

- Cobs cleaned from kernels of corn are uniformly defined across countries and considered as a residue in EU RED II and UK RTFO (UK Department for Transport, 2021). **This fraud risk is considered low.**

- Corn dry starch is uniformly defined across countries and typically considered as a co-product. Yields and cellulose/non-cellulose ratios are well documented. **This fraud risk is considered low.**

- DDGS are uniformly defined across countries but their classification as co-product is explicit in UK RTFO and US Renewable Fuel Standard. Yields and cellulose/non-cellulose ratios are well documented. **This fraud risk is considered low.**

- TCO is relatively well defined but can also be called distiller's corn oil and can be easily confused in literature with crude corn oil that is extracted from wet milling. Its classification as co-product or residue is difficult to characterise with certainty (single counted in the UK RTFO and considered as renewable diesel, alongside soybean oil, in US Renewable Fuel Standard). Yields are well documented. **This fraud risk is considered medium.**

- Starchy effluents can be precisely described (See detailed description in Task 2 assessments) but are only partly covered in policies, e.g. by UK RTFO (waste slurry from the distillation of grain mixtures and waste starch slurry). Their classification as residues or waste is difficult to characterise with certainty. Yields and cellulose/non-cellulose ratios are only partially documented. **This fraud risk is considered medium.**

- Dextrose ultrafiltration retentate, hydrol and raffinate from sugar refining have very specific characteristics but are not specifically included in any biofuel/biogas policy. Their classification as residues or waste is difficult to characterise with certainty. Yields and cellulose/non-cellulose ratios are not well documented. This fraud risk is considered high.

9.3.7.1.3. Secondary Risk Indicators (Amplifiers)

Supply chain characteristics:

No risk score is attributed to cobs cleaned from kernels of corn, since primary indicators are low risk.

Technical corn oil and DDGS may be traded between a large number of intermediaries, globally and in large volumes. Production of TCO and DDGS happens primarily in the United States (US Department of Agriculture, 2019), so relatively little TCO and DDGS are produced in countries with weak governance. **This fraud risk is therefore considered medium.**

Global dry starch production represents approximately 3% of the total use of corn grains according to FAOSTAT for the year 2018, thus representing large volumes. Global corn imports represented approximately 12.7% of total world production in 2017-2018 (US Department of Agriculture, 2018) and may provide additional corn supplies to countries willing to increase corn starch production. However, exports from Asia have been reported to decline due to the high price of corn starch. In addition to the price of starch, transport costs and disruptions have also impacted the EU imports from Asia. In the EU, the price of corn starch in the paper industry is expected to decline to its lowest value in the past ten years. There is also competition from modified starches for which the industrial market is projected to remain relatively stable (Packaging Europe, 2021). On the other hand, the inclusion of dry starch from corn dry fractionation in Annex IX may trigger a large adoption of the dry fractionation technology by existing dry milling facilities in the US, followed by important exports to the European Union. Therefore, imports to the EU may primarily come from the United States, where the rule of law is considered strong. **This fraud risk is considered medium.**

There is no evidence that the other feedstocks in this category are traded between a large number of intermediaries, globally or in large volumes. They are typically used locally, due to their tendency to degrade rapidly. Therefore, it is assumed that feedstocks used in the European Union would also be produced in the European Union and **this fraud risk is considered low**.

Assurance:

- Cobs cleaned from kernels of corn are assumed to be used locally given their low value in regard of transportation costs, and therefore can easily be traced back to their origin. Conversion technologies (anaerobic digestion or ligno-cellulosic ethanol production) are well understood. Assurance providers are expected to know this feedstock well and can use RED default values for GHG emissions of biogas or bioethanol produced out of agricultural residues. **No risk score is attributed to cobs cleaned from kernels of corn, since primary indicators are low risk**

- Corn dry starch, DDGS and TCO are more difficult to trace back to their origin, given that they can be aggregated from multiple sources and traded globally by a large number of intermediaries. **This fraud risk is considered high.** However, conversion technologies (anaerobic digestion, transesterification or conventional ethanol production or ligno-cellulosic ethanol production) are well understood and have typical yields and default GHG values. Assurance providers are expected to know these feedstocks well. **This fraud risk is considered low.**

- There is limited documentation regarding the traceability of starchy effluents and dextrose ultrafiltration retentate, hydrol and raffinate from sugar refining, but stakeholders consulted in this study indicate that these feedstocks cannot be shipped over long distance due to rapid degradability. Therefore, they are likely to be primarily used on or near the processing site where they were produced and can be easily traced back to origin. **This fraud risk is considered low.** Conversion technologies (anaerobic digestion or ligno-cellulosic ethanol production) are well understood, but there are no typical yields or default GHG value in EU RED II. Assurance providers are not expected to have significant expertise with these feedstocks and may require additional training. **This fraud risk is considered high.**

9.3.7.2. Fruits and vegetable residues and waste

9.3.7.2.1. Definition

Fruit and vegetable residues and waste includes materials generated through the processing (e.g. peeling, chopping, pressing) of fruits and vegetables into food items, such as sauces, yogurts, soups, ice creams, etc. Fruits and vegetables that have been processed and are considered defective and unfit for human consumption are also included in this assessment, along with other residues as defined below. To note this does not include damage to fruits and vegetables prior to processing (i.e. at the cultivation/harvesting stage).

Examples of other residues include the following:

- Residues and parts of raw materials that are generated along the processing lines and accumulate in the equipment and/or along the conveyor belts.

- Raw materials and/or semi-finished products collected during the cleaning of bins, containers, silos and containers in general, once emptied, are deemed unsuitable for the food chain.

Products classed as defective and unfit for human consumption are those that do not conform to the standards for end-use in the food chain. This could be due to undesirable physical characteristics including weight, shape, and damage during production, or incorrect chemical composition. These types of products could still be suitable for use as animal feed provided that they comply with feed safety legislation (European Commission, 2018).

9.3.7.2.2. Primary Risk Indicators

Feedstock physical characteristics:

Fruit and vegetable residues have different physical and chemical compositions which makes it difficult to distinguish between crops (seeds, stems, stones etc). There is potential for fruit and vegetables to be mislabelled as contaminated/degraded because then they would be deemed unsuitable for human consumption. If deemed unsuitable for human consumption the fruit and vegetables would be classed as residues and therefore would be diverted from food use to other applications such as animal feed or energy production. However, there would be little economic incentive to do so because there would be less value in selling fruit and vegetables as residues compared to as main products. Therefore, there would be **medium risk** of mislabelling unincentivized feedstocks (UIF) as incentivized feedstocks (IF).

Feedstock definition characteristics:

The quantity and types of residues generated during processing of fruits and vegetables varies depending on the raw material and processing method applied (Kasapidou et at. 2015). This means the feedstock is not uniformly defined across all regions that it is traded which could lead to higher risk of fraud. Products deemed unsuitable for use as food/feed is covered under EU RED II as food waste. If these residues can technically be used for food/feed applications, then EU RED II definition would not apply, regardless of whether there is no economic incentive.

Fruit and vegetable residues are sometimes referred to as waste in the literature, as well as pomace, pulp, cake etc. However, generally, residues and wastes can be considered similar in terms of double counting and therefore the risk associated with feedstock characterisation is low.

The chemical composition, including the cellulose content, differs between types of fruit and vegetable residues and also between processing sites owing to differences in plant configurations. Comprehensive characterisation of the residues is required to reliably determine the composition (Esparza et al. 2020), due to the heterogeneity of the feedstock, which can be difficult and therefore the risk of fraud is high.

Despite the characterisation of the feedstock as waste/residue being low risk of fraud, the ambiguity in the definition across regions and difficultly to reliably determine the cellulose contents could result in **medium risk** of fraud associated with the feedstock definition.

9.3.7.2.3. Secondary Risk Indicators (Amplifiers)

Supply chain characteristics:

There is currently significant commercial application of fruit and vegetable residues in animal feed. These residues are generally traded seasonally and locally due to the cost of transportation and storage and therefore this feedstock type is unlikely to cross multiple borders. This means there is likely to be a small number of intermediaries in the supply chain at a local level. Fruit and vegetables can be grown in countries with weak rule of law, including Brazil, India, and Mexico, however it is unlikely they will be processed into residues in the country of origin then exported to the EU as this is not economically viable. Therefore, there would be **low risk** of fraud associated with the supply chain of fruit and vegetable residues.

Assurance:

Fruit and vegetable residues are segregated at the point of production so can be traced back to their origin when used locally. Conversion of fruit and vegetable residues to biogas utilises mature technology so there is a low risk posed by the inability to audit processing volumes. However, anaerobic digestion of fruit and vegetable residues to produce biogas is not as commonly implemented compared to other feedstocks such as manure and sludge. This raises the risk of fraud for this conversion method to **low-medium** level.

Fruit and vegetable residues can also be converted to biochar, bio-oil and syngas via pyrolysis and gasification technologies. However, these technologies are not as mature as anaerobic digestion for treatment of this feedstock due to technical, economic, and legal barriers (Esparza et al. 2020). Verification of conversion yields for these less developed thermal treatments is more difficult due to these technologies being in the early stages of development when concerning fruit and vegetable residues and therefore present a **medium-high** risk of fraud.

9.3.7.3. Nut shells and husks

9.3.7.3.1. Definition

<u>Nut shells</u>

The outer, usually inedible, shell of nuts are defined as nut shells. These are composed of lignin, polysaccharides (including cellulose, hemicellulose, starch and fructans) and extractives (Queirós et al., 2020). Their quantities vary depending on the species, for example, walnut shells have 10.6% extractives, 30.1% lignin, and 49.7% polysaccharides; almond shells 5.7% extractives, 28.9% lignin, and 56.1% polysaccharides; and pine nut shells 4.5% extractives, 40.5% lignin, and 48.7% polysaccharides. Nut shells have high resistance to breakdown and some, such as pistachio shells, can take several years to decompose (Smyth, 2020). Nut shells are mainly collected in large volumes in nut processing plants.

<u>Husks</u>

Husks are the dry or membranous outer covering of various seeds/ grains. They are mainly composed of cellulose, hemi-cellulose and lignin. They also contain volatile matter, ash and moisture. The percentage of each of these components varies depending on the species, for example, rice husk has 36% cellulose, 19.7% hemi-cellulose, 19.4% lignin and 20% ash content (Phyllis database, 1997a) while millet husks have 33.3% cellulose, 26.9% hemi-cellulose, 14% lignin (Phyllis database, 1997b), and coconut husks have 27.8% cellulose, 13.6 hemicellulose and 36% lignin (Phyllis database, 2003). In this assessment, we refer to husks that are collected in processing plants.

9.3.7.3.2. Primary Risk Indicators

Physical characteristics:

Nut shells and husks can be easily identified through a visual inspection given their structure, as well as by chemical analysis since different nut shells and husks have varying amounts of components such as cellulose, etc., as described above. However, the similarity between baled husks and other cellulosic materials such as straw, bagasse and grasses increases the risk of mislabeling and potentially intentional fraud. However, the other materials that could be easily mistaken for baled husks are generally also included in Annex IX, part A, and so there may be no incentive for and little consequence of intentional mislabelling. Furthermore, it is highly unlikely that nut shells/husks will be incentivised as cellulosic feedstock since they are already namely included in Annex IX - Part A (paragraph l).

Overall there appears to be little financial incentive to make other material resemble nut shells and husks and therefore the risk of being misidentified/ mislabelled is assumed to be **low for both nut shells and husks.**

Feedstock definition characteristics:

Nut shells

Nut shells appear to be uniformly defined across all regions. However, the classification of nut shells as residue or waste are not clearly defined in EU or UK regulations. Cellulose/ligno-cellulose to non-cellulose/ligno-cellulose ratios have been determined for each type of nut shell and vary by species.

Husks

Husks are uniformly defined across all regions. However, the classification of husks as residue or waste are not clearly defined in EU or UK regulations. Cellulose to non-cellulose ratios have been determined for each type of husk and these vary by species.

Feedstock definition characteristics for nut shells and husks are overall in the **low risk** category.

9.3.7.3.3. Secondary Risk Indicators (Amplifiers)

Supply chain characteristics:

Nut shells

There is evidence of nuts/ nut shells being traded globally. For example, the EU is the largest walnut import market in the world (shelled and in-shell walnuts). Italy is an especially large importer of in-shell walnuts, which are shelled and further processed within the country. The leading supplier of walnuts to the EU is the US, followed by Chile and France. Another example is of cocoa shells being imported into the EU. Some nut shells are being commercially supplied as solid fuel (Lesprom, n.d.). Furthermore, some nuts/nut shells may go straight from the origin country to the EU but some may not (CBI, 2019). For example, due to high domestic processing costs, part of the walnuts produced in France are shelled mainly in Moldova and then the shelled walnuts are re-imported (CBI, 2019). While nut shells are traded commodities, the number of intermediaries they are traded between is indeterminable from available data. Nut shells are produced across the world, including in many countries with weak rule of law.

Supply chain characteristics for nut shells are overall in the **medium risk** category.

Husks

Husks may be traded globally in fairly large volumes and can be bought from many sources. Both coconut and rice husks are traded directly from the country of origin (mostly in Asia) to the EU. An increasing number of biomass firms are looking at collecting rice husks in high volume, torrefy them and export the resulting material. Therefore, it is assumed that husks are produced across the world, including in many countries with weak rule of law.

Supply chain characteristics for husks are mainly in the **medium risk** category. The only exception is the **low risk of the feedstock crossing multiple non-EU borders** as they appear to be go straight from the origin country to the destination in the EU.

Assurance:

<u>Nut shells</u>

Nut shells are generated in nut processing plants and therefore can be traced back to their origin when used locally. However, as mentioned above, nut shells are traded. Once mixed with locally generated feedstock, it would not be possible to trace the imported feedstock back to their place of origin.

The technologies for conversion energy or fuel of nut shells are mainly direct combustion as solid fuel, gasification and pyrolysis. These technologies may or may not be well understood on the part of auditors since there are relatively few commercial scale pyrolysis plants, especially those that convert feedstocks directly to liquid fuel. Typical yields for nut shells are however not documented.

Nut shells composition and use as biofuel feedstock are generally known and understood, or easily researched. We therefore assume that assurance providers will not find it too difficult to evaluate this feedstock.

<u>Husks</u>

Rice husks are generated in paddy rice processing plants and therefore can be traced back to their origin when used locally. However, as mentioned above, husks are traded. Once mixed with locally generated feedstock, it would not be possible to trace the imported feedstock back to their place of origin.

Currently, rice husks are mainly used in animal bedding, horticulture, insulation as well as energy production (Myanmar Insider, 2016). The technologies for conversion of rice husks are mainly direct combustion as solid fuel, gasification and pyrolysis. These technologies may or may not be well understood on the part of auditors since there are relatively few commercial scale pyrolysis plants, especially those that convert feedstocks directly to liquid fuel. Typical yields for rice husks are however not documented.

Rice husk composition and use as biofuel feedstock are generally known and understood, or easily researched. We therefore assume that assurance providers will not find it too difficult to evaluate this feedstock.

Assurance for nut shells/husks are mainly in the **medium risk** category. The only exception is the **low risk of assurance providers lacking specific knowledge/ experience** of this feedstock and derivatives.

9.3.7.4. Potato and sugar beet pulp

9.3.7.4.1. Definition

<u>Potato pulp</u>

Potato pulp is one of the resulting products from the production of potato starch that is used in its wet form for certain applications. For other uses such as in animal feed, the pulp is sometimes partially dried and pelleted. Production of 100 kg of potato starch produces 3-3.5 kg of dried potato pulp (Feedipedia, 2020). Potato pulp contains starch, cellulose, hemicelluloses, pectin, proteins, free amino acids and salts (Mayer et al. 1997).

Sugar beet pulp

Sugar beet pulp is the residual material generated after the extraction of raw juice from sugar beet cossettes (elongated slices of sugar beet). The beet pulp can be fed directly to cattle or pressed, dehydrated and pelletised in sugar mills. Processing 1 tonne of sugar beet typically produces 70 kg of dry sugar beet pulp (Tomaszewska et al. 2018). Sugar beet pulp consists of carbohydrates, proteins and minerals (Duraisam et al. 2017).

9.3.7.4.2. Primary Risk Indicators

Feedstock physical characteristics:

Potato pulp

The chemical composition of potato pulp differs from other potato derivatives such as peel and potato hash silage. Potato pulp has a lower starch, protein, and ash content, and a higher fibre and cellulose content compared to potato peel and hash (Ncobela et al., 2017). Chemical analysis of potato pulp is necessary to ensure the protein and fibre content are reliably reported and suitable for livestock feed (Feedipedia, 2020). There may be risk of intentionally allowing food-grade potatoes to degrade or be contaminated, or labelled as such, in order to be directed to processing which will result in pulp being produced as a residue. However, potato food products have higher economic value than biofuel so there is little economic incentive to intentionally allow potatoes to degrade. The related fraud risk is therefore considered to be **medium**.

Sugar beet pulp

Sugar beet can be differentiated from other sugar compounds, including sugar cane, by chemical composition (Duraisam et al., 2017). Screening is carried out to ensure consistency in the composition of beet pulp for application in animal feed (Triple Crown, 2015). The testing of sugar beet pulp on a regular basis to ensure authenticity may be difficult. There may be risk of sugar beet being mislabelled as degraded or contaminated which would direct the sugar beet to processing, producing pulp as a residue. However, there would be little economic incentive to intentionally allow sugar beet to degrade as more value can be obtained from sugar beet as a product. Therefore, the overall fraud risk is considered to be **medium risk**.

Feedstock Definition:

Potato pulp

Potato pulp is referred to as waste in some literature however, generally, residues and wastes can be considered similar in terms of double counting. The cellulose content is higher in potato pulp compared to raw potato. The chemical composition and physical properties of potato pulp is affected by the botanical origin and processing method applied (Muzík et al., 2012). Therefore, the risk associated with feedstock characterisation is **low-medium**.

Sugar beet pulp

The cellulose content of sugar beet pulp is approximately 20% while the yield depends on multiple environmental factors during sugar beet production (Duraisam et al., 2017). Sugar beet pulp is referred to as waste in some literature which creates uncertainty with characterisation since the feedstock is assessed here as a co-product. Therefore, there would be **medium risk** of fraud associated with the feedstock definition of sugar beet pulp.

9.3.7.4.3. Secondary Risk Indicators (Amplifiers)

Supply chain characteristics:

Potato pulp

In 2019, the largest exporters of potato starch were Germany (6), the Netherlands (5), Denmark (1), Poland (28) and France (20) (Tridge, 2020; WJP, 2020). Few potatoes are imported from non-EU countries and due to the high moisture content of potato pulp it is more suited to local trade and therefore unlikely to cross non-EU borders. This suggests there would also be a small number of intermediaries in the supply chain so the overall fraud risk would be **low**.

Sugar beet pulp

In 2016-2017, 5 million tonnes of dried sugar beet pulp was produced from the 140 million tonnes of sugar beet that was harvested in the EU for the chemical industry (Farm Europe, 2018). The largest producers of dried sugar beet pulp contributing to 66% of global production are France (20), Germany (6), Russia (94), USA (21) and Egypt (125). The ranking of these countries represented in brackets suggests there would be high risk associated with imports from Russia and Egypt to the EU, and low risk for imports from the USA. Wet beet pulp is produced primarily from The Netherlands (5), Belgium (14), Poland (28), Turkey (107), Russia (94), Ukraine (72) and Iran (109). Imports from Ukraine present medium risk while imports from Turkey, Russia and Iran present high risk associated with the rules of law (Beet and Feed, n.d.; WJP, 2020). Sugar production is mainly produced from large facilities and can be transported in large volumes with a small number of intermediaries in the supply chain. Less than 100 sugar factories located across Germany, USA, France and the UK, provided over 50% of the global supply of dried sugar beet pulp. Transportation of dried sugar beet pulp is more economically viable, compared to wet pulp, because dried pulp is lighter and pelletized meaning it may pass through multiple non-EU borders with Japan and Morocco being the largest importers (ED&F Man, n.d). Therefore, there may be a **medium-high risk** of fraud associated with the supply chain for sugar beet pulp, depending on the country of origin and the country importing the feedstock.

Assurance:

Potato pulp and sugar beet pulp

Process resides are typically segregated at the processing stage of the supply chain. It may be difficult to tie dried sugar beet pulp to a particular origin when traded globally across multiple non-EU borders. Potato pulp and wet sugar beet pulp are more likely to be traded locally meaning it would be easier to identify the relevant processing plant. These feedstocks can be converted to biogas using anaerobic digestion (Muzík et al., 2012) which is a mature technology. However, anaerobic digestion of potato and sugar beet pulp to produce biogas is not as commonly implemented compared to other feedstocks such as manure and sludge (Esparza et al., 2020). Therefore, the risk associated with auditing anaerobic digestion for feedstock conversion to biogas would be **low-medium risk**.

Conversion of sugar beet pulp to bioethanol is less mature due to the additional pre-treatment steps and hydrolysis steps required (Marzo et al., 2019). There is no commercial demonstration of using potato pulp or sugar beet pulp for bioethanol production so this process would have a **high risk** for auditing.

There is little information reported on the application of other conversion technologies such as pyrolysis and gasification for the thermal treatment of potato and sugar beet pulp (Cakan et al., 2019) therefore auditing of these routes would also present **high risk**.

9.3.7.5. Bagasse

9.3.7.5.1. Definition

Bagasse is the residual, fibrous material left-over after the stalks of sugarcane or sweet sorghum are crushed to extract the sugar within. Bagasse has low-economic value (Kim & Day, 2011) and is commonly burned to produce process steam and electricity at the sugar-mill. The production of paper and pulp is also common. And production of bagasse pellets for energy production is also practiced (e.g. in Brazil). (Midwest Research Institute, 1997). Sugarcane contains about 120 kg sugar and 130 kg bagasse (dry) per ton of sugar cane as harvested. Sweet Sorghum is variety of sorghum grass that has a high sugar content (Mathur et al., 2017).

9.3.7.5.2. Primary Risk Indicators

Feedstock physical characteristics:

Bagasse from sugar cane contains 50% cellulose, 25% hemicellulose, and 25% lignin (Pandey et al., 2000). Bagasse from sweet sorghum contains 45% cellulose, 34% hemicellulose, and 21% lignin (Kim & Day, 2011). These compositions are similar to other lignocellulosic materials such as corn stover, straw, and other varieties of grasses which could make distinguishing between them and bagasse difficult. For example, sugarcane plant tops, limbs, leaves, and any other material removed during harvest prior to sugar extraction are considered straw (Costa et al., 2015). Sugarcane straw is composed of "32.4–44.4 % cellulose, 24.2–30.8 % hemi- celluloses, and 12.0–36.1 % lignin" (Costa et al., 2015). The similar appearance of bagasse and straw could lead to mislabelling. However, both are included in Annex IX, part A, and so there is no incentive for intentional mislabelling and no consequence from accidental mislabelling in terms of achieving policy goals.

There is currently no clear economic benefit from degrading the original crop, either sugarcane or sweet sorghum, as the sugar is a high value product. However, reducing the efficiency of sugar extraction to leave more sugar in the bagasse could be attractive if incentives for bagasse ethanol are sufficiently higher than those for sugarcane and molasses ethanol and high compared to the value in the food market. Distinguishing bagasse with high sugar content from reduced efficiency processing from business-as-usual bagasse would only be possible with chemical testing. There is not readily available data on bagasse prices. One study estimated the value of bagasse to be 13 USD/ton at 50% moisture (Chang, n.d.). It is most relevant to compare this to the price of sugar juice, since that is the material that could be left in the bagasse and claimed to be bagasse. The price of white sugar is less relevant because it includes the cost of milling sugar. There is not readily available price data on sugarcane juice, and so we infer this from the price of sugarcane. The price of sugarcane in Brazil in 2016 was 20.5 USD/ton (FAOSTAT). Bagasse represents 27-28% of the dry weight of sugarcane, with the remainder sugar (Pandey et al., 2000). Accepting the value estimate of bagasse from Chang, we can infer that the value of sugarcane juice is roughly 23 USD/ton (on a moisture equivalent basis), around double the value of bagasse. It thus seems plausible, though not certain, that the incentives related to inclusion in Annex IX could overcome this price difference and incentivize a producer to reduce the pressing efficiency of sugarcane in order to claim some of the sugarcane juice as bagasse.

Overall, there is a **medium risk** of fraud for bagasse based on its feedstock characteristics.

Feedstock definition characteristics:

Bagasse appears to be uniformly defined and classified and therefore is at low risk of fraud. Across the scientific literature, it is sometimes referred to as a waste, sometimes as a residue, and sometimes as a co-product, although it is not clear that the difference in classification would lead to mislabelling given the clearly defined nature of the material.

The cellulose to non-cellulose composition of bagasse from sugarcane is 50% cellulose, 25% hemicellulose, and 25% lignin and represents 27-28% of the dry weight of sugarcane (Pandey et al., 2000). Bagasse from sweet sorghum contains 45% cellulose, 34% hemicellulose, and 21% lignin (Kim & Day, 2011). The cellulosic composition of bagasse is therefore well defined.

Overall, there is a **medium-low risk** of fraud for bagasse based on feedstock definition characteristics.

9.3.7.5.3. Secondary Risk Indicators (Amplifiers)

Supply chain characteristics:

According to European Trade Statistics, bagasse is a traded commodity whose volume and transaction amounts fall under "Beet-pulp, bagasse and other waste of sugar manufacture; Other" (HS code 23032090). Bagasse was reportedly imported or exported between EU member states and 31 other countries in 2019 (European Commission DG Trade, n.d.). Over 443 thousand tonnes of bagasse was imported to the EU in 2019. Bagasse that is exported and imported could potentially be traded between multiple intermediaries. However, because bagasse is bulky, it is likely that it is usually used close to the source.

Sugarcane is the worlds' dominant sugar crop and is grown in the tropical or sub-tropical climates of countries in Africa, Latin America, the Caribbean, and Asia. Global sugar production is expected to reach 207 million tons in 2028 with the share of sugar crops for ethanol production to increase to 21% (OECD-FAO, 2019). This increases the risk of fraud because sugarcane, and by extension bagasse, is produced in some countries with weak rule of law. The top 10 countries producing sugarcane (according to FAOSTAT), and thus bagasse, range from low to high risk levels on the rule of law rating:

Table 46 : Rule of law ranking for major molasses producers

Country	Rule of law ranking
Brazil	67

India	69
China	88
Thailand	71
Pakistan	120
Mexico	104
Colombia	77
Australia	11
Guatemala	101
United States	21

Overall, there is a **medium risk** of fraud for bagasse based on its supply chain characteristics.

Assurance:

Bagasse is separated from sugarcane or sweet sorghum after sugar extraction at the sugar-mill. The bagasse then travels to the ethanol production facility. In many cases the ethanol production facility may be located near the sugar-mill, and so tracking the feedstock origin may be simple. Bagasse is likely usually segregated from other materials in its supply chain.

Lignocellulosic ethanol production commonly utilizes a biochemical conversion process that occurs in three steps: pre-treatment, hydrolysis, and fermentation (Basso et al., 2013). These technologies/production processes are well understood and studies investigating the ethanol yields from bagasse, as well as other lignocellulosic residues from sugarcane (Pereira et al., 2015), have been published (Gao et al., 2018; de Albuquerque Wanderley et al., 2013; Wang et al., 2019). However, the yields are not standardized, which increases fraud risk.

Bagasse has similar composition and appearance with other lignocellulosic materials (i.e. straw or corn stover). While these materials are also covered in Annex IX, Assurance providers may lack specific knowledge to distinguish between bagasse and other lignocellulosic resources. This ambiguity would increase the risk of fraud.

Overall, there is a **medium risk** of fraud for bagasse based on assurance characteristics.

9.3.7.6. Final molasses

9.3.7.6.1. Definition

Final molasses is a sugary material remaining after sugar is crystallised out of sugarcane or sugarbeet juice. The sugar production process generally involves several rounds of boiling and crystallisation, resulting in different ‘grades’ of molasses as more sugar is extracted from the liquid. Molasses from the first crystallisation may be referred to as ‘A molasses’. Molasses from the second crystallisation may be referred to as ‘B molasses’. Final molasses refers to the molasses remaining after the third crystallisation (sometimes referred to as blackstrap molasses, or 'C-molasses').

9.3.7.6.2. Primary Risk Indicators

Feedstock physical characteristics:

Final molasses is somewhat similar in composition and appearance to A- and in particular to B-molasses extracted at the first and second crystallisation, the main difference being the reduced sugar content. A-molasses can be readily identified because the sugar they contain will crystallise spontaneously, but B-molasses is harder to distinguish from final molasses by inspection. Final molasses may be chemically distinguished by assessing the sugar content, and may potentially be distinguished by darker colour and by stronger smell/flavour. The sugar content of molasses may be measured in 'degrees Brix', a measure of the percentage by mass of sugars in a solution.

An example of the challenges of distinguishing grades of molasses is available in India, where since 2018 support has been provided to produce ethanol from not only final molasses but also from B-molasses (Energyworld, 2018). The financial support received by producers of ethanol from final molasses is less per litre than that offered to producers of ethanol from B-molasses or from sugarcane juice receive (Cogencis Information Services, 2019). This differentiated support reflects the higher potential value of sugarcane juice/B molasses in other markets. This creates an incentive to misidentify ethanol from final molasses into one of the other categories (note that this value hierarchy would be reversed in Europe if molasses were added to Annex IX – ethanol from final molasses would receive a higher value due to double counting). In order to manage this risk of misidentification, guidelines were introduced in India placing requirements on sugar mills to track and segregate molasses streams (Sahu, 2018). The guidelines require strict adherence to the principle that final and B-molasses should be kept in separate receiving tanks, and set detailed requirements for monitoring and recording the different product streams.

It is normal for sugar factories to monitor the characteristics of final molasses (Khan & Tehreem, 2020), and therefore the information necessary to confirm the status of batches of molasses should be available in principle. Molasses of different grades could however potentially be mixed at points in the supply chain after leaving the factory.

Given that ethanol production from sugars and from high grade molasses remains common in many regions, the inclusion of final molasses in Annex IX would create a clear financial incentive for mislabelling fraud (the value in the EU of a given batch of ethanol from a higher grade of molasses could be increased by simply mislabelling the feedstock as final molasses). Given this strong incentive this fraud risk is considered to be **high**.

Feedstock definition characteristics:

The concept of final molasses is clearly understood in the global sugar industry due to the ubiquity of the three-crystallisation sugar production process, but the terminology used varies. It also seems likely that some batches of traded molasses may not be explicitly labelled as final or otherwise, which could introduce space for confusion and make it more difficult to robustly segregate final molasses in the supply chain. This fraud risk is considered **medium**.

To the best of our knowledge there are no jurisdictions in which it would be normal to treat final molasses as wastes, although there is anecdotal evidence of some final molasses being disposed of without use in countries with underdeveloped markets (Brander et al., 2009). In Task 2 of this assessment final molasses have been identified as a co-product, which matches the designation under the RTFO (UK Department for Transport, 2021). Final molasses may be considered as a residue rather than as a co-product by sugar manufacturers in some markets. This fraud risk is considered **low**.

9.3.7.6.3. Secondary Risk Indicators (Amplifiers)

Supply chain characteristics:

Molasses is produced everywhere sugarcane or sugarbeet is processed. Molasses is an internationally traded resource with HS commodity codes defined for sugarcane and 'other' molasses (170310 and 170390 respectively) but there is no distinction in standard trade codes between final molasses and A/B-molasses. Global data reported for 2019 by UN Comtrade (2020) identify 3.7 million tonnes of sugarcane molasses exports and 2.2 million tonnes of exports of sugarbeet molasses (noting that some of this material may be re-exported and therefore be counted more than once in these statistics). It is unclear what fraction of traded molasses are final molasses, although one source (Brander et al., 2009) suggests that "in practice all traded molasses is [final molasses]". Sugar production is relatively centralised (sugar mills are large industrial facilities) and can be moved in large batches, and therefore fewer actors need to be involved in the molasses supply chain than in supply chains for resources with a more disaggregated supply (e.g. UCO). This fraud risk is considered **medium**.

Both sugarcane and sugarbeet molasses are produced in significant quantities outside of the EU, including in some countries with relatively poor governance, as shown in Table 47. This fraud risk is considered low to high depending on source of material.

Table 47 : Rule of law ranking for major molasses producers

Country	% of global molasses production	Rule of law ranking
Brazil	19%	67
India	21%	69
Thailand	10%	71
China	6%	88
Pakistan	4%	120
United States of America	4%	21
Mexico	3%	104

Assurance:

Molasses are likely to be kept segregated from other materials in the supply chain, but it is possible that grades of molasses could be mixed to produce a product with intermediate characteristics if sold to markets such as animal feed or ethanol production where either final molasses or B-molasses could be utilised. The guidelines for segregated handling introduced in India support the presumption that B-molasses could be mixed into or mislabelled as final molasses if there was a clear value proposition. Given that ethanol yields would also be higher from B-molasses due to the higher fermentable sugar content, double counting of final molasses would create a clear value incentive to mislabel B- (or even A-) molasses as final molasses. This fraud risk is considered **medium**.

The process for producing ethanol from molasses is well understood by assurance providers. Auditors would be able to compare molasses output at the mill level to industry standards and require measurement of the brix of the molasses batches as approaches to check for inclusion of B molasses. Detectable differences in ethanol yield can be expected for different grades of molasses making it more difficult to falsify records. This fraud risk is considered **low**.

Assurance providers are likely to have experience in the sugar supply chain and should be familiar with the grades of molasses produced, but may need additional training to identify cases in which B molasses may be being included in batches of final molasses. This fraud risk is considered **medium**.

9.3.7.7. Oilseeds and Oil Palm Residues

9.3.7.7.1. Definition

This category includes the following feedstocks:

- Palm Oil Mill Effluent (POME) is the liquid portion of the waste from a palm oil mill generated during the palm oil production process. This wastewater is released to a system of ponds (POME ponds) to remove solids, oil and grease before discharging the water into waterways. The oil contained in the wastewater (POME oil) settles on top of the POME pond and can be extracted (skimmed off) and used as feedstock for biofuel production. POME comprises most of the water in FFB, as well as water from steam extraction and has an average moisture content of 94% (Paltseva, et al, 2016; ISCC, Dec 2018).

- Sludge Oil is the floating residual oil that is separated during the initial stage of POME discharge to the pond. We distinguish sludge oil from POME as the liquid portion of the mill waste diverted before it reaches the POME ponds (AIP Conference, 2017).

- Palm mesocarp fibre (MF) is the material remaining following oil extraction by pressing of palm fruits. PPF is primarily lignocellulosic material, but also contains some oily material that is not generally extracted through pressing (Vijaya, S., et al., 2013). In Malaysia there are mills that have solvent extraction systems for the oil. Most mill use all MF for mill energy generation.

- Palm empty fruit bunches (EFB) EFB result from the sterilization and stripping of FFB. EFBs take on oil content during sterilization when the high heat and pressure causes transfer of the fatty acids entrained in the palm fruits to the fibrous EFB husk. The fatty acid profile of EFB oil is similar to Crude Palm Oil, though slightly higher proportions of Lauric Acid (C12:0) (and correspondingly lower percent of Palmitic Acid) compared to Crude Palm Oil (Volpi, M , 2019) have been observed. The oil can be mixed back into the CPO, since it is essentially the same CPO absorbed into the EFBs during the sterilization process. The EFB are the fibrous portions of the FFB once the fruits have been removed for processing by a thresher. (ISCC, 2021f)

- Fatty acid distillates (FADs) are produced at vegetable oil refineries one of the resulting products from the deodorization step in vegetable oil refining. They can be produced from a wide range of oilseed crops and are comprised of FFA (80%, primarily palmitic acid and oleic acid), triglycerides (5-15%) and to a lesser extent, components such as vitamin E, sterols, squalene and volatiles (Golden Agri-Resources, 2020). (Ahmed et al., 2019; Ping et al., 2009; Golden Agri Fact Sheet, June 2020). The current analysis is limited to Palm Oil derived Fatty Acid Distillates only, also known as PFAD.

- Olive oil extraction residues, and in particular olive pomace, are the material left over after primary olive oil pressing, which includes the fruit mesocarp and seed fragments. The fleshy mesocarp retains up to 8% of the initial volume of oil after the first pressing, which can be extracted with solvents but often is not due to low value of the resulting oil. There are somewhat different feedstock markets for de-oiled and non de-oiled olive pomace, so these will be treated as separate categories where applicable.

- High oleic sunflower oil (HOSO) extraction residues are generated during oxidation/hydrolysis of HOSO for pelargonic/azelaic acids and glycerine, which are used as ingredients for the production of pesticides, cosmetics, bio-lubricants and plasticizers. Both of the following compound classes can be used for biodiesel/FAME production though no documented cases of that have taken place; they are more often used for combined heat and power at the extraction plant or for hydrotreated vegetable oil/renewable diesel. HOSO extraction residues include:

    - High Boiling Vegetable Fraction (FAV): mixture of di- and triglycerides of C4-C18 fatty acids and of C6-C11 dicarboxylic acid resulting from glycerin and azaleic acid purification.

    - Fatty Acids and Keto-Fatty Acids (PSK-Keto): mixture of free carboxylic and keto-carboxylic acids resulting from pelargonic and azaleic acid purification.

9.3.7.7.2. Primary Risk Indicators

Feedstock physical characteristics:

The feedstocks in this category have different physical characteristics, with variable associated risks:

<u>POME</u>

Sludge oil (pre-pond): This effluent material is clearly distinguishable from other wastes derived from a palm oil mill due to its high moisture content (mostly water) and other characteristics. However, once the water has been extracted from this material it will be hard to distinguish from other wastewater derived fatty acids (e.g. municipal waste water treatment plant, brown grease). While POME and Sludge Oil are similar, sludge oil is likely to have a lower acid value compared to POME skimmed from a pond.

POME (pond skimmed): This effluent material is clearly distinguishable from other wastes derived from a palm oil mill due to its high moisture content (mostly water) and other characteristics. However, once the water has been extracted from this material it has nearly the same fatty acid composition as crude palm oil (CPO), with the exception of a higher free fatty acid content (Primandari, 2013). While POME and Sludge Oil are similar, POME is likely to have a higher acid value compared to sludge oil. Both pre-pond sludge oil and pond skimmed POME carry a **high risk** for physical characteristics due to the potential to mislabel CPO as POME.

Palm mesocarp fibre oil (Palm Pressed Fibre Oil – PPF Oil): This material has distinct chemical properties. For example, the fatty acid profile is slightly different, with a notably higher level of lauric acid (C12:0) and also higher phosphorus content, which may affect its usability as a biofuel feedstock. In addition, there is some indication that it has higher levels of Vitamin E (~2150 ppm compared to 800 ppm, and carotenes (1500 ppm compared to 600 ppm) which would increase its value. Nevertheless, physical appearance (e.g. colour) is similar and could potentially be mistaken for CPO. Consultation with a palm oil mill expert indicated that mill presses could be intentionally adjusted to allow for more oil to be left in the mesocarp fibre, but that it was unlikely given the higher phosphorus, carotene and Vitamin A. A **high risk** is associated with palm mesocarp fibre oil physical characteristics because of the similarity to CPO and potential for misrepresentation.

EFB and EFB Oil: This material has distinctive physical characteristics coming out of the mill, however once densified (e.g. pellets) it may be difficult distinguish from other fibrous matter. EFB may be useful for its lignocellulosic matter, or alternatively an EFB liquour can be pressed from it, accounting for approximately 0.5% of the FFB oil, or about 5% relative to dry Empty Fruit Bunches (Md Yunos, N. S. H., et al, 2015). Consultation with a palm oil mill expert indicated that it would be easy to leave FFB in the sun or subject them to physical mishandling in order to raise the free fatty acid value, however most refineries currently do not accept oil with high FFA content (or discount the value of the CPO to do so). so there are commercial reasons why a CPO mill would not do so. However, if the market were to favour FFAs over CPO then refineries may no longer disincentivize high FFA feedstock. Finally, it is possible to convert EFBs to a pyrolysis oil, which can then be traded more easily. (MD Solikhah et al, 2018; Chang, 2014) EFB and EFB oil therefore carry a **medium risk** for physical characteristics.

Palm Fatty Acid Distillate: This material is produced from the palm oil refinery during purification of the Crude Palm Oil and has visually and chemically distinct characteristics compared to other co-products and residues from palm oil processing. It is a light brown semi-solid at room temperature with a technical specification (Ahmed et al., 2019) which can be tested through fairly simple analytical tools. It has a lower Moisture and Insolubles specification than POME/Sludge Oil, and a higher acid value (70%) (Sinaran Palm Services, 2021). The Free Fatty Acid content of crude palm oil will increase the longer that palm fruits are left in the sun and or subject to physical mishandling. Some palm oil refineries will discount the value of CPO they process if the acid value is over a certain threshold value (e.g. 8%). As noted above, this disincentive could go away if the market value of PFAD were to increase significantly. A **medium risk** level is associated with physical characteristics of PFAD.

<u>Olive oil extraction residues</u>

De-oiled pomace: This material does not resemble any non-incentivized feedstocks and is generally only suitable for anaerobic digestion or composting. Physical characteristic risk is therefore **low**.

Non de-oiled pomace: The remaining oil in pomace cannot be easily distinguished from pure olive oil from the first pressing, as well as other vegetable oil. This means that non-incentivized material could potentially be falsely labelled as such, or oil could be labelled as having been derived from this residue when in fact it was not. **High risk** therefore applies here.

High oleic sunflower oil extraction residues: Both FAV and PSK-Keto are feedstocks for typical FAME and HVO processes. They are chemically distinct from other feedstocks such as virgin oils, but the likelihood of regular chemical testing to verify their authenticity is low. They could therefore be used as a basis for blending unincentivized feedstocks into for sale as incentivised (i.e. included in Annex IX) feedstocks in the EU, since it would not be easy to visually detect the fraud and chemical analysis is unlikely to regularly occur. This category therefore carries **high risk**.

Feedstock definition characteristics:

The feedstocks in this category have different characteristics, with variable associated risks:

POME: Sludge oil (pre-pond) and POME (pond skimmed): Inconsistencies in definitions is a recognized problem for this material as industry terms varied from country to country. At least one VS (ISCC) has established a working group of technical experts specifically to improve definitions around this material as lack of consensus on naming and definitions was causing issues. Examples of different names encountered for this material include: Palm Sludge Oil, Minyak Kolam, Palm Acid Oil, POME. These definitions are still under development in ISCC and a draft document with definitions has been published by ISCC as of May 2021 (ISSC , 2021e). In the current evaluation we use the term "Sludge Oil" to refer to the mill effluent discharge captured before it goes to the lagoons, and POME to refer specifically to the effluent that is skimmed from the surface of the lagoons. Confusion on terminology represents a high risk of misclassification and harmonization of terminology will be important, though steps towards this are already being made. A **medium risk** level should be applied.

Oil palm mesocarp fibre oil (Palm Pressed Fibre Oil – PPF Oil): As a relatively new source of material, definitions of this material are still under development. Stakeholder comments indicated poor understanding of this material, mistaking it for CPO by commenters. Furthermore, our analysis found that mechanically extracted PPF Oil may be of similar quality as CPO, suggesting a potentially higher fraud risk. PPF Oil extracted using hexane may be a slightly lower fraud risk as it has additional compounds making it unsuitable for fuel production (e.g. high phosphorus content). It may be useful to distinguish between these materials based on extraction method, and to generally improve definitional awareness of this material. **Medium risk** is appropriate here.

EFB and EFB Oil: The definition of Empty Fruit Bunches is generally well understood. EFB Oil is generally understood as the oil that is transferred from the fruits to the stalks and stems of the bunch during the sterilization process. If the material become available in densified forms (E.g. briquettes, carpet, torrefied, liquor, pyrolysis oil) it may be useful to come up with common terminology for these modified forms of the material. EFB oil therefore carries **low-medium risk.**

Fatty acid distillate: PFAD is derived from the refining of crude palm oil to a food grade product. Although PFAD does have a comparable economic value on a mass basis to refined palm oil, it only represents 4.9% of the total output by mass, thus its economic value is only about 4.5% that of palm oil on an output weighted basis. Therefore, PFAD is generally categorised as a residue. Nevertheless, several EU Member States explicitly classify PFAD as a co-product (e.g. UK, NL). This results in a **medium risk** level for PFAD.

Olive oil extraction residues: Both de-oiled and non de-oiled pomace are clearly defined. Those involved with industry or regulation, whether at the EU-level or member states, should have a harmonized understanding of what each entails, so definitional risk is **low-medium**.

High oleic sunflower oil extraction residues: Neither FAV nor PSA-Keto have been widely defined by any mandate or scheme, EU or otherwise. Though there is risk of industry and regulatory players having lack of awareness of the feedstocks and their definitions, it should be straightforward and low-risk to clearly define these feedstocks uniformly for all who interact with them. EU RED II incentivization may create an unintended incentive to intentionally tune the process to produce more of these residues versus the pelargonic/azelaic acid and glycerine main products, which would technically make FAV and PSK-Keto co-products and no longer residues. It is also unclear whether FAV and PSK-Keto could be generated out of the processing of vegetable oils other than sunflower oil. A **medium risk** level applies.

9.3.7.7.3. Secondary Risk Indicators (Amplifiers)

Supply chain characteristics:

Supply chain characteristics are similar for most palm oil derivatives, namely that the vast majority of trade originates in Indonesia and Malaysia, which collectively produce about 84% of the total palm oil production globally (GreenPalm, website) and the supply chain is long and complex, including a large number of intermediaries and overseas shipping, in which continuous traceability from the biofuel producer to the feedstock source may be challenging for residue materials which are typically aggregated before shipment (Van Duijn, 2013). Increasing volumes of RSPO IP and RSPO SG certified crude palm oil show that physical traceability is possible, but mostly for the main products (CPO and PKO).

Sludge oil (pre-pond) & POME (pond skimmed): Both have the same supply chain characteristics, namely that POME oil is increasingly available as a globally traded commodity. Supply chains are disconnected such that the source of the residue is likely to be unknown to the final biofuel producer. Verbal communication from economic operators active in this market indicate that local collectors may often aggregate POME from mills to sell into international markets. A **medium-high risk** should be applied to both materials.

Oil palm mesocarp fibre oil (Palm Pressed Fibre Oil – PPF Oil): There is little information available about international trade of palm pressed fibre oil (PPF Oil). Communication with stakeholders indicates that technology to extract PPF oil is increasingly available as mills recognize this may be an area of significant yield loss when PPF extraction technology is not utilized. International trade of PPF POil is likely to increase over the coming years. This constitutes a **medium-high risk**.

EFB: EFBs are not currently widely traded commodities due to lower bulk density of the biomass. Some examples of methods to densify EFBs include: compaction to a briquette (Nazari et al, 2019), compressing the EFB into a carpet-like material (20 mm in thickness) known as EFB mat or Ecomat (ECO) (Sung et al, 2010), or conversion to a biooil (pyrolysis oil). EFBs may also be processed using crushers to extract the oil and water trapped in the stalks and fibres. An increasing number of Palm Oil Mills extract the oil from EFBs, and industry experts indicate this technology is becoming common. A **medium-high risk** therefore applies.

Palm fatty acid distillate: Globally, an estimated 2.5-3.6 million tonnes of PFAD are produced. Most palm refining is undertaken in the country of origin, though there are large volumes of palm oil refining in the EU. Since Indonesia and Malaysia represent the largest share of global palm cultivation (80-85%), these countries correspondingly produce the largest volumes of PFAD (IISD, 2019). PFAD is a highly traded commodity and Malaysia exported 208 kt of PFAD and palm acid oil to Europe in 2018, around a third of the total PFAD export globally (Malaysian Palm Oil Council, 2018). Some palm oil refining also takes place in Europe, where 4 million tonnes of crude palm oil was refined in 2018, which would correspond to approximately 160 kt PFAD (T&E, 2019). This indicates that PFAD is both produced domestically within Europe and imported. **Medium-high risk** is appropriate here.

Olive oil extraction residues: Neither de-oiled nor non de-oiled pomace are widely traded, as the material's bulk and low value does not justify transporting long distances. Incentivization may lead to greater trading volumes and more complex networks for non de-oiled pomace as it has greater potential value, but initially at least the risk is **low-medium**. For de-oiled pomace, **no risk score is attributed for this indicator, since primary indicators are low risk**.

High oleic sunflower oil extraction residues: Production of FAV and PSK-Keto is currently very limited due to the technology (hydroxylation plus oxidative cleavage reaction) not yet being widespread, occurring primarily in Italy which has relatively strong rule of law with a WJP score of 27. The majority of non-EU sunflower production occurs in Ukraine, Russia, and Turkey, which rank 72, 94, and 107 out of 128 respectively on the WJP index. If processors in weak rule of law countries switch from the more common ozonation reaction to processes that produce these residues, risk will be higher. Incentivization could influence the potential for this to occur. Additionally, some pelargonic/azelaic acid production is known to occur in China, which ranks poorly at 88 on the WPJ index. The current risk level is **low-medium**, though it may be subject to change dependent on the location of production.

Assurance:

The feedstocks in this category have different assurance characteristics, with variable associated risks:

<u>POME</u>

Sludge oil (pre-pond): The POME production process is well understood, and modern palm oil mills seek to reduce the amount of oil entrained in effluent through the use of specialized equipment (e.g. tricanters). Typical Sludge Oil / POME oil yields are available in the literature (Ahmad, 2003) but often not known by assurance providers. It may be the case that Sludge Oil (effluent extracted before discharge) is higher risk than POME skimmed from effluent ponds. Communication with economic actors in the market indicates that increasingly POME oil is being aggregated by collectors into large bulk quantities, making it more difficult to identify volumes produced from a particular source and increasing the fraud risk that the material is contaminated with CPO. Typical POME oil production from CPO mills is well understood (2.1 - 7.6 kg/ton FFB for plants with horizontal sterilizers, 6.0 - 28.8 kg/ton FFB for plants with vertical sterilizers) (ISCC, April 2021). Assurance providers are familiar with POME production due to experience in verification of CPO mills, but are generally unfamiliar with typical POME production yields and would be unlikely to notice if yields were out of typical ranges without technical training. **Medium risk** is appropriate.

POME (pond skimmed): The POME production process is well understood, and modern palm oil mills seek to reduce the amount of oil entrained in effluent through the use of specialized equipment (e.g. tricanters). Typical Sludge Oil / POME oil yields are available in the literature (Ahmad, 2003) but often not known by assurance providers. It may be the case that Sludge Oil (effluent extracted before discharge) is higher risk than POME skimmed from effluent ponds. Communication with economic actors in the market indicates that increasingly POME is being aggregated by collectors into large bulk quantities, making it more difficult to identify volumes produced from a particular source and increasing the fraud risk that the material is contaminated with CPO. Typical POME production from CPO mills is well understood (2.1 - 7.6 kg/ton FFB for plants with horizontal sterilizers, 6.0 - 28.8 kg/ton FFB for plants with vertical sterilizers) (ISCC, April 2021). Assurance providers are familiar with POME production due to experience in verification of CPO mills, but are generally unfamiliar with typical POME production yields and would be unlikely to notice if yields were out of typical ranges without technical training. **Medium risk** is also appropriate here.

Palm mesocarp: Hexane extracted PPF oil will usually be segregated in the mill, as it is essentially a separate production line within the facility. Mechanically extracted PPF may or may not be segregated. Remnant PPF oil constitutes 4-11% by dry mass of the mesocarp fibre. Our evaluation found that both mechanical and chemical extraction methods exist, and that this was a novel feedstock, with which verifiers have less experience. Mechanical extraction likely represents higher fraud risk due to the possibility to mix in with regular CPO whereas solvent extraction produces PPF oil with high phosphorus and free fatty acid content, generally making it undesirable to be blended in with the CPO stream. Assurance providers are generally unfamiliar with PPF oils and will not usually be familiar with typical yields without technical training. **Medium-high risk** applies.

EFB and EFB Oil: Extraction of EFB oil is currently being installed at a large number of extraction mills in order to maximize palm oil mill extraction yields (Cala, May 2021). EFB oil is generally extracted at the mill itself, and due to their high moisture content, it is unlikely EFBs would transported away from the mill prior to extraction of EFB oil. As mentioned earlier there are technologies being considered to densify EFBs to allow the fibrous material to be internationally traded, however that is currently not taking place due to the high moisture content of EFBs which require significant energy to dry and densify (Salleh, 2018). The material is generally well known and understood by assurance providers from palm oil mill certification processes. **Low-medium risk** is appropriate here.

Fatty acid distillate: PFAD is generally traded in segregated supply chains as a distinct material due to the fact that it is widely used in the chemicals and fuels markets. Other materials with similar properties could be mixed with PFAD as long as the technical specification is maintained (e.g. FFA >70%, MIU <1%, Unsaponifiables <5%). Due to the fact that it is widely traded as a commodity it may be challenging to link PFAD to a particular palm oil refinery in some cases. PFAD is extracted through both physical and chemical processes, both of which are well understood and established. PFAD yields correspond directly to the fatty acid content of the input CPO. The material is generally well known and understood by assurance providers from palm oil mill certification processes. This is a **low-medium risk.**

Olive oil extraction residues: Pomace is not generally mixed with other feedstocks in trading channels and is generally used in the same regions (in pomace oil mill or as feed) as the olive pressing facilities that generate it. The recovery rates for mature pomace oil extraction technologies are well-known within the industry but possibly less known on the part of assurance providers as the industry is somewhat insular and concentrated within a handful of Mediterranean countries. Technologies are being developed to achieve higher oil recovery rates oil with less solvent contamination (Lama-Munoz et al, 2011), which may create more potential for risk since assurance providers will be less aware of new recovery rates. However, the market price for pomace oil continues to trend downward which dampens the drive to commercialize associated technology, therefore technology risk should remain **low-medium** unless prices rise considerably.

High oleic sunflower oil extraction residues: Due to the small volumes currently produced, it will be simple to keep FAV and PSK-Keto separate from existing feedstock supply chains. Assurance providers are most likely completely unfamiliar with these feedstocks and will not have any point of reference for evaluation of the process used to create them or their conversion factors when used in biofuel processes. Due to the unfamiliarity, **medium-high risk** applies.

9.3.7.8. Animal by-products (non-fats) – Category 2 and 3

9.3.7.8.1. Definition

Animal products are separated at the slaughterhouse (abattoir) into parts that are fit for human consumption and those that are prohibited from entering the human food chain (collectively termed as “Animal By-products” (ABP)). In the EU, ABPs are categorised into three categories according to their potential health risk, following the principles set out in Regulation (EC) 1069/2009 (EU ABP Regulations). (European Commission, 2009)

- Category 1 is the highest risk material, and includes specified risk material linked to non-classical diseases like BSE & scrapie (e.g. bovine spinal cord and brain), and fallen stock (ruminants).
- Category 2 is high risk material, and includes material not fit for human consumption (e.g. digestive tracks) and fallen stock (non-ruminants).
- Category 3 is the lowest risk material, and includes material fit for human consumption at the point of slaughter, animal products without a specified disease risk (e.g. egg shells, feathers, bristles and horns) and former foodstuffs and catering waste.

When products of different categories are mixed, the entire mix is classified according to the highest risk category in the mix (e.g. if Category 1 and 3 ABPs are mixed then this is classified as Category 1).

ABPs are treated via rendering. Animal fats are one of the outputs of the rendering process (±12-15% share by mass), along with protein (±25%) and water (55-60%). (Alm, 2021)

Depending on the material category the protein is either classified as meat and bone meal (MBM) or processed animal protein (PAP). PAP is a biosecure feed ingredient with a high protein value arising from Category 3 material, whereas MBM arises from Categories 1 and 2 material and therefore cannot be used as a feed ingredient.

9.3.7.8.2. Primary Risk Indicators

Feedstock physical characteristics:

ABP (non-fats) that have not been subject to rendering may include material such as digestive tracks, organs or feathers, which are easily distinguishable from other biofuel or biogas feedstocks. ABP (non-fats) arising from a rendering plant are protein rich 'meals'. PAP may be similar in appearance to crop meals (e.g. soy), although the nutrient profile will likely differ. There would likely be limited economic incentive to mislabel crop meal as PAP, however, due to the established demand (and value) as animal feed, unless the premium for biofuel production was significantly higher. Therefore, there would be a **low overall risk** of mislabelling unincentivized feedstocks as incentivized feedstocks.

ABP (non-fats) arise from the rendering process, following separation of material at the slaughterhouse into parts that are fit for human consumption and those that are prohibited from entering the human food chain. The risk of a slaughterhouse deliberately producing more ABP at the expense of food grade meat, or contaminating food grade meat, is considered to be very low as there is no economic incentive to do so. The outputs from rendering lie within a typical range depending on the material rendered; it is not feasible to modify the production process to generate more ABP (non-fats). **This indicates a low risk of fraud.**

Risk indicators in relation to land properties (e.g. degraded or abandoned land) are not applicable for ABP (non-fats).

Feedstock definition characteristics:

The production, trade and use of animal fats market in the EU is strictly regulated. In Europe, ABP (non-fats) are classified according to level of health risk, as set out under the ABP Regulations. Third countries apply different classifications, however only Category 3 equivalent ABP (non-fats) can be exported to the EU. In this light, the risk of misrepresentation of the material at the point of origin is considered to be **low** as is the risk of reclassification along the supply chain.

Category 1 and 2 materials are uniformly regarded as wastes in the EU, whereas Category 3 material may be either regarded as a waste or residue. The classification outside of the EU for equivalent material is likely to be broadly consistent.

The cellulose to non-cellulose ratio is not relevant for animal fats.

9.3.7.8.3. Secondary Risk Indicators (Amplifiers)

Supply chain characteristics:

As described above, the ABP market is strictly regulated in the EU, involving licensed operators along the supply chain from origin to end-use. The supply chain for ABP non-fats involves a relatively small number of market participants (points of origin and intermediaries). Operators are approved by the relevant competent authority in each Member States (so called Approved Establishments) and are subject to regular veterinary inspections (European Commission, no date-a). In general, European countries have a relatively high rule of indicator score (World Justice Project, 2021).

The trade of ABP non-fats into the EU is possible, but restricted to establishments that have been authorised by the European Commission. It is understood that only Category 3 equivalent material can be exported to the EU. Exporters also need to register trades in the EU TRACES database (European Commission, no date-b). **No risk score is attributed for secondary risk indicators, since primary indicators are low risk.**

Assurance:

The transport of ABP is strictly controlled via the ABP Regulations from origin to end-use (i.e. rendering plant to the biofuel production plant). Commercial documentation accompanies each load of ABP and identifies the origin of the material, its category type and other relevant details (e.g. trailer ID). As mentioned above, imports to the EU must be registered in the TRACES database. These measures ensure full traceability of the material along the supply chain.

ABP non-fats are not widely used for biofuel or biogas production, although conventional technologies (e.g. trans-esterification) can in principle be applied. Specific issues relating to use of this material as a substrate for biogas production are the high ammonia and protein content, which can be toxic to the microorganisms (Alm, 2021). Only one example of use in biofuel production was identified, using poultry feather meal to produce FAME biodiesel in Pakistan. As such, some risk would be posed by the inability to accurately audit processing volumes due to lack of generally-known conversion and yield ratios for this feedstock. The limited understanding of this material among assurance providers may pose an additional risk. **No risk score is attributed for secondary risk indicators, since primary indicators are low risk.**

9.3.7.9. Animal fats – Category 1, 2 and 3

9.3.7.9.1. Definition

Animal products are separated at the slaughterhouse (abattoir) into parts that are fit for human consumption and those that are prohibited from entering the human food chain (collectively termed as "Animal By-products" (ABP)). In the EU, ABPs are categorised into three categories according to their potential health risk, following the principles set out in Regulation (EC) 1069/2009 (EU ABP Regulations). (European Commission, 2009)

- Category 1 is the highest risk material, and includes specified risk material linked to non-classical diseases like BSE & scrapie (e.g. bovine spinal cord and brain), and fallen stock (ruminants).

- Category 2 is high risk material, and includes material not fit for human consumption (e.g. digestive tracks) and fallen stock (non-ruminants).

- Category 3 is the lowest risk material, and includes material fit for human consumption at the point of slaughter, animal products without a specified disease risk (e.g. egg shells, feathers, bristles and horns) and former foodstuffs and catering waste.

When products of different categories are mixed, the entire mix is classified according to the highest risk category in the mix (e.g. if Category 1 and 3 ABPs are mixed then this is classified as Category 1).

ABPs are treated via rendering. Animal fats are one of the outputs of the rendering process (±12-15% share by mass), along with protein (±25%) and water (55-60%) (Alm, 2021).

Animal fats share a similar fatty acid profile to palm oil (Malins, 2017). The free fatty acid (FFA) content of animal fats generally depends on the category and is strongly influenced by the conditions in which the dead animals were processed (see below).

9.3.7.9.2. Primary Risk Indicators

Feedstock physical characteristics:

Category 3 animal fats are typically traded at 1-2% FFA (around 5% in summer or in southern Europe), and Category 1 animal fats are typically traded at up to 20% (Alm, 2021). Animal fats (in particular Category 1) can include high levels of constituents such as salts, sulphur and phosphorous. Therefore, animal fats may have physio-chemical characteristics that make it difficult to distinguish from some waste oils (such as similar FFA profile). However, animal fats (including tallow) are typically solid at room temperature, whereas oils are typically liquids, which provides a way of differentiating between the two. The risk of misrepresentation of the material is considered to be **low to medium**.

Animal fats arise from the rendering process, following separation of material at the slaughterhouse into parts that are fit for human consumption and those that are prohibited from entering the human food chain. The risk of a slaughterhouse deliberately producing more ABP at the expense of food grade meat, or contaminating food grade meat, is considered to be very low as there is **no economic incentive** to do so. The outputs from rendering lie within a typical range depending on the material rendered; it is not feasible to modify the production process to generate more animal fats. **This indicates a low risk of fraud.**

A potential risk with animal fats is the risk of deliberately downgrading low risk material (i.e. Category 3 material) by mixing it with higher risk (i.e. Category 1 or 2 material). This is considered low since rendering plants aim for a high level of material segregation to maximise the overall economic value of the outputs (i.e.

animal fats and protein) at the rendering plant. The higher value realised from Category 3 and food grade material, particularly processed animal protein (PAP), ultimately drives the market. Therefore, this is also considered to be a **low risk of fraud**. This is supported by the fact that in excess of 700,000 tonnes of Category 3 animal fats are already used for biofuel production in the EU despite not being included in Annex IX Part B.

Risk indicators in relation to land properties (e.g. degraded or abandoned land) are not applicable for animal fats.

Feedstock definition characteristics:

The production, trade and use of animal fats market in the EU is strictly regulated. In Europe, animal fats are classified according to level of health risk, as set out under the ABP Regulations. Third countries apply different classifications, however only Category 3 equivalent animal fats can be exported to the EU. In this light, the risk of misrepresentation of the material at the point of origin is considered to be **low** as is the risk of reclassification along the supply chain.

Category 1 and 2 materials are uniformly regarded as wastes in the EU, whereas Category 3 material may be either regarded as a waste or residue. The classification outside of the EU for equivalent material is likely to be broadly consistent.

The cellulose to non-cellulose ratio is not relevant for animal fats.

9.3.7.9.3. Secondary Risk Indicators (Amplifiers)

Supply chain characteristics:

As described above, the animal fats market is strictly regulated in the EU, involving licensed operators along the supply chain from origin to end-use. Operators are approved by the relevant competent authority in each Member States (so called Approved Establishments) and are subject to regular veterinary inspections (European Commission, no date-a). The supply chain for animal fats involves a limited number of market participants (points of origin and intermediaries). Animal fats are often transported over relatively short distances, in particular Category 1 animal fats which are typically transported direct from the rendering plant to the biofuel plant without storage.

The trade of animal fats into the EU is possible but made challenging due to differences in material treatment methods and handling rules in third country markets. For example, according to Navigant (2020) all of the animal fats consumed for biofuels production in the EU in 2018 were from reported as EU origin. It is understood that only Category 3 equivalent animal fats can be exported to the EU, and furthermore only facilities that have been approved by the European Commission are permitted to export to the EU. All exports must be registered in the EU TRACES database (European Commission, no date-b). In general, European countries have a relatively high rule of indicator score (World Justice Project, 2021). **No risk score is attributed for secondary risk indicators, since primary indicators are low risk.**

Assurance:

The transport of animal fats is strictly controlled via the ABP Regulations from origin to end-use (i.e. rendering plant to the biofuel production plant). Commercial documentation accompanies each load of animal fats and identifies the origin of the material, its category type and other relevant details (e.g. trailer ID). As mentioned above, imports to the EU must be registered in the TRACES database. These measures ensure full traceability of the material along the supply chain.

Conversion of animal fats to biofuel production (FAME, HVO and HEFA) utilises mature technology and is applied at commercial scale. According to the industry body EFPRA, over 1.2 million tonnes of animal fats are used as a feedstock for biofuel production in Europe of which over 700,000 tonnes were Category 3 and the remainder Category 1 (EFPRA, 2020). This implies that assurance providers are familiar with animal fats as a feedstock for biofuel production, including the different categories. Additionally, a default GHG emission value is available for Category 1 and 2 animal fats under the REDII. **No risk score is attributed for secondary risk indicators, since primary indicators are low risk.**

9.3.7.10. Drinks, distillery and brewing products

9.3.7.10.1. Definition

<u>Grape marc and wine lees</u>

Grape pomace or grape marc is the major solid by-product generated during wine making process (Moreno et al., 2020). It is comprised of skins, seeds and any other solid remaining after pressing (Moreno et al., 2020). Wine lees are a sludge material made of yeast cells and other insoluble particles that accumulate at the bottom of wine tanks after alcoholic fermentation (De Iseppi et al., 2020). Wine lees are rich in organic compounds (De Iseppi et al., 2020).

<u>Citrus fruit pulp and peels</u>

Drink production residues and waste are generated during the production of non-alcoholic drinks, including but not limited to fruit pulp and peeling (e.g. citrus) (Annex IX T2 assessment). The assessment will be about the material obtained from the processing of non-alcoholic drinks in general while referring to the citrus pulp and peel feedstock as an example.

Citrus pulp is the material generated during the industrial processing of citrus fruits and consists of peel and pulp, with a high moisture content of more than 80% (Annex IX T2 assessment). Citrus peel and pulp contain water-soluble sugars, fibres, organic acids, amino acids and proteins, minerals, oils and lipids (Annex IX T2 assessment).

<u>Distillery heads and tails, and fusel oils</u>

Alcoholic distillery residues and wastes includes heads and tails. The impurities have boiling points that are either higher or lower than ethanol. The impurities with the lower boiling points are known as heads. Heads include acetaldehyde, acetone and other volatile trace components. Tails on the other hand are less volatile alcohols with higher boiling points (Annex IX T2 assessment). Tails include acetic acid, furfural and a group of alcohols known as fusel oils comprising of propanol, butanol and amyl alcohols. Fusels are alcohols with more than two carbon atom and an oily consistency therefore popularly termed as fusel oils (Annex IX T2 assessment).

9.3.7.10.2. Primary Risk Indicators

Feedstock physical characteristics:

Grape marc, wine lees, citrus fruit pulp and peels can be distinguished from other feedstocks given their physical appearance. Distillery heads and tails, and fusel oils have specific chemical compositions that should be identifiable in the lab. There appears to be little financial incentive to intentionally degrade grapes, fruits or grains to increase the volume of these residues/wastes given the higher economic value of food/ beverage products, compared to biofuel/biogas feedstocks. Risk of being misidentified is therefore assumed to be **low for grape marc, wine lees,**

citrus fruit pulp and peels, while it is considered to be a **medium risk for distillery heads and tails and fusel oils** given the requirement of chemical analysis.

Feedstock definition characteristics:

Grape marc and wine lees

Grape marc and wine lees are uniformly defined across all regions given their origins in the wine making industry. Whenever these are considered unsuitable as food, they would be covered under EU RED II or UK RTFO as food waste, but if a potential use as food remains technically possible (even if economically unattractive), such definition would not apply. Neither the characteristics making grape marc and wine lees suitable for energy production rather than food use nor their classification as residue or waste are clearly defined in EU regulations. Grape marc and wine lees are double counted under the UK's RTFO and are defined as 'processing residues from the wine making industry'. The cellulose to non-cellulose ratios for grape marc and wine lees can vary by the species of grapes used.

Feedstock definition characteristics for grape marc and wine lees are overall in the **medium risk** category.

Citrus fruit pulp and peels

Citrus fruit pulp and peels are uniformly defined across all regions. Whenever these are considered unsuitable as food/feed, they would be covered under EU RED II or UK RTFO as food waste, but if a potential use as food remains technically possible (even if economically unattractive), such definition would not apply. Neither the characteristics making citrus fruit pulp and peels suitable for energy production rather than food/feed use nor their classification as residue or waste are clearly defined in EU or UK regulations. Cellulose can be extracted from different fruit pomace as well as orange peels, and the cellulose to non-cellulose ratios will vary by type of fruit (Szymanska-Chargot et al., 2017; Bicu and Mustafa, 2011).

Feedstock definition characteristics for citrus fruit pulp and peels are overall in the **low risk** category.

Distillery heads and tails, and fusel oils

Distillery heads and tails, and fusel oils are uniformly defined across all regions given their origins in the brewing/ distillery industry. The classification of distillery heads and tails, and fusel oils as residue or waste are not clearly defined in EU or UK regulations.

Feedstock definition characteristics for distillery heads and tails, and fusel oils are overall in the **low risk** category.

9.3.7.10.3. Secondary Risk Indicators (Amplifiers)

Supply chain characteristics:

Grape marc and wine lees

Wine lees are traded globally (OEC, 2019a). Grappa, which is produced using grape marc, is traded globally but there is little evidence of grape marc itself being traded (OEC, 2019b). Grape marc and wine lees are being converted into bioethanol as demonstrated by several companies who are grape marc and/or wine lees ethanol certified by the ISCC (valid till 2021 or 2022) (ISCC, 2021a). Most of these companies (19 in number) are based in Spain, 6 are in Italy, and one in Portugal. Most have been certified as 'Collecting point' and 'Distillery' (ISCC, 2021b) while a few are certified as 'Point of origin' and 'Ethanol plant' (ISCC, 2021c). As per the ISCC, collecting points of waste and residues are economic operators that collect or receive waste and residue materials directly from the points of origin (ISCC, 2021d). This could be an indication of grape marc and wine lees being aggregated by traders and processed within a certain region. 'Points of origin (PoO)' for waste or processing residues are operations where the waste or residue either occurs or is generated (ISCC, 2021d). This material is the source for most commercial tartaric acid (natural production route rather than synthetic route), which is used in cooking and in organic chemistry. Grape marc and wine lees are produced across the world, including in many countries with weak rule of law.

Supply chain characteristics for grape marc and wine lees are overall in the **medium risk** category.

<u>Citrus fruit pulp and peels</u>

Orange peels and dried citrus pulp are traded globally (Heuzé et al., 2018). They may be converted into biogas/biofuels on site or may be aggregated by traders and processed within a certain region. Citrus fruit pulp is mainly used as animal feed when farms are located close to the processing plants. Orange peels are being used by the gin industry in the UK (Beacon Commodities, 2021). Although biogas production is possible using citrus fruit pulp and peels, it is not done at scale due to presence of toxic components in the feedstock. Citrus fruit pulp and peels are produced across the world, including in many countries with weak rule of law.

Supply chain characteristics for citrus fruit pulp and peels are overall in the **medium risk** category.

<u>Distillery heads and tails, and fusel oils</u>

There is no evidence of distillery heads and tails, and fusel oils being traded globally, making it a low risk option. They may be converted into biogas/biofuels on site or may be aggregated by traders and processed within a certain region. Distillery heads and tails are used for the production of fuel grade bioethanol, while fusel oils can be used as a blending agent with gasoline. Distillery heads and tails, and fusel oils cannot be used in food or feed. Distillery heads and tails, and fusel oils are produced across the world, including in many countries with weak rule of law. This makes it a medium risk option.

Supply chain characteristics for distillery heads and tails, and fusel oils are overall in the **medium-low risk** category.

Assurance:

<u>Grape marc and wine lees</u>

Grape marc and wine lees are generated in wineries and therefore can be traced back to their origin when used locally. However, as mentioned above, wine lees are traded. Once mixed with locally generated feedstock, it would not be possible to trace the imported feedstock back to their place of origin.

The technologies for conversion of grape marc and wine lees are mainly anaerobic digestion (biogas) and fermentation (ethanol), which are well understood. Typical conversion/yield factors for grape marc and wine lees are however not documented.

Grape marc and wine lees composition and use as bioethanol feedstock are generally known and understood, or easily researched. As mentioned already, there are 26 companies, based mainly in Spain, that have active grape marc/ wine lees ISCC EU certificates. We therefore assume that assurance providers will not find it too difficult to evaluate this feedstock.

Assurance for grape marc and wine lees are mainly in the **low risk** category. The only exception is the **medium risk of the conversion technology not having typical values for yield/conversion**.

Citrus fruit pulp and peels

Citrus fruit pulp and peels are generated in fruit processing plants and therefore can be traced back to their origin when used locally. However, as mentioned above, citrus fruit pulp and peels are traded. Once mixed with locally generated feedstock, it would not be possible to trace the imported feedstock back to their place of origin.

Although not practised widely, the technology for conversion of citrus fruit pulp and peels is anaerobic digestion (biogas), which is well understood. Typical conversion/yield factors for citrus fruit pulp and peels are however not documented.

Citrus fruit pulp and peels composition and use as biofuel feedstock are generally known and understood, or easily researched. We therefore assume that assurance providers will not find it too difficult to evaluate this feedstock.

Assurance for citrus fruit pulp and peels are mainly in the **low risk** category. The only exception is the **medium risk of the conversion technology not having typical values for yield/conversion.**

Distillery heads and tails, and fusel oils

Distillery heads and tails, and fusel oils are generated in brewing/distillery plants and therefore can be traced back to their origin.

The biofuel conversion process and technology associated with fusel oils is still a topic of research. Conversion/yield factors for distillery heads and tails, and fusel oils into biofuels is not documented.

Assurance providers may not be used to assessing distillery heads and tails, and fusel oils specifically, but are likely to have experience working with the brewing/distillery industry.

Assurance for distillery heads and tails, and fuels oils are mainly in the **medium risk** category. The only exception is the **high risk associated with the fact that the conversion technology is not well understood**.

9.3.7.11. Bakery and Confectionery products

9.3.7.11.1. Definition

Bakery and confectionery residues and waste are raw or baked material, primarily composed of carbohydrates (incl. starch, glucose, fructose, etc.), with variable amounts of proteins, fats and cellulose.

Bakery residues and waste are generated during the production of bread, pasta, wafer, dough and commercially supplied products containing bread or dough, such as sandwiches, pizzas or pies. Examples of bakery residues and waste include flour, dough, breadcrumbs, bread crust, fermentation residues, wastewater etc.

Confectionery residues and waste are generated during the production of sweets, including chocolate and sugar confectionery and gum products. Examples include cocoa residues, nuts, sugar, wastewater etc.

Bakery and confectionery residues and waste are also generated at the distribution/retail stage when businesses (e.g. supermarkets, bakeries and restaurants) discard unsold/expired products before they reach the end consumer.

9.3.7.11.2. Primary Risk Indicators

Feedstock physical characteristics:

Bakery or confectionery main products could be intentionally mixed with bakery or confectionery residues and waste. , which could not be easily detected, either via a visual inspection or through a chemical analysis. The financial incentive appears, however, moderate, due to the higher economic value of food products, compared to biofuel/biogas feedstocks. Similarly, the financial incentive for bakery/confectionery main products to be intentionally degraded or prematurely considered expired is considered moderate, based on the assumption that revenues from food products remain higher than for biofuel/biogas feedstocks. Therefore, the risk of intentionally mixing, degrading or contaminating main bakery/confectionery products to make these resemble bakery/confectionery residues is considered **medium**.

Another risk exists that other types of biogenic wastes from food processing units (e.g. food waste from canteen, garden waste, etc.) are mixed with bakery/confectionery residues and waste, which would be challenging to track and identify. Since those biowaste from industrial facilities are already incentivized (EU RED II – Annex IXA point d) Biomass fraction of industrial waste not fit for use in the food or feed chain, including material from retail and wholesale and the agro-food and fish and aquaculture industry, and excluding feedstocks listed in Part B of this Annex), **this fraud risk appears low.**

Feedstock definition characteristics:

Bakery and confectionery residues and waste are not uniformly defined across all regions, due to the diversity of product supply chains they are generated from. Whenever these are considered unsuitable as food/feed, they would be covered under EU RED II or UK RTFO as food waste, but if a potential use as food/feed remains technically possible (even if economically unattractive), such definition would not apply. The related fraud risk is considered **medium.**

Neither the characteristics making bakery and confectionery residues and waste suitable for energy production rather than food/feed use nor their classification as residue or waste are clearly defined in EU or UK regulations. The related fraud risk is considered **high.**

Conversion/yield factors for processing bakery and confectionery residues and waste into biogas are not documented. The related fraud risk is considered **medium.**

9.3.7.11.3. Secondary Risk Indicators (Amplifiers)

Supply chain characteristics:

No documented evidence was found that bakery or confectionery residues and waste are traded between a large number of intermediaries, globally or in large volumes, partly due to the rapid degradation of this feedstock. This is confirmed by feedback from stakeholders consulted during this study (Ferrero, 2020), who indicate that bakery and confectionery residues and waste are primarily used locally for biogas production or as animal feed. No current or future import of bakery or confectionery residues and waste from non-EU countries is being reported/documented, which can be explained by the facts that 1) the EU is the largest exporter of processed agricultural products (European Commission, 2021) and 2) a limited amount of bakery (and admittedly confectionery) residues are currently being used as animal feed (Heuzé et al., 2018), thus leaving a large share of those residues and waste unexploited, which limits the need for imports.

Therefore, **the risk related to the number of intermediaries is considered low, but the risk related to large volumes is considered medium**, given the large production of bakery and confectionery residues and waste in the EU. Bakery and confectionery waste or residues used in the EU for energy production are therefore expected to be produced in the European Union, where the rule of law can be considered robust. This risk is therefore **low.**

Assurance:

According to the stakeholders consulted for this study, bakery and confectionery residues and waste are used locally, which means they could be traced back to their origin. It could however be assumed that residues and waste from different industrial facilities could be aggregated, which would make their tracking back to origin difficult. The related fraud risk is considered **medium.**

The technologies for conversion of bakery and confectionery residues and waste are mainly anaerobic digestion (biogas) and fermentation (ethanol), which are well understood. Typical yields for bakery and confectionery residues and waste are however not documented. The related fraud risk is considered **medium.**

We assume that it will be difficult for assurance providers to distinguish between the different types of residues and waste, assess their potential for food/feed uses and determine whether they should be considered as residues or waste. A higher risk exists for auditors when expired bakery or confectionery products are being mixed with other waste, which makes difficult to distinguish them.

Furthermore, EU RED II does not include a default GHG value for bakery or confectionery residues used for biogas or biofuel production. Therefore, this fraud risk is considered **high** and specific training might be required for assurance providers, based on clear guidance from regulators.

9.3.8. Processing residues – others

9.3.8.1. Tall oil pitch

9.3.8.1.1. Definition

Tall oil is extracted from black liquor produced during the kraft paper pulping process. Tall oil pitch is the remaining material after other fractions have been extracted during tall oil refining, comparable in this regard to heavy fuel oil from oil refining. Precise chemical composition will vary by original wood feedstocks for the pulping process and by distillation process. One commercial supplier (Foreverest Resources, 2021) quotes a tall oil pitch composition of 29% fatty acids, 7% dissociate fatty acid, 9% diatomic alcohol, 7% rosin acid, 23% dissociate rosin acid, 5% hydrocarbon, 11% monobasic alcohol and 9% sterol.

9.3.8.1.2. Primary Risk Indicators

Feedstock physical characteristics:

Tall oil pitch is visually and chemically distinct from other tall oil fractions and from other feedstocks. If the value of tall oil pitch increases due to its inclusion on Annex IX such that it is worth more than traditionally higher-value tall oil fractions such as distilled tall oil and tall oil fatty acids, it could in principle create an incentive for tall oil refiners to reduce the rate of extraction of these other fractions (i.e. labelling a larger fraction of refined material as tall oil pitch) or to mix some of the lower value lighter fractions back in to the pitch. Given, however, that both tall oil and tall oil pitch are included in Annex IX - Part A this is not considered a significant risk. **This fraud risk is therefore considered low.**

Feedstock definition characteristics:

Tall oil pitch is clearly defined as the highest boiling point fraction of tall oil remaining after fractionation. The precise quantity of material that can be characterised as tall oil pitch from a given supply of crude tall oil will therefore be somewhat dependent on the fractionation technology applied. More sophisticated fractionation systems (e.g. use of high vacuum) may lead to lower pitch yields (cf. Neste Engineering Solutions, 2018; Nevanlinna & Vikman, 2020). **This fraud risk is considered low.**

Tall oil, and therefore by implication tall oil pitch, is identified as a residue in EU RED II. It is also identified as a residue eligible for double counting under the UK RTFO. Tall oil pitch is unlikely to be considered as a co-product in other jurisdictions or by businesses given the relatively low value it holds, and is unlikely to be discarded without energy recovery and therefore is unlikely to be treated as a waste. **This fraud risk is considered low.**

9.3.8.1.3. Secondary Risk Indicators (Amplifiers)

Supply chain characteristics:

Most tall oil pitch is believed to be used locally for process energy at tall oil distillation sites (Aryan & Kraft, 2021; Malins, 2017). There is some reference to non-energy applications in the literature (e.g. Foreverest Resources, 2021) which would require trading of tall oil pitch, but these seem to be niche uses for now. If developed as a feedstock for hydrotreating (HVO) or for other biofuel production technologies, tall oil pitch could potentially be aggregated across a larger area and transported internationally, just as is seen with other oily feedstocks. **No risk score is attributed for secondary risk indicators, since primary indicators are low risk.**

Kraft pulping is globally distributed, the largest producers of kraft pulp (and therefore tall oil and tall oil pitch) are shown in Table 48 with their global rule of law rankings. **This fraud risk is considered low to high depending on source country.**

Table 48 : Major producers of tall oil pitch and their rule of law rankings

Country	% of global kraft pulping	Rule of law ranking
United States	31%	21
Brazil	13%	67
China	7%	88
Canada	6%	9

Sweden	6%	4
Japan	5%	15
Indonesia	5%	59
Finland	5%	3
Russian Federation	4%	94

Assurance:

Tall oil pitch is likely to be segregated to the point of processing into biofuel, as it has particular properties distinct from other oily feedstocks and may require some pre-treatment. Aryan & Kraft (2021) note that tall oil must generally be depitched before hydrotreating to renewable diesel, which implies that it would not be desirable to mix tall oil pitch with other renewable diesel feedstocks, although this may be less of a concern if using tall oil pitch as a gasification feedstock.

The process for biofuel production from tall oil pitch is relatively novel and has no default LCA values, and we are not aware of public documentation of process yields for hydrotreating tall oil pitch or for gasification-based pathways.

Assurance providers will be used to working with the forest industry but are unlikely to have dealt directly with tall oil pitch previously.

No risk score is attributed for secondary risk indicators, since primary indicators are low risk.

9.3.8.2. Crude glycerine

9.3.8.2.1. Definition

Crude glycerine, also referred to as glycerin and (in its pure form) glycerol and by the chemical name 1,2,3-propanetriol, is a compound of carbon, hydrogen and oxygen. Crude glycerine is generated during the soap manufacturing process, and in recent years has been produced in large quantities as a processing residue of FAME biodiesel manufacture by transesterification (Malins, 2017). Crude glycerine produced during transesterification of vegetable oils consists of roughly 80% glycerol, 10-15% water, traces of unreacted methanol and a small quantity of salts and 'MONG' (matter organic non-glycerol) (Maquirriain et al., 2020). The constituents may vary by feedstock and by the level of pre-treatment applied before transesterification (Maquirriain et al., 2020; Wan Isahak et al., 2015). Crude glycerine may also be synthesised from fossil resources, but this has become unusual as the growth of the biodiesel industry has expanded the crude glycerine supply.

9.3.8.2.2. Primary Risk Indicators

Feedstock physical characteristics:

Crude glycerine is chemically well defined and distinct from other feedstocks. However renewable glycerol and synthesised fossil glycerol are chemically similar and may be difficult to distinguish without carbon 14 testing. The market for synthesised fossil glycerol has however been strongly affected by increased crude glycerine availability from biodiesel production (Ciriminna et al., 2014) and very little if any fossil glycerol is now produced. In general, the per-tonne price of glycerine in the EU is quite low compared to fossil resources (ICIS, 2020) and thus a very significant market shift would be required before double counting created a value incentive to report fossil glycerine as renewable. **This fraud risk is considered low.**

It would not be readily possible to increase crude glycerine production in biodiesel manufacture as the yield is determined by the basic chemistry of the process. **This risk is considered medium.**

Feedstock definition characteristics:

Crude glycerine is a well-defined material. **This fraud risk is considered low.**

The understanding of glycerine as waste, residue or co-product, however, may vary between regions and stakeholders. Under EU RED II, glycerine is identified as a residue, and it is treated as a double counted residue under the UK RTFO. In some contexts however it may be understood as a co-product of biodiesel production, e.g. in the U.S. some reporting requirements for biodiesel producers identify glycerine as a co-product (U.S. EIA, 2009). **This fraud risk is considered medium.**

9.3.8.2.3. Secondary Risk Indicators (Amplifiers)

Supply chain characteristics:

Trade in glycerol, crude glycerine, glycerol waters and glycerol lyes is reported under HS code 1520. UN Comtrade (2020) reports significant trade flows, with more than 2 million tonnes of exports reported in 2019. The largest exporters are countries that produce a lot of biodiesel – Indonesia, Brazil, Western European countries, Malaysia and Argentina. Crude glycerine can be relatively easily transported and where larger numbers of smaller biodiesel plants are still operational it is possible that material could be handled by several intermediaries prior to being supplied for biofuel production.

The EU remains the largest producer of biodiesel in the world, producing about a third of the global supply (U.S. EIA, 2021), and is therefore also the world's largest producer of crude glycerine. (UN Comtrade, 2020) data shows that the EU also imports modest quantities of glycerine from countries including Argentine, Indonesia, the USA and Brazil. The Rule of Law rankings for the world's main biodiesel producers (and therefore also major crude glycerine producers) are shown in Table 49.

No risk score is attributed for secondary risk indicators, since primary indicators are low risk.

Table 49: Rule of law rankings for major biodiesel producers

Country	% of global biodiesel production	Rule of law ranking
Indonesia	18%	59
United States	14%	21
Brazil	13%	67

Germany	8%	6
Argentina	5%	48
FranceFrance	5%	20
Spain	5%	19
Netherlands	4%	5
Thailand	4%	71

Assurance:

Glycerine is chemically distinct from other potential biofuel feedstocks and is therefore likely to be kept segregated. **This fraud risk is considered low**. Biofuel production from glycerine is not yet widely practiced (technology pathways include anaerobic digestion and gasification) and default LCA data are not available for these processes. **This fraud risk is considered medium**. Most crude glycerine is produced in the biodiesel industry, and therefore producers will generally be used to working with certification bodies, and assurance providers will be experienced working with the biodiesel industry even if they do not have specific experience with the crude glycerine supply chain. **This fraud risk is considered medium**.

9.3.8.3. Raw methanol

9.3.8.3.1. Definition

The kraft paper pulping process produces methanol as a residue. The 'raw' methanol produced in the process is dilute form and is mixed with contaminants including sulphurous organic compounds, ethanol, ammonia and turpentine (Warnquist et al., 2019). Raw methanol therefore may not be supplied to biofuel markets as a finished methanol product without further purification.

9.3.8.3.2. Primary Risk Indicators

Feedstock Physical Characteristics:

The mixture from which raw methanol may be extracted, sometimes referred to as "foul condensates", has a somewhat distinctive set of constituents, but the raw methanol itself is chemically indistinguishable from methanol produced out of fossil molecule except through a C-14 analysis. It would therefore be possible in principle that raw methanol could be contaminated with fossil methanol to increase the volume of material reported. If the supply was contaminated with large amounts of additional fossil methanol this could be identified by comparing quantities of methanol supplied with expected raw methanol yields, but given that there is some variability in raw methanol yields from the pulping process it may be difficult to identify cases where more modest amounts of additional methanol were added based only on considering volumes reported. Carbon 14 testing could be used to demonstrate the renewable origin of methanol providing that batches of renewable methanol were physically segregated up to the point of testing. Any aggregation of renewable batches in the supply chain would make it more difficult to identify discrepancies in C14 content (as the fossil component in a contaminated batch would be diluted by aggregation). Mislabelling as renewable would give considerable added value to fossil methanol used as a fuel additive, and therefore there is a clear incentive for mislabelling fraud. **This fraud risk is considered high.**

Methanol production in pulping is determined by the interaction of the type of wood processed and the process chemicals used. It may in principle be possible to adjust the chemical mix to marginally increase methanol yield, but this is unlikely to deliver economically efficient outcomes. **This risk is considered medium.**

Feedstock Definition Characteristics:

The definition of raw methanol from pulp mills is clear. Raw methanol meets the definition of a residue in the context of EU RED II. **This fraud risk is considered low.**

There may be some inconsistency across mills and regions in relation to whether raw methanol is locally considered as a waste or a residue, depending on how effectively the energy value of the methanol is recovered. **This fraud risk is considered medium.**

9.3.8.3.3. Secondary Risk Indicators (Amplifiers)

Supply Chain Characteristics:

Raw methanol purification is likely to occur either on site (as in the existing examples of which we are aware: Alberta-Pacific Forest Industries Inc., 2021; Södra, 2021), or else potentially by aggregation from several pulp mills to a centralised purification facility. In either case, the supply chain can be expected to involve only a small number of actors (mill operator, purification plant operator, perhaps an independent aggregator).

Raw methanol is not currently traded internationally to the best of our knowledge, but 'pure' methanol (primarily from fossil sources) is widely traded. If trade in renewable methanol developed to use the same infrastructure as the existing methanol trade this may introduce risks of both purposeful and accidental contamination with fossil methanol. **Overall, the supply chain related fraud risk is currently considered medium.**

Kraft pulping is globally distributed, the largest producers of kraft pulp (and therefore raw methanol) are shown in Table 50 with their global rule of law rankings. **This fraud risk is considered low to high depending on source country.**

Table 50 : Major producers of kraft pulp and their rule of law rankings

Country	% of global kraft pulping	Rule of law ranking
United States	31%	21
Brazil	13%	67
China	7%	88
Canada	6%	9
Sweden	6%	4
Japan	5%	15
Indonesia	5%	59

Finland	5%	3
Russian Federation	4%	94

Assurance:

Given the limited deployment of raw methanol purification technology it is difficult to draw firm conclusions about how a supply chain may develop. At present, it is likely that fully segregated supply chains are used by plants already operating raw methanol purification systems, but with an expanded industry there may be opportunities to reduce handling costs through a mass balance system intermingling renewable and fossil methanol. This is only relevant after raw methanol purification, raw methanol itself will be kept segregated to avoid the introduction of contaminants to other materials. **This fraud risk is considered medium.**

The basic conversion technology for raw methanol (methanol purification) is relatively simple and likely to be low carbon intensity given the prevalence of the use of biomass for energy in the pulp industry, but there is no GHG emissions value for this process in EU RED II, and there are not yet standard LCA values available for the process. Producers would therefore need to report and certify actual values. Methanol may be used as a gasoline additive in low blends or potentially as a marine fuel, but could also be further upgraded to MTBE (allowing higher-blend use in gasoline) or to DME (for blending in diesel or use in specialised engines, and technologies exist to produce synthetic fuels from methanol. These upgrading processes are relatively well characterised in the lifecycle analysis literature (e.g. JEC Well-to-Wheels), but do not have default GHG emissions values in EU RED II. **This risk is considered medium.**

Assurance providers are likely to have experience working with forest products (for instance in the context of FSC) but are unlikely to have specifically considered certifying raw methanol before. **This fraud risk is considered medium.**

9.3.8.4. Soapstock and its derivatives

9.3.8.4.1. Definition

Soapstock and its derivatives, including acid oil and its components, free fatty acids, glycerides, acylglycerols, pigments, and other lipophilic materials, are materials resulting from the vegetable oil refining process (Casali et al., 2021).

9.3.8.4.2. Primary Risk Indicators

Feedstock physical characteristics:

Soapstock and its derivatives can vary in their physico-chemical properties, with varying fatty acid composition, lipid chain length, molecular arrangement, and degree of saturation (King et al., 1998). For example, flax soapstock had linolenic and linoleic acid contents of 11.4% and 13.2%, respectively, while soybean soapstock had linolenic and linoleic acid contents of 3% and 2.8%, respectively (Dumont & Narine, 2008). These differences in fatty acid content manifest in variation of physico-chemical properties, such as titer value, viscosity, specific gravity, colour, iodine value, ultraviolet absorption, etc., that also can help enable distinction of sources (Soap and Detergent Association, 1965). The American Oil Chemists' Society has developed methods to quantify these different properties and characterize fatty acid content of soapstock from different sources (American Oil Chemists' Society, 2021). Alternative methods that are quicker and simpler, namely gas chromatography, have been developed as well. For example, gas chromatography performed on flax and soybean soapstock was able to determine the content (mass %) of various fatty acids. However, it does not appear that there is a consensus on industry standards for what the composition or physico-chemical characteristics of soapstock and its derivatives should be for each source. Soapstock can appear similar to other materials. As a result, other feedstocks with high fatty acid contents, such as used cooking oil, or with similar fatty acid contents, such as unrefined vegetable oil, could be difficult to distinguish from soapstock and derivatives and thus increase fraud risk (Hammond & Wang, 2005).

It may be possible to contaminate virgin vegetable oil to make it appear as soapstock and derivatives, to mix virgin vegetable oil with soapstock and derivatives, or to deliberately alter the vegetable oil refining process to produce more soapstock. However, soapstock and derivatives have significantly lower economic value than virgin vegetable oils; as discussed in Task 2, the value of soapstock and derivatives is roughly one-fifth that of crude vegetable oil. It would take large incentives related to inclusion in Annex IX to overcome this price differential, although it is unknown what the cost savings would be from increasing soapstock production by reducing the refining efficiency of vegetable oil. It is thus unlikely but not impossible that there could be an incentive for producing fraudulent soapstock and derivatives.

Overall, there is a **medium** risk of fraud for soapstock and derivatives based on physical characteristics.

Feedstock definition characteristics:

Soapstock and derivatives are not uniformly defined. Within the literature, soapstock and derivatives are sometimes referred to as a residue and sometimes as a by-product or co-product. In the RTFO, "soapstock acid oil" is categorized under "wastes and processing residues" (RTFO Guidance, 2018). This is an example of using a different term for these materials ("soapstock acid oil") compared to others in the literature ("soapstock" and "acid oil").

Overall, there is a **medium** risk of fraud for soapstock based on feedstock definition characteristics.

9.3.8.4.3. Secondary Risk Indicators (Amplifiers)

Supply chain characteristics:

Soapstock and its derivatives are produced globally, anywhere vegetable oil is refined, including in many countries with weak rule of law. Because soapstock and its derivatives are used in multiple different industries (e.g. soapmaking, animal feed, oleochemical production), the number of intermediaries in current supply chains could be variable and it is possible to have a large number of intermediaries.

Soapstock and derivatives are traded internationally, but in small volumes compared to their total production. Under the harmonized commodity description and coding system, the international classification system for products traded globally, soapstocks are included under two different codes: the first including "Soapstocks containing oil with characteristics of olive oil" the second including "Oil foots and dregs; soapstocks (excl. those containing oil with characteristics of olive oil)". For completeness the values under both codes were combined to determine the volume of soapstock traded and number of parties involved. In 2019, 10 countries outside the EU imported or exported soapstock with an EU member state. The total gross volume traded was over 6.6 thousand tonnes with a value of about 860 million Euro. Within the EU during 2019, 26 member states imported or exported soapstock for a total value of 13.7 million Euro for over 117 thousand tonnes of soapstock. These amounts are modest compared to the 13 million tonnes of soapstock we estimated could be produced globally in 2030 in Task 2. This suggests that soapstock is most often not traded.

Overall, there is a **medium** risk of fraud for soapstock and derivatives based on supply chain characteristics.

Assurance:

Soapstock and its derivatives are segregated during the neutralization stage of the vegetable oil refining process and thereafter are segregated in the supply chain (i.e. soapstock and acid oil are not mixed with refined vegetable oil or other types of materials, but soapstock and acid oil from different vegetable oil origins could be mixed together). Soapstock and derivatives are produced globally and there is no standardized way to tell what feedstock they are produced from, so any particular batch of soapstock and derivatives could not be easily tied to a particular origin. It is possible that soapstock and derivatives could be aggregated from many different producers before being shipped to a biofuel facility. This could make tracking and verification more difficult, but verification could occur similar to the current practices for verifying UCO.

Soapstock and acid oil can be converted to biodiesel using esterification and transesterification, which are mature technologies, but biofuel yields are not standardized. Additional catalytic reactions or pre-treatment steps may be necessary as a result of the high fatty acid content and of heterogeneity of fatty acid composition across feedstocks, and this could potentially contribute to variability in biofuel yields (Vyas et al., 2010). Soapstock and acid oil can also be converted to biogas using anaerobic digestion. Anaerobic digestion and subsequent biogas upgrading are mature technologies. The conversion yields are not standardized.

Soapstock and derivatives are not currently commonly used in biofuel production, have heterogeneous properties, and can appear to be similar to other substances. Thus, assurance providers are not likely to have specific knowledge of this feedstock.

Overall, there is a **high risk** of fraud for soapstock based on assurance characteristics

9.3.9. Agriculture waste

9.3.9.1. Animal manure

9.3.9.1.1. Definition

Animal manure is defined as "excrement and/or urine of farmed animals other than farmed fish, with or without litter" (Regulation (EC) No 1069/2009). Animal manure has many documented negative environmental and public health impacts: specifically, pollution of the air and water and release of greenhouse gas (methane) emissions (Scarbrough, 2014). As a result, manure management—which includes collection, closed storage (which avoid methane leakage), spreading, and transport— is present in most countries and heavily regulated in the world's largest livestock and poultry producing countries.

9.3.9.1.2. Primary Risk Indicators

Feedstock physical characteristics:

Generally, animal manure does not share similar physico-chemical properties or characteristics with other feedstocks and therefore has low associated fraud risk up to the point where biogas/biomethane would become undistinguishable from biogas/biomethane from other feedstocks. It may be common for some amount of animal bedding (e.g. straw) to be mixed into manure; however, these materials are also eligible in Annex IX, part A and thus there would be no incentive for deliberately adding straw and other bedding materials to manure. Generally, other materials would not likely be mistaken for manure, but it could be possible to mix in other materials with manure while retaining the appearance of manure, for example mixing animal slaughter waste in with manure at a slaughterhouse.

Overall, there is a **low risk** of fraud for manure based on physical characteristics.

Feedstock definition characteristics:

Animal manure is generally uniformly defined and classified as a waste across all jurisdictions and therefore does not have high definitional risk. There are a number of terms for manure (e.g. dung, droppings, "cow chips,") but these terms are not typically mistaken for materials other than manure.

Animal manure is a heterogenous feedstock with differences in methane conversion factors for each type of animal, type of feed consumed by the animal, and the presence of other materials, i.e. bedding or litter, that can get mixed into manure. This litter can consist of cellulosic materials such as straw or woodchips which leads to variation in the cellulose to non-cellulose ration of the feedstock (U.S. EPA, 2018). Additionally, the cellulosic composition of animal feed and the respective animals' digestibility of its feed impacts the cellulosic composition of the feedstock. Therefore, the cellulose to non-cellulose ratio for animal manure is not standardized and highly variable. In particular, it could be possible to deliberately add straw, woodchips, or other bedding material into animal manure to increase its volume and biofuel yield. However, these organic bedding materials are generally also included in Annex IX, part A, and so there may be little incentive for, or consequence of, this kind of intentional contamination.

Overall, there is a **medium** risk of fraud for manure based on feedstock definition characteristics.

9.3.9.1.3. Secondary Risk Indicators (Amplifiers)

Supply chain characteristics:

Animal manure is present throughout the world, including in many countries with weak rule of law, with large variation in the level of production and degree of regulation pertaining to its management. This would increase the risk of fraud. However, animal manure neither appears to be traded globally in large volumes nor does it appear to be traded between a large number of intermediaries. The current regulations and traceability standards for animal manure import to the EU would reduce the associated risk.

The EU has passed regulations on the management of manure within the EU and the import of manure from outside the EU. Specifically, Regulations (EC) No 1069/2009 (European Commission, 2009) and No 142/2011 (European Commission, 2011a) establish requirements for traceability and handling of animal by-products and their derivatives, including manure. Unprocessed manure is prohibited from being imported or transported through the EU while processed manure is allowed when abiding by regulations. Entities outside the EU are also held to these standards and must be approved prior to being allowed to export animal by-products or derived products to the EU. Finally, the European Commission created the Trade Control and Expert System (TRACES) to document and regulate the import and export of animal by-products, including manure, as well as transport of manure within the EU. This existing traceability infrastructure indirectly reduces fraud risk in the context of Annex IX.

Overall, there is a **low risk** of fraud for manure based on supply chain characteristics.

Assurance:

The EU's regulation pertaining to manure management and TRACES system indirectly documents and transparently tracks the chain of custody of animal manure. This inherently reduces fraud risk with respect to Annex IX.

Animal manure is a heterogenous feedstock and is typically converted to biogas through anaerobic digestion, a mature technology. Methane conversion factors (MCFs), which describe the conversion efficiency of manure into methane in terms of energy content, vary depending on the manure management methods deployed, type of animal, and type of feed (Dong et al., 2006). Different feeds have different energy contents and animals have varying digestibility with regards to different feeds.

The type of manure, liquid or solid, as well as ambient temperature also impact methane formation and subsequent conversion yield (Dong et al., 2006).

Manure management also influences the conversion yield of animal manure into biogas via anaerobic digestion. Methane collection rates, i.e. how quickly manure is collected and contained after its produced, can impact conversion yields significantly (U.S. EPA, 2018).

In addition to the heterogeneity of animal manure, the co-digestion of different feedstocks—such as agricultural residues, sewage sludge, food waste, and municipal solid wastes—mixed with animal manure has been found to improve biogas production from anaerobic digestion (Scarlat et al., 2018). As a result, the feedstock—animal manure – could be mixed with other materials, some of which are also feedstocks under Annex IX, prior to biogas production.

Although assurance providers are familiar with anaerobic digestion, due to the heterogeneity of the feedstock and methane yields, assurance providers may lack the knowledge and experience to deal with the variability of this feedstock and its derivatives.

Overall, there is a **medium-low risk** of fraud for manure based on assurance characteristics.

9.3.10. Food/feed production waste

9.3.10.1. Brewers' Spent Grain and Whey Permeate

9.3.10.1.1. Definition

<u>Brewers' spent grain</u>

Brewers' spent grain (BSG) is generated by the brewing industry alongside beer as a wet side product (Mussatto, 2014). This material consists of barley grain husks including parts of the pericarp and seed coat layers of these grains. In some cases, according to the kind of beer that is produced, other cereals such as maize, rice, wheat, oats, rye or sorghum can be used in mixture with the barley malt for the wort elaboration. In such cases, the insoluble part of these grains after the mashing process is separated with BSG. Therefore, BSG can be derived from barley malt only or from a mixture of barley malt with other cereal grains.

<u>Whey permeate</u>

Liquid whey permeate is generated alongside whey protein and other solids through the ultrafiltration of whey, followed by a diafiltration process. It is composed mainly of lactose, salts, nonprotein nitrogen, and water (Parashar et al., 2016). Larger dairy farms may choose to apply reverse osmosis technology to process the raw whey permeate into whey permeate concentrate (European Commission, 2019). Alternatively, liquid whey permeate can be subjected to evaporation followed by spray drying and crystallisation, resulting in dried or powdered whey permeate (European Commission, 2019).

9.3.10.1.2. Primary Risk Indicators

Feedstock physical characteristics:

There is a potential risk of grains damaged at the brewery being mixed with BSG although there is no reference to substantiate this. Furthermore, the financial incentive risk for grains to be intentionally degraded to resemble BSG is considered moderate, based on the assumption that revenues from beverage products remain higher than for biofuel/biogas feedstocks. Therefore, the risk of intentionally mixing, degrading or contaminating grains to make these resemble BSG is considered **medium**.

Similarly, liquid whey permeate and liquid whey composition is quite similar[14] and there could be the potential risk of the latter being mixed to increase volumes of the former, although there is no external reference to substantiate this. Dehydrated samples can be sent for chemical analysis, however, whey permeate and whey powder both contain high percentages of lactose, and so they might be difficult to distinguish when mixed (Milk ingredients, 2017; Think USA Dairy, 2018). Whey permeate powder can be identified via chemical analysis and there is limited chance of it being mixed with whey powder to increase volumes given the existing market for whey powder as a health supplement. Furthermore, the conversion of liquid whey permeate to powder is energy and cost intensive and the whey permeate powder generated is sold as food/feed. Therefore, there is little evidence of liquid whey permeate being converted to whey permeate powder and then being sent to a processing unit for biogas/biofuel production.

Overall, there is a **moderate risk** of other material being mistaken for BSG and whey permeate.

Feedstock definition characteristics:

<u>BSG</u>

BSG is uniformly defined across all regions given its origins in the brewery industry. Whenever these are considered unsuitable as food/feed, they would be covered under EU RED II or UK RTFO as food waste, but if a potential use as food/feed remains technically possible (even if economically unattractive), such definition would not apply. BSG or draff is single counted under the UK's RTFO (DfT, 2021). However, neither the characteristics making BSG suitable for energy production rather than food/feed use nor their classification as residue or waste are clearly defined in EU or UK regulations. Wet BSG may be considered to be a residue as it has an economic value and is used as animal feed, however, this is dependent on the availability and demand of nearby farmers. In most cases a significant portion of feedstock, which would in theory be suitable for feed or

[14] Whey is a dilute nutrient stream and is composed of approximately 94% water (6% total solids), 4.5% lactose, 0.8% protein, and 0.7% minerals (Kilara and Vaghela, 2004). Whey permeate is composed mainly of lactose, salts, nonprotein nitrogen, and water (Parashar et al., 2016). Raw milk tampering with rennet/cheese whey from curd cheese making is a food fraud of concern to dairy processors and food inspection services of developing countries (De Pádua Alves et al., 2017).

energy generation, is discarded ending partly in landfills. While the cellulose to non-cellulose ratio of BSG is well defined, conversion/yield factors for processing BSG into biogas/biofuels is not documented.

Whey permeate

Whey permeate (liquid/ powder) is uniformly defined across all regions given its origins in the dairy industry. Whenever these are considered unsuitable as food/feed, they would be covered under EU RED II or UK RTFO as food waste, but if a potential use as food/feed remains technically possible (even if economically unattractive), such definition would not apply. Neither the characteristics making whey permeate suitable for energy production rather than food/feed use nor their classification as residue or waste are clearly defined in EU or UK regulations.

Feedstock definition characteristics for BSG and whey permeate are overall in the **medium risk** category.

9.3.10.1.3. Secondary Risk Indicators (Amplifiers)

Supply chain characteristics:

BSG Brewers Spent Grain

No documented evidence was found that BSG is traded between a large number of intermediaries, globally or in large volumes. Wet BSG has a shelf life of a few days after which microbial growth causes spoilage (Annex IX T2 assessment). Although drying is energy intensive, it can be done for preservation (Chetrariu and Dabija, 2020). This also decreases transport and storage costs due to increased energy density. Currently, BSG is mainly used by local farmers as feed or for biogas production. China, Brazil and Russia are among the leading producers of BSG and these geographies are considered to have a significantly low Rule of Law Indicator score compared to the EU (China: 88 out of 128 – High risk; Brazil: 67 out of 128 – Medium risk; Russia: 94 out of 128 – High risk) (WJP Rule of Law Index, 2021). However, no current or future import of BSG from non-EU countries is being reported/documented. BSG used in the EU for energy production are therefore expected to be produced in the European Union, where the rule of law can be considered robust.

Supply chain characteristics for BSG are mainly in the **low risk** category. The only exception is the **medium risk** posed by the feedstock being generated globally including in regions that have a lower Rule of Law indicator score compared to the EU.

Whey permeate

No documented evidence was found that liquid whey permeate is traded between a large number of intermediaries, globally or in large volumes. However, whey permeate powder is a globally traded product and is therefore subject to higher supply chain risks. Currently, liquid whey permeate is used in animal feed production, and some dairy processing plants have started using this as feedstock for biogas and ethanol production. Whey permeate powder is used in food/feed production. No current or future import of liquid whey permeate from non-EU countries is being reported/documented. Liquid whey permeate used in the EU for energy production is therefore expected to be produced in the European Union, where the rule of law can be considered robust. While whey permeate powder can be imported, as mentioned above, there is little evidence of liquid whey permeate being converted to whey permeate powder and then being sent to a processing unit for biogas/biofuel production. The liquid to powder conversion process is energy and cost intensive, and the whey permeate powder is used for food/feed purpose. Furthermore, whey permeate powder is generated mainly in the US and the EU where the rule of law can be considered robust (USA: 21 out of 128 – Low risk) (WJP Rule of Law Index, 2021).

Supply chain characteristics for liquid whey permeate are in the **low risk** category. On the other hand, whey permeate powder is globally traded and is subject to higher supply chain risks. Nevertheless, there is little evidence of the powder going into digesters or fermenters at this time, so the risk seems minimal (and the material can be tested for).

Assurance:

BSG

BSG is generated in breweries/distilleries and is most likely used locally given that it is a wet feedstock that is difficult to transport over large distances without spoilage, which means it could be traced back to its origin.

The technologies for conversion of BSG are mainly anaerobic digestion (biogas) and fermentation (ethanol). Recently, hydrolysates of organosolv pretreated BSG were used for lipid production by oleaginous yeast, and these lipids were subjected to the transesterification process to produce biodiesel (Patel et al., 2018). These technologies, other than the pretreatment steps for biodiesel production, are well understood. Typical yields for BSG are however not documented.

Given that BSG or draff is single counted under the UK's RTFO, we assume that assurance providers may be used to assessing BSG specifically.

Assurance for BSG are mainly in the **low risk** category. The only exception is the **medium risk** of no widely accepted default values for the conversion yields of BSG to biogas/bioethanol.

Whey permeate

Liquid whey permeate is generated in dairy processing plants and is used locally as a fertiliser and can also be used locally for biogas/bioethanol production as recently demonstrated by some dairy companies (Fermented Nutrition, 2020; Carbery Group, 2020; The Chemical Engineer, 2016; McWalter, 2019), which means it could be traced back to its origin.

The technologies for conversion of liquid whey permeate are mainly anaerobic digestion (biogas) and fermentation (ethanol), which are well understood. Typical conversion/yield factors for converting liquid whey permeate into biogas or ethanol are however not documented.

Assurance providers may not be used to assessing liquid whey permeate specifically, and very few, if at all, are likely to have any experience working with the dairy processing industry. We assume that it could be difficult for assurance providers to assess the potential of liquid whey permeate for food/feed uses and determine whether they should be considered as residues or waste. Therefore, specific training might be required, based on clear guidance from regulators.

As mentioned above, there is little evidence of liquid whey permeate being converted to whey permeate powder and then being sent to a processing unit for biogas/biofuel production. Nevertheless, it would be useful to provide assurance providers guidance on assessing/identifying whey permeate powder in case it were to be contaminated with other powders having similar physical characteristics.

Assurance for whey permeate are mainly in the **low risk** category. The only exceptions are the **medium risk** of assurance providers lacking specific knowledge/ experience of assessing whey permeate, and no widely accepted default values for the conversion yields of whey permeate to biogas/ bioethanol.

9.3.11. Waste – others

9.3.11.1. Vinasse

9.3.11.1.1. Definition

Vinasse is the dilute material remaining after the process of ethanol production from sugarbeet or sugarcane juice, or from molasses (El Takriti et al., 2017).

9.3.11.1.2. Primary Risk Indicators

Feedstock physical characteristics:

Vinasse is a chemically distinct material, not similar to any feedstock commonly used for EU biofuels at the moment. The main constituents of dry matter in vinasse include protein, fibre, glycerol, monosaccharides and sugar alcohols (Cárdenas-Fernández et al., 2017; Rodrigues Reis & Hu, 2017). This fraud risk is considered medium.

It would be possible in principle to add soluble primary materials to vinasse with a view to increasing biogas yields, for example it might be possible to contaminate vinasse with sugarcane/sugarbeet juice. Such contamination with primary resources would be readily detectable through chemical analysis unless the compounds added were naturally present in vinasse, for example glycerine, galactose or D-fructose. Adding a large quantity of any one constituent compound would create an imbalance in composition that would be detectable in principle. It would therefore be expected to be relatively difficult to contaminate vinasse with additional digestible material in a way that was difficult to detect chemically. In the absence of systematic chemical testing, however, it may be difficult to guarantee that material had not been contaminated with primary resources to increase biofuel/biogas yields. Given the potentially high water-content of vinasse there would be potential to distort mass balance tracking (for example by replacing part of the water content of a batch with additional primary resources) than for low water-content resources. Inclusion of vinasse in Annex IX would create a clear value incentive to contaminate vinasse with primary materials such as sugars or starches, and therefore **this fraud risk is considered medium**.

Feedstock definition characteristics:

Vinasse is clearly defined in the sugarcane and sugarbeet industries. Similar dilute residuals from other industries may also sometimes be referred to as vinasse, for instance the wine industry. It may be possible therefore that batches of dilute residuals from outside the sugar industry could enter the supply chain labelled as vinasse. This could be mitigated by clear tracking of feedstock-source data through the chain of custody. **This fraud risk is considered medium.**

Vinasse is understood as a low value material and unlikely to be considered as a co-product, but characterisation as a waste or residue is likely to vary between contexts. In regions where vinasse disposal through fertirrigation is common or where it is still disposed of without utilisation it is more likely to be considered a waste, in regions such as the EU where there is a more established market as animal feed it is likely to be understood as a residue. **This fraud risk is considered medium.**

9.3.11.1.3. Secondary Risk Indicators (Amplifiers)

Supply chain characteristics:

Given the high water-content in vinasse, it is not normally economically efficient to move it long distances for treatment (Fuess et al., 2017), and therefore it is unlikely that vinasse would be handled by multiple intermediaries between production and processing for biogas. To the best of our understanding cross border trade in vinasse is very limited, and therefore it is considered unlikely that vinasse would cross multiple borders before processing to biogas. **This risk is considered low.**

Similar to molasses, vinasse is produced everywhere sugarcane or sugarbeet is processed. This includes countries that have relatively poor governance. **This fraud risk is considered low to high depending on source of material.**

Assurance:

Vinasse is likely to be kept segregated from other materials in the supply chain and as the supply chain is likely to be relatively short, the origin should be well documented and verifiable. **This fraud risk is considered low.**

Production of biogas from vinasse is relatively novel and there are no default LCA values available for vinasse-based biogas production, but the anaerobic digestion process more generally is well understood and there are studies of biogas production from vinasse available in the literature. **This fraud risk is considered medium.** Assurance providers are likely to have considerable experience in the sugar supply chain, but are unlikely to have directly considered vinasse as a certifiable resource in the past. **This fraud risk is considered medium.**

9.3.11.2. Thin stillage

9.3.11.2.1. Definition

Thin stillage contains the soluble constituents of the fermentate ('solubles') from ethanol production with cereal feedstocks. The m ain constituents of dry matter in thin stillage include glycerol, lactic acid, proteins, crude fats, and carbohydrates (Kim et al., 2008; Ratanapariyanuch, 2016) and it has a low pH (Wilkins et al., 2006). The precise constituents of this stillage can be expected to vary according to process details and feedstock (Ratanapariyanuch, 2016).

9.3.11.2.2. Primary Risk Indicators

Feedstock physical characteristics:

Thin stillages from different grains may be somewhat similar to each other, but are quite distinct from other feedstocks considered (Mustafa et al., 2000). T**his fraud risk is considered low.**

In principle it may be possible to contaminate thin stillage with soluble materials from primary feedstocks, for instance sugars. This may be difficult to identify through mass balance monitoring alone. This could potentially be detected through chemical analysis unless the contamination was done with compounds naturally present in thin stillage. It is normal in some regions (e.g., Germany) to produce biogas from primary materials such as maize. In such cases, there would be an incentive to fraudulently identify some fraction of the maize input to the process as an Annex IX feedstock in order to gain access to double counting for a higher fraction of produced gas, which could potentially be done via thin stillage contamination. **This fraud risk is considered medium.**

Feedstock definition characteristics:

Thin stillage is clearly defined in the grain ethanol industry. In some cases, the term thin stillage may be used to refer to residual dilute material from non-cereal ethanol production systems, for instance used as an alternative term to vinasse in the sugar ethanol industry. **This fraud risk is considered medium.**

In task 2 thin stillage was identified as a residue in the context of EU RED II. There may be some ambiguity for corn ethanol producers as the condensed distillers solubles produced from thin stillage are treated as part of the DGS co-product within the GHG calculations for EU RED II, and thereby have emissions allocated to them (BioGrace, 2017). **This fraud risk is considered medium.**

9.3.11.2.3. Secondary Risk Indicators (Amplifiers)

Supply chain characteristics:

Given the high water-content of thin stillage it is unlikely that the material would be transported long distances for further processing in dilute form. It is normal in the ethanol industry to reduce thin stillage by evaporation leaving distillers' solubles, in which form it may be viable to transport the material over longer distances, potentially via aggregators and intermediaries, but at present we are not aware of any established trading systems for distillers' solubles. **This fraud risk is considered low**.

Production of grain ethanol happens primarily in the U.S. (50 billion litres in 2020, WJP rank 21), the EU (4 billion litres in 2020, WJP rankings from 1 to 60), China (3 billion litres in 2020, WJP ranking 88), and Brazil (2.5 billion litres in 2020, WJP ranking 67). **This fraud risk ranges from low to high depending on the source country.**

Assurance:

Thin stillage is likely to be segregated from any other materials up to the point of biofuel production – **this risk is considered low.**

The technology for biogas production from thin stillage is well understood but there are no default LCA values available for this pathway in EU RED II, and we are not aware of data enabling the identification of 'typical' yields for the process. **This fraud risk is considered medium.**

Thin stillage is produced by the ethanol industry, and therefore the suppliers are likely to be used to working with assurance providers to achieve certification. Assurance providers are likely to be used to working with ethanol producers but may not have explicitly considered thin stillage in the past. The risk for thin stillage associated with assurance characteristics is considered **medium-low**.

9.3.11.3. Brown grease

9.3.11.3.1. Definition

Brown grease is a mix of fats, oils, greases (FOGs), water, and various debris collected by food industry (restaurants, cafeterias, processing centres) as a result of traps that prevent these contaminants from clogging sewage piping. It is generally removed by specialized grease collectors and disposed of in landfills or wastewater treatment plants with limited aggregation and trading. While the compounds necessary to produce FAME or HVO are present, the highly contaminated and low-quality nature of BG leads to much higher than normal processing costs due to extensive pretreatment required in the form of dewatering (sometimes up to 85% water content) and filtration/separation.

9.3.11.3.2. Primary Risk Indicators

Feedstock physical characteristics:

BG is by definition a highly contaminated waste consisting of various types of FOGs, and as such has a distinctly different physical and chemical profile which makes it easy to distinguish from other feedstocks. Water and debris (both biogenic and non-biogenic) content is much higher than other similar materials. Mixing other fats/oils such as UCO or animal fat into BG for the purpose of fraudulently receiving benefits from inclusion in Annex IX or intentional mislabelling would most likely decrease the overall value more than waste incentives could justify, and the difference in physical/chemical profile would likely cause the fraud to be noticed. However, if significant pretreatment has already occurred, BG would be physically and chemically more similar to related materials and risk of dilution or mislabeling could increase. Overall a **low-medium risk** applies to this category.

Feedstock definition characteristics:

There appears to be some potential for misalignment in definition for BG. A google search finds that while a majority define BG as the FOGs collected in grease traps, one trader's website defines BG separately from trap grease as "comprised of used cooking oil and often contains rendered low quality animal fats such as tallow, poultry or lard with higher Free Fatty Acids than a yellow grease which has a maximum of 15% Free Fatty Acid." (Universal Green Commodities, 2021). This stands in contrast to the UK government definition of "the grease that is removed from wastewater sent down a restaurant's sink drain." (UK Department for Transport, 2020). Characterization as a waste should not be in question in any jurisdiction. Feedstock definition therefore carries a **low-medium risk**.

9.3.11.3.3. Secondary Risk Indicators (Amplifiers):

Supply chain characteristics:

Brown Grease is generated throughout most of the developed world with wide variation in level of organization and aggregation. Grease traps are not nearly as common outside of the developed world as they are not often required by local regulation, so a negligible amount is expected to be available from countries with weak rule of law in the next several years (Wallace et al., 2016). Fewer, more specialized trading market participants equals lower risk; if the brown grease only passes through a small number of entities, then risk is reduced in terms of records being closer to the source of collection and less potential to accidentally or intentionally falsify transfer documents. Smaller volumes may allow for more physical segregation accounting to be used to measure inflows and outflows, decreasing risk. In the case that mass balance accounting is used, a higher fraud risk would apply since mass balance is inherently riskier due to the comingling of certified, non-certified, and non-incentivized materials in the same container or process (e.g. if brown grease is mixed with another FOG on the way to a processor, or is mixed at the plant on the way into the processing unit). **No risk score is attributed for secondary risk indicators, since primary indicators are low risk.**

Assurance characteristics:

Brown grease is likely to remain segregated in supply chains due to the high water and impurity content that would significantly degrade UCO or other oils. Brown grease generally requires significant and costly dewatering and filtration pretreatment before entering into traditional FAME or HVO processes, though at least one modular technology is now available in the US that claims efficient separation of high purity brown grease within a self-contained system (Greasezilla, n.d.). This reduces risk of falsifying transfer documents by greatly limiting the number of market participants, vs more widespread technologies such as soy oil extraction/refinement (more participants = greater risk). After pretreatment, brown grease will be used in standard FAME, HVO, or possibly biogas processes, in which conversion yields should be fairly predictable. Assurance providers may not have extensive experience with brown grease, though they are likely to be very familiar with UCO which has a similar industry structure (points of origin, collecting points, traders, processors, etc). **No risk score is attributed for secondary risk indicators, since primary indicators are low risk.**

9.3.11.4. Used Cooking Oil

9.3.11.4.1. Definition

Used cooking oil (UCO) is the material left after cooking food for human consumption in virgin cooking oil, and typically comes from restaurants, institutional cafeterias, industrial food processing facilities, and to a very small extent, households. It may be entirely of vegetable origin, mixed vegetable and animal origin, or entirely of animal origin. It is generally classified according to whether it is entirely of vegetable origin, or has any animal content at all.

9.3.11.4.2. Primary Risk Indicators:

Feedstock physical characteristics:

UCO is comprised primarily of triglyceride molecules with varying levels of contamination resulting from the type of food cooked in it and how long it was used for cooking before being processed. The cooking process of repeated reheating causes the fatty acid profile to be different from unincentivized virgin oils such as soy or rapeseed oil, but it is unlikely that regular chemical analysis will be done to ensure UCO integrity due to testing cost and the scale of material movements. At least one EU country only incentivizes UCO entirely of vegetable origin, though it is not easy to verify that a batch has no animal content.

As of April 2021, UCOME was trading at a 30% premium to Palm Methyl Ester in the EU, indicating a high incentive for fraud risk. Despite the chemically different fatty acid profiles, it is not possible to physically distinguish unadulterated UCO from that which has been diluted with virgin oil. Pure virgin oil is visually and olfactorily distinct from UCO, as the lack of contaminants and heat cycles causes it to appear clear and with a light aroma, versus UCO which may retain some cloudiness and "burnt" smell even after filtration and dewatering. Adding virgin oil to UCO would not completely eliminate this appearance/smell except at very high rates, so **the risk of altering unincentivized feedstocks such as virgin oil to appear as UCO through dilution or other mislabelling is high.**

Feedstock definition characteristics:

"Used cooking oil" serves as a concise, self-explanatory definition as well as title, and this is generally well-understood throughout value chains and regulatory/assurance bodies. However, the fact that certain countries prioritize UCO that is entirely of vegetable origin and deprioritize or disallow UCO partially or entirely of animal origin creates the potential for some confusion and/or fraud. Sometimes the term "yellow grease" is used interchangeably with UCO, though it has also been used to refer only to partially animal-based UCO (i.e. not entirely of vegetable origin). The mostly synonymous relationship between these terms causes resulting fraud risk to be generally low, though some confusion could still occur. It is uniformly considered to be a waste product, so little doubt is present in that sense. This category therefore carries a **low-medium risk.**

9.3.11.4.3. Secondary Risk Indicators (Amplifiers):

Supply chain characteristics:

The trading networks for UCO are vast and complex, as it has been a primary feedstock for biodiesel production since the early 2000s and is also used for HVO production. It often passes through many entities such as collectors, storage contractors, and multiple traders before reaching a processor, and it is not uncommon for a given batch to cross the ocean. ISCC reported that the countries with the highest volumes of UCO certified under the ISCC EU certification scheme in 2018 were China (523,511 tonnes), USA (216,912 tonnes), Indonesia (168,832 tonnes) and Saudi Arabia (74,429 tonnes). The majority of this UCO is assumed to have been exported to the EU (including the UK).

Any region with restaurants and institutions that deep fry food is likely to have UCO collection and trading, which includes both stable non-corrupt countries and unstable corrupt countries with weak rule of law. It is entirely possible that a biodiesel or HVO plant is using UCO that was collected within 50 km by that same entity, and also possible that the UCO came from 5,000 km away and was touched by several entities before conversion. Recent media attention has focused on the large amounts of UCO imported from southeast and east Asia into the EU, and concern that fraudulent activity is occurring based on the very high UCO export level vs population size and likelihood of diluting crude palm oil into UCO. The countries of primary concern and their rank on the WJP Rule of Law Index (1 to 128, 1 being least corrupt and highest adherence to rule of law) are as follows: China (88), Indonesia (59), Malaysia (47). A **medium-high risk** is therefore applied to UCO supply chain characteristics.

Assurance:

UCO is not typically mixed directly with other triglyceride feedstocks in vessels for shipment, though this can change in the case of intentional fraud through dilution with unincentivized oils. In some cases, it may be physically adjacent to other non-incentivized feedstocks (e.g. if 1,000 litre intermediate bulk containers are used to ship both UCO and virgin soybean oil on the same truck). The conversion technologies are mature and well-understood, and assurance providers are very familiar with this feedstock as it is regularly traded and used by the companies they certify. Additionally, the European Union recently implemented stricter traceability rules. This category therefore carries overall **medium risk.**

9.3.12. Wastewater

9.3.12.1. Sewage sludge

9.3.12.1.1. Definition

Sewage sludge refers to the residual, semi-solid material that is produced as a by-product during sewage treatment of industrial or municipal wastewater (also termed biosolids). Sewage sludge mostly goes through primary (physical) and secondary (biological) treatment processes, and sometimes through stringent tertiary treatment (nutrients removal and suspended solids) before it is discharged to the environment or used for different purposes such as in agriculture. Around 70% of the European urban wastewater receives tertiary treatment with the percentage varying in different regions.

The most common processes used to treat sludge in Europe are anaerobic digestion, lime stabilisation and incineration.

9.3.12.1.2. Primary Risk Indicators

Feedstock physical characteristics:

Sewage sludge is by definition a highly contaminated waste, and as such has a distinctly different physical and chemical profile compared to other biofuel or biogas feedstocks. Sewage sludge tends to concentrate heavy metals such as zinc or cadmium, poorly biodegradable trace organic compounds as well as pathogens (viruses, bacteria, etc.) present in waste waters.

Although sewage sludges can exhibit wide variations in their properties depending on their origin and treatment, they are nonetheless distinct from other feedstocks. Sewage sludge can be easily identified through a visual and/or olfactory observation. **The risks of intentional mislabelling or altering another feedstock to look like sewage sludge is therefore considered to be low**.

Sewage sludge is a material that arises from the treatment of wastewater. It is not feasible to deliberately generate more sewage sludge as the volume produced is entirely dependent on the volume of wastewater (from households) processed. There is also **no economic incentive** to deliberately generate more sewage sludge as this would directly result in higher wastewater processing treatment costs. Furthermore, modifying the wastewater treatment process to produce more material is not readily feasible. Additionally, many wastewater treatment works are operated by public authorities. The material cannot be readily produced by degradation or contamination of primary material, and mixing with other feedstocks would likely immediately decrease the value more than waste incentives could justify. **This indicates a low risk.**

Risk indicators in relation to land properties (e.g. degraded or abandoned land) are not applicable for sewage sludge.

Feedstock definition characteristics:

Despite the variations that may exist in sewage sludge, its misrepresentation is considered a low risk given its distinct physical characteristics and the fact that it not widely traded. Sewage sludge is assumed to be uniformly treated as a waste material in the EU/globally. The cellulose to non-cellulose ratio is not relevant for sewage sludge.

The risk of feedstock definition fraud is considered to be **low**.

9.3.12.1.3. Secondary Risk Indicators (Amplifiers)

Supply chain characteristics:

Sewage sludge is produced globally; production is concentrated in or near to large population centres. Supply chains involve a limited number of market participants (points of origin and intermediaries). Furthermore, the wastewater treatment market is highly regulated within Europe. Sewage sludge is not a globally traded commodity; some trade within Europe exists although this is understood to be limited (typically across short distances) and restricted to pre-treated sludge. In general, European countries have a relatively high rule of indicator score (World Justice Project, 2021). **No risk score is attributed for secondary risk indicators, since primary indicators are low risk.**

Assurance:

Sewage sludge is widely used to produce biogas at (or near to) the wastewater treatment plant at commercial scale. Anaerobic digestion of this feedstock to produce biogas is well understood, so there is a low risk posed by the inability to audit processing volumes. Sewage sludge may be used as a feedstock in advanced thermal conversion pathways such as gasification, pyrolysis and hydrothermal liquefaction, but these applications are currently niche. **No risk score is attributed for secondary risk indicators, since primary indicators are low risk.**

9.3.12.2. Municipal wastewater and derivatives (other than sludge)

9.3.12.2.1. Definition

Derivatives extracted from municipal wastewater (other than sludge), include fats, oils and greases (FOGs). FOG discharge to the sewers can arise from multiple sources, but primarily from commercial sources such as food service establishments. FOG then continue through the sewer system until it reaches the wastewater treatment plant (sewage treatment works). Waste FOG can accumulate in the sewer system and congeal with other non-flushable waste, such as wet wipes. In extreme cases, this can lead to blockages in the sewer system, often referred to as 'fatbergs'.

The composition of FOGs within the sewer system is variable. A study by Williams et al. (2012) found that the physical characteristics and melting point of FOGs collected different distances into the sewer system and from sewage treatment works and pumping stations were similar, but their moisture content was noticeably different. FOGs collected at sewage treatment works had higher moisture content. They also found significant differences in the proportions of oil in the FOG deposit, with pumping stations having a mean of about 18%, sewers 9% and sewage works 1.2% (Arthur and Blanc, 2013).

FOG blockages in the sewers have to be either dug out by hand or broken down into smaller pieces using high pressure jets of water jets. The broken up fatberg pieces either continue through the sewer system, or are otherwise removed (Lanes for Drains, no date). FOGs that continue through the sewer system are otherwise dealt with at the wastewater treatment plant using a variety of techniques (Wallace et al., 2017).

9.3.12.2.2. Primary Risk Indicators

Feedstock physical characteristics:

FOGs from sewers are by definition a highly contaminated waste, and as such has a distinctly different physical and chemical profile compared to other biofuel or biogas feedstocks. An analysis of the fatberg in London showed a significant share of long chain free fatty acids (53% palmitic, 18% oleic), along with significant concentrations of metal ions, such as calcium (Cranfield Water Science Institute, 2018). FOGs from sewers can be easily identified through a visual and/or olfactory observation. **The fraud risk is therefore considered to be low.**

There is **no economic incentive** for food service establishments or households, to deliberately increase the volume of FOG discharge to the sewers. Mixing with other FOGs, such as rapeseed oil or UCO, would likely immediately decrease the value more than waste incentives could justify. There may a risk if mixed with lower quality FOGs, such as brown grease. **Overall, the risk of intentional mislabelling of altering another feedstock to look like FOGs from sewers is considered to be low**.

Risk indicators in relation to land properties (e.g. degraded or abandoned land) are not applicable for FOGs from sewers.

Feedstock definition characteristics:

FOGs from sewers are assumed to be uniformly treated as a waste material in the EU/globally. The trade of FOGs from sewers within and to Europe is strictly controlled and subject to strict regulations in light of the sanitary risk of the material. Global trade does not exist. The cellulose to non-cellulose ratio is not relevant for FOGs.

The risk of feedstock definition fraud is considered to be **low**.

9.3.12.2.3. Secondary Risk Indicators (Amplifiers)

Supply chain characteristics:

Waste FOGs from sewers are produced globally; production is concentrated in or near to large population centres. FOGs extracted from sewers are traded in extremely limited volumes, between few parties, and over relatively short distances. The global trade of FOGs is not known to exist (typical end-use is landfilling). In general, European countries have a relatively high rule of indicator score (World Justice Project, 2021). FOGs extracted at a sewer works may be used for biogas production on-site, or otherwise landfilled. **No risk score is attributed for secondary risk indicators, since primary indicators are low risk.**

Assurance:

FOGs from sewers arises from a limited number of points of origin (i.e. specific sections of sewers or wastewater treatment plants).

To be usable for any biofuel conversion process with currently available technology, FOGs require significant and costly pre-treatment. This reduces risk by greatly limiting the number of market participants[15]. However, if a novel (i.e. IP-protected) technology were developed that could cost effectively transform FOG into fuel, some risk would be posed by the inability to accurately audit processing volumes due to lack of generally-known conversion and yield ratios for the novel system. FOGs are not widely used as a substrate for biogas production, and at high concentrations FOG can inhibit methane generation, without novel pre-treatment technologies. Thus, conversion and yield ratios are not yet well understood. **No risk score is attributed for secondary risk indicators, since primary indicators are low risk.**

9.3.13. Solid waste

9.3.13.1. Biogenic Fraction of Municipal Solid Waste and Biowaste

9.3.13.1.1. Definition

This evaluation is focused on the following categories of biogenic waste, namely:

- “Biomass fraction of mixed municipal waste, but not separated household waste subject to recycling targets under point (a) of Article 11(2) of Directive 2008/98/EC” (Point b in current Annex IXA)
- “Biowaste as defined in point (4) of Article 3 of Directive 2008/98/EC from private households subject to separate collection as defined in point (11) of Article 3 of that Directive” (Point c in current Annex IXA)
- “Biomass fraction of industrial waste not fit for use in the food or feed chain, including material from retail and wholesale and the agro-food and fish and aquaculture industry, and excluding feedstocks listed in Part B of this Annex” (Point d in current Annex IXA)

[15] At this time only one company, Argent Energy, is understood to be using FOGs from sewers as a feedstock to produced biofuel (FAME).

- Biowaste as defined in point (4) of Article 3 of Directive 2008/98/EC, which are neither from households nor from industries (e.g. restaurants) (Not currently included in Annex IX)

Based on a policy evaluation conducted in in Task 2 of this project, the above feedstock types concretely include the following categories:

- Yard and garden waste including grass clippings, branches, leaves etc…
- Residential food waste (from households only, curbside pickup or centralized dropoff).
- Industrial biowaste, including material from retail/wholesale businesses and the agro-food, fish, and aquaculture industries.
- Food waste from restaurants and institutional sources.

9.3.13.1.2. Primary Risk Indicators

Feedstock physical characteristics:

The feedstocks in this category vary widely and can potentially include any biological waste material. A large diversity of non-processed, processed, and post-consumer food, non-food vegetable, and animal refuse could fall into this category. There is inherent risk in having such a broad mix of potential materials covered under one category, though it is unclear whether it would be financially attractive to intentionally degrade or mislabel unincentivized feedstocks to pass as a material in this category. A **medium risk** level is therefore applied.

Feedstock definition characteristics:

The definition of "biowaste not fit for food or feed" applied to these subcategories should be clear and straightforward across all regions. However, as with UCO distinctions based on animal content or lack thereof, some countries may choose not to accept biowaste feedstocks with animal components, though it remains to be seen whether this will be the case. Additionally, the waste classification in the EU is extremely complex, with EU RED II referring to the Waste Framework Directive, which is itself linked to other policy papers. As a result, there is a large number of biogenic waste categories and it is quite difficult to know exactly what fits under each. This complexity can create confusion, especially as Member States may add their own national policies for recyclable and/or compostable material. There could be significant variation in ligno-cellulosic content between subcategories and between batches, which would be problematic if these feedstocks are intended to meet cellulosic targets. Given the uncertainty around these potential scenarios that could lead to higher fraud, this category has **medium risk.**

9.3.13.1.3. Secondary Risk Indicators (Amplifiers)

Supply chain characteristics:

These feedstocks are not traded extensively or transported very far due to their low value and high bulk. If they are used for bioenergy, it is generally within 30 to 300 km depending on the material (Matsakas et al, 2017). Wet food wastes are more costly to transport than dry yard wastes such as chipped branches, hence the difference in transportation distances. With the possible exception of dry woody wastes, feedstocks in this category have very low likelihood of crossing multiple non-EU borders.

There is however some risk associated with the amount of these feedstocks being produced in countries with weak rule of law. While they may not have advanced MSW collections schemes that allow biowaste to be collected separately from households, restaurants etc, there may be large agro/aqua-processing operations that generate substantial amounts of biogenic waste. For example, the largest aquaculture producers are China and Indonesia, with WJP rule of law scores of 88 and 59 out of 128, respectively. The countries with the highest food processing volumes (other than USA) along with their WJP scores are China (88), India (69), and Brazil (67). While feedstock material will not likely be exported from these operations to the EU, resulting biofuels very likely would be and it may be difficult to verify the authenticity of the entire supply chain in many cases. **Low-medium risk** should be associated with solid waste supply chain characteristics.

Assurance:

Segregation of the biogenic fraction of MSW and other biowaste from other non-biogenic feedstocks is efficiently implemented in a limited number of EU countries. It is assumed that in such case, segregation from other biomass feedstocks in supply chains should not be difficult due to its unique nature and lack of trading complexity. However, in countries with less established MSW and biowaste collection schemes, segregation from other biomass feedstocks would be more challenging.

Mature processing technologies such as biogas digesters will often be used, but in some cases use of novel technologies such as direct pyrolysis to diesel will make verification of process conversion/yield more difficult to verify. Many biofuel processes will only function with biogenic feedstocks (e.g. biogas digester), and it should be fairly straightforward to assure that processes that can utilize both biogenic and non-biogenic (e.g. pyrolysis to diesel that can use mixed trash or yard waste as feedstock) are accurately tracking incentivized input on a mass balance accounting basis. Assurance providers involved in biofuel certifications may not be familiar with the EU nomenclature on biowaste and the specificities of their supply chain and processing. A **medium risk** level is therefore appropriate.

9.4. SUBTASK 3.5 – REVIEW OF EXISTING FRAUD RISK MITIGATION MEASURES

9.4.1. Introduction

Task 3.5 aims to identify existing fraud risk mitigation measures, which fully or partially address the fraud risks identified for the existing Annex IX feedstocks and shortlisted candidates in Tasks 3.1 to 3.4.

Existing fraud risk mitigation measures were identified in EU RED II (European Union, 2018), as well as the assessment protocol used by the European Commission in the context of the EU approval of voluntary schemes, direct communications from the Commission to voluntary schemes and Regulation 2018/1999.

The following sections describe the measures applied to the different stakeholders involved (economic operators, voluntary schemes, assurance providers, Member States and the Commission). The measures were then evaluated against the risks identified in previous tasks to inform suggestions for improvement/expansion of existing measures and the development of new measures.

For voluntary schemes, a distinction is made between measures required in EU RED II or as part of the EU approval process (Assessment Protocol), and measures implemented by voluntary schemes to further enhance their assurance level.

9.4.2. Evaluation of existing measures to mitigate fraud risks

9.4.2.1. Description of existing measures

9.4.2.1.1. Existing measures at EU level

Since the enactment of the EU RED (2009/28/EC), the European Union primarily relied on independent voluntary schemes (certification) to establish compliance with sustainability and traceability requirements.

Following the documented and suspected cases of fraud over the physical characteristics of feedstocks (See Tasks 3.1 and 3.2), new anti-fraud measures were established through direct communications to the voluntary schemes (European Commission, 2014), amendments to EU RED via the "ILUC Directive" (European Commission, 2015) and in EU RED II. The aim of these measures is to make the chain-of-custody and assurance rules more stringent and efficient in reducing fraud risks, especially for globally traded waste and residues such as used cooking oil. Additional rules were communicated to the approved voluntary schemes over the life span of EU RED (e.g. European Commission, 2017). In addition, the assessment protocol (European Commission, 2020a) used by the European Commission to grant EU approval to voluntary schemes and subsequent exchanges with the Commission over the approval process provide voluntary schemes with detailed guidance over sustainability, chain-of-custody, assurance and governance rules.

- **General principles** can be found in EU RED II, which requires that:
  - Assurance providers "verify that the **systems used by economic operators are accurate, reliable and protected against fraud**, including verification ensuring that materials are not intentionally modified or discarded so that the consignment or part thereof could become a waste or residue. It shall evaluate the frequency and methodology of sampling and the robustness of the data."
  - "Information about the **geographic origin and feedstock type** of biofuels, bioliquids and biomass fuels per fuel supplier shall be made available to consumers on the websites of operators, suppliers or the relevant competent authorities and shall be updated on an annual basis".
  - A "Union Database" is put in place by the Commission to "enable the **tracing of liquid and gaseous transport fuels** that are eligible for being counted towards the numerator referred to in point (b) of Article 27(1) or that are taken into account for the purposes referred to in points (a), (b), and (c) of the first subparagraph of Article 29(1)." This measure is still in the process of implementation.
  - A **mass balance system** is required from economic operators via voluntary schemes for tracking **sustainability characteristics (e.g. GHG intensity) across the supply chain**. Information about the sustainability and greenhouse gas emissions saving characteristics and sizes of the consignments shall remain assigned to the mixture; the sum of all consignments withdrawn from the mixture shall be described as having the same sustainability characteristics, in the same quantities, as the sum of all consignments added to the mixture and requires that this balance be achieved over an appropriate period of time. *Note: economic operators*

may implement stricter chain-of-custody systems (e.g. segregation or identity preserved).

  - EU RED II does not explicitly require physical feedstock characteristics or geographic origins to be monitored through a mass balance system, although the **type of feedstocks would generally be included as part of standard product documentation** as part of ISO standards used for auditing such as ISO 17065 (ISO/IEC 17065:2012(E)) which includes the need for the certification body to maintain information on the certified products (ISO 17065, 7.8). Nevertheless, it is standard practice for voluntary schemes to require product documentation to understand the physical characteristics of products and their origin.

  - EU RED II (Art. 28) requires member states to cooperate in the transmission of information deemed helpful to monitor and detect cases of fraud.

- **Specific measures** are further detailed in the draft REDII Assessment Protocol for the approval of voluntary schemes published in 2020 (European Commission, 2020a). These include the following requirements for voluntary schemes to implement in their standard documentation:

  - A "**limited level of assurance**" must be guaranteed by assurance providers. It implies a reduction in risk to an acceptable level as the basis for a negative form of expression by the auditor such as "based on our assessment nothing has come to our attention to cause us to believe that there are errors in the evidence".

  - In the specific case of waste and residues, assurance providers must **verify the existence of the feedstock supplier and volume supplied** from at least the square root of the Points of Origin on a list provided by Collecting Points. Verification can be done remotely unless there is doubt concerning the existence of the point of origin. **Collecting Points must provide a list of all Points of Origin** that have signed a self-declaration and their indicative volume of waste or residue that they can supply. Mandatory surveillance audits must be conducted by the certification body six months after the first (initial) certification. For collecting points and traders that deal with both waste and residues and with virgin materials (e.g. vegetable oils) an additional surveillance audit must be conducted three months after the first certification audit (covering the first mass balance period).

  - Rules for group auditing include the necessity to **physically inspect** a sample of the group members. The exact size of the sample is determined by the size of the entire group through a set formula.

  - Detailed rules are defined regarding the **training, competences, audit process and monitoring of auditors and personnel from accredited assurance providers**, which rely, among other sources, on international ISO standards.

  - The EU requires competent authorities of Member States and voluntary schemes (through an internal monitoring system) to bypass accreditation bodies and **directly monitor the work of accredited assurance providers** (e.g. certification bodies and independent auditors) to increase the scrutiny and probability to detect non-compliances and frauds.

  - Voluntary schemes and assurance providers are required to implement a **grievance mechanism** so that third parties can raise concerns over compliance of economic operators in the process of or having achieved certification. Even if the process does not trigger any extraordinary compliance check, this allows for additional information to be collected by assurance providers in the perspective of upcoming audits. In addition, voluntary schemes are now required to provide an annual report to the European Commission, which includes, among other activities, a summary of all complaints received in the previous calendar year.

- Economic operators, assurance providers and voluntary schemes must **keep relevant documentation records for 5 years**. An annual reporting obligation exists on voluntary schemes, which facilitates the monitoring of traded certified material (feedstocks and fuels).

- **Stringent rules are in place regarding previous participation of economic operators in other voluntary schemes.** Voluntary schemes must check whether economic operators are currently engaged with another VS, cross-check against other VSs' certificates list and conduct some customer due diligence.

- Ensure that economic operators enter all relevant information in the **Union Database**, as soon as it is created.

The **EU-approval of voluntary schemes** is granted by the Commission following a stringent and detailed verification that the scheme's documentation fully complies with EU RED II and the Assessment Protocol rules. Any change in the legislation or accompanying guidance is immediately notified to EU-approved schemes, who are required to implement these as soon as practically possible.

9.4.2.1.2. Additional measures from voluntary schemes

This study included a consultation of four EU-approved voluntary schemes under the RED (ISCC, RSB, Bonsucro and REDCert) and two additional voluntary schemes that exclusively focus on forest biomass (Forest Stewardship Council (FSC), and Sustainable Biomass Partnership (SBP)). This aimed to understand: 1) whether additional measures are being voluntarily implemented by these schemes; and 2) whether these measures are efficient in mitigating fraud risks.

Risks related to feedstock physical characteristics

Depending on the type of feedstocks, risks in relation to their physical nature exist when the physical-chemical properties of an incentivized feedstock are difficult to distinguish from others, if other feedstock materials could easily and purposefully be degraded or contaminated (e.g. by weather events, pests or pathogens) to fit the definition of the feedstock

Based on their experience with market players, ISCC had expressed concerns regarding the limitations in the ability of assurance providers to scientifically distinguish the physical nature of waste-based fuels (e.g. UCO Methyl-ester) with purposely contaminated virgin oils. Due to this challenge, technical specifications or physical characteristics of some sustainable products are not widely defined within the scope of their sustainability certification processes, but ISCC suggested that this is an area where additional research activities could help improve their abilities to detect fraudulent feedstocks.

The experience from voluntary schemes certifying biomass for non-energy purposes is relevant for this study. For example, FSC uses mature technologies to identify the genus, species, family and origin of the wooden feedstocks. While this technology is reportedly cheap, accessible and effective for wooden products, similar solutions are not currently available for all feedstocks, e.g. agricultural crops, biogenic waste, etc.

The main method to evaluate feedstock compliance with relevant sustainability, chain-of-custody and assurance rules is through third-party audits. The assessment protocol for voluntary schemes states that "group audits can only be conducted for raw material providers with a small production site", but has not yet provided a quantifiable threshold. As a result, all respondents to the Fraud Mitigation questionnaire have determined internal thresholds in which only point of origins supplying above that threshold will be audited on-site.

Supply chain fraud risks

When a large number of intermediaries and regions are involved in the supply chain of biofuel production, fraudulent activities can potentially occur for each transaction between economic operators and geographical regions due to collusion risks and different levels of regulation information.

The systems put in place by voluntary schemes as preventative measure against these fraud risks are adapted to the complexity of the certified products. Some voluntary schemes only rely on the onsite auditing and monitoring of mass balance systems while others such as FSC and Bonsucro are also working on developing blockchain technology as an additional mechanism to establish a sophisticated repository of interactions and transactions between traders and economic operators to mitigate fraudulent activities or collusion.

In order to enhance the traceability of compliant material across the supply chain, many voluntary schemes have suggested that certification bodies should have a contractual obligation with economic operators to ensure auditors have access to all information required to conduct verifications. This information includes, but is not limited to, evidence supporting mass balance system as specified in the Assessment Protocol. **Most voluntary schemes require that economic operators disclose additional information such as transportation documents, certified documents from other voluntary schemes and, in some cases, feedstock supplier audits or sustainability certification to assist with the auditing process.**

The Assessment Protocol requires the audit intensity (i.e. the frequency, duration and depth of audits, as well as involved audit teams) to increase depending on the level of supply chain risk. In response to this, **many voluntary schemes have introduced risk assessment tools and risk management procedures** in which economic operators are obligated to participate. This allows certification bodies to adopt a risk-based auditing approach.

Some additional measures implemented by individual voluntary schemes include:

- Integrity assessment programs to verify correct certification of sustainable products between operators on a risk-based / semi-random selection basis.

- SURE (Sustainable Resources Verification System – a spin-off from REDCert) maintains dialogue with voluntary schemes in charge of certification of suppliers of a given supply chain in case of suspected fraud cases such as false declaration of feedstock.

- ISCC has implemented internal reviews to close operational gaps in audit procedures as additional risks are identified through certification processes.

Fraud risks around feedstock definition

Fraud risk arises when there is a lack of clear or uniform definition of the feedstock across regions. This is particularly prominent in sectors/supply chains where co-products, residues or waste are produced, processed or traded.

To avoid inconsistency, almost all voluntary schemes default to using RED for feedstock definition but have provided additional guidance or obligations for auditors and economic operators to determine feedstocks that are not clearly defined by RED or other relevant legislation. Moreover, ISCC also keeps their stakeholders up to date on relevant definitions and related clarifications via system updates.

Fraud risks to chain of custody and assurance systems

In complex biofuel supply chains and processing, there is a risk that feedstock cannot be easily segregated if an economic operator opts for a stricter chain-of-custody system than mass balance or not easily tied to a particular origin and that assurance providers lack knowledge in the given conversion technology.

Methods used by voluntary schemes to minimise chain of custody and/or assurance system fraud risks often take a two-pronged approach obligating both the economic operators and auditors above and beyond guidelines set by the Assessment Protocol (European Commission, 2020a).

Waste and residue aggregators must also maintain procurement management on top of mass balance systems.

From the voluntary scheme's side, audit assurance systems more stringent than the Assessment Protocol are put in place to manage complex chain of custody risks. For example, RSB has gone beyond the "limited assurance level" obligated by the Assessment Protocol to require auditors to have a "reasonable assurance level" when conducting chain of custody and greenhouse gas related audits. This also includes expanding the scope of technical reviews to include chain of custody information. Lastly, in addition to continuous training courses for auditors as required in the Assessment Protocol, one voluntary scheme out of those contacted during this study also holds bi-annual calibration workshops for active auditors as a platform for knowledge sharing.

9.4.2.2. Efficiency of existing measures against fraud related to the physical characteristics of feedstocks

This section evaluates how existing measures (both at EU and voluntary scheme levels) actually mitigate the identified risks, based on feedback from consulted stakeholders and internal expertise and the practical experience collected by SCS over the concrete implementation of EU assurance requirements in their day-to-day work as auditors. Measures are described as effective in having either a moderate or high impact on the identified fraud risks. Measures identified as having no impact are not described.

9.4.2.2.1. Physico-chemical properties and alteration of different feedstocks

These risks relate to the difficulty to distinguish feedstocks on the basis of their physico-chemical properties and the possibility for economic operators to purposefully alter an unincentivized (i.e. not included in Annex IX) to make it visually or chemically similar to an incentivized (i.e. included in Annex IX) feedstock. Feedstocks included in Annex IX could therefore be fraudulently substituted by or mixed with feedstocks that are not included in Annex IX. This risk lies with the difficulty for assurance providers to systematically detect the exact physico-chemical nature of feedstocks, either through a visual inspection or via a simple test. The mixing of limited amounts of unincentivized feedstocks into larger amounts of incentivized feedstocks could also fail to be detected by economic operators and/or assurance providers.

Effective mitigation measures would therefore need to provide greater certainty of the physico-chemical nature of the feedstocks used for biofuel production, in particular the type of biomass from which it originates, and/or the type of co-product, residue or waste. The measures currently being considered and implemented generally focus on increased mass balance oversight requirements, including more frequent audits, and greater scrutiny of high-risk supply chains (e.g. double counting materials).

Examples of mitigation measures that have been implemented related to physico-chemical properties include the following:

Moderate Impact

- A ***mass balance system*** is required from economic operators via voluntary schemes for tracking sustainability characteristics across the supply chain

- ***Increased mass balance requirements*** in EU RED II related to high-risk feedstocks. Specifically, the EU RED II VS Assessment Protocol indicates that voluntary scheme must include "mandatory surveillance audit by the certification body six months after the first (initial) certification. For collecting points and traders that deal with both waste and residues and with virgin materials (e.g. vegetable oils), the surveillance audit is conducted three months after the first certification audit (covering the first mass balance period)."

- ***Increased Auditor Training*** requirements

Practical experience shows that normal auditing procedures are somewhat effective in finding instances of mixing/dilution or mislabelling. They also act as a deterrent to would-be violators by creating a layer of scrutiny that makes fraudulent behaviour less appealing due to the greater likelihood of being caught than if these auditing procedures were not in place. However, assurance providers have noted certain cases, in which they suspect fraud but are unable to adequately verify the feedstock type or source. **Increased mass-balance requirements** have been implemented already by a number of voluntary schemes to address these risks, some of which have now been incorporated into the draft REDII Assessment Protocol (European Commission, 2020a).

The draft REDII Assessment Protocol for the approval of voluntary schemes requires **additional measures**, such as:

- Points of Origin (PoO) delivering more than 10 tonnes per month require mandatory onsite audits; and

- PoOs delivering less than that threshold requires auditors to verify the location of the PoO on a sample basis.

One scheme (RSB) requires Operators maintain records for individual deliveries from PoOs, including amount of waste generated per month for PoOs, records of incoming and outgoing amounts of sustainable material, and provide reports on certified products on a bi-annual basis. There has been some discussion within voluntary schemes about reducing the threshold for onsite audits to 5 tonnes per month, which was therefore tentatively added to the draft REDII Assessment Protocol (Article 13(4)). However, there are concerns about the economic impact such measure would have, as it would greatly increase the number of sites requiring sampling, and therefore auditing time and cost.

Finally, some schemes have implemented **more regular mandatory required training for auditors**. These are useful to help auditors identify materials, especially when physico-chemical properties may not be adequate. To the extent that these trainings provide information on typical yields for materials that are generated through either collection or processing, it is helpful to assurance providers to make certain that materials are indeed what they are classified as.

9.4.2.2.2. Incentivized Feedstocks based on Land Use Characteristics

This risk relates to the difficulty to distinguish feedstocks on the basis of the land they were cultivated on (abandoned or degraded land) or agricultural practices (intermediate and cover crops). Land status may be difficult to establish with certainty over several years in the past if country records are incomplete or difficult to access, especially for farmers renting their land. In rotation systems, determining what crop can be considered as the main crop can also prove complex if more than two crops are cultivated in rotation over two or three-year long cycles.

Mitigation measures shall therefore ensure that the European Commission, voluntary schemes, assurance providers and end-users have practical and cost-effective means to verify and confirm the exact status of the land before and after the operations started, and/or the exact type of agricultural practices being implemented. Guidance on how to determine main crops and intermediate/cover crops would be particularly needed.

Examples of mitigation measures related to Land Properties that have been implemented by voluntary schemes include the following:

Moderate Impact

- ***Increased Audit Intensity*** *– Requirement for Onsite Auditing for Certain Operations*
- ***Technology Tools*** *– For example Remote Sensing*

Increasing the proportion of audits, in which sites are physically inspected, decreases risk, especially if the timing of the visit coincides with harvest of the incentivized crop. Inability to directly observe crop harvest from incentivized land categories increases risk of misreporting the yield of the incentivized material. For some crops (e.g. annuals) it can be difficult in practice to conduct a thorough audit at the appropriate time since the farmers are often under significant stress to complete harvest while conditions are ideal, and would rather not host a thorough inspection during crucial times. Some schemes are investigating the use of **remote sensing tools** to identify and confirm the existence of land that meets certain categories (e.g. ISCC CORSIA for reclaimed mine lands). Other schemes are investigating the use of blockchain technology, which they see as increasing confidence in the traceability of the material.

9.4.2.3. Efficiency of existing measures against fraud related to the supply chain characteristics of feedstocks

9.4.2.3.1. Number of intermediaries in the supply chain & Trading Patterns

This risk relates to the increased probability of intentional or non-intentional fraud across the supply chain as the number of intermediaries increases. This is particularly the case with intermediaries, who merely transfer feedstocks or derivatives to the next economic operators without any processing, e.g. aggregators, traders, brokers, etc.

Mitigation measures shall therefore ensure that the European Commission, voluntary schemes and assurance providers have practical and cost-effective means to inspect any economic operator acquiring feedstocks or derivatives throughout the supply chain. Situations with higher risks should be clearly identified to avoid unnecessary verification costs when a physical inspection is not or less frequently required.

This risk relates to the increased probability of intentional or non-intentional fraud across the supply chain as feedstocks and derivatives are traded globally and/or in large volumes. Global trading leads to feedstocks and derivatives to cross multiple borders, which increases the risk of incompatibility, losses or misinterpretations of product documentation. This could make the falsification of product nature or origin more difficult to detect.

Mitigation measures shall therefore ensure feedstocks and derivatives, which are traded globally and/or in large volumes undergo a **higher level of scrutiny and tracking across the supply chain**.

Examples of mitigation measures that have been implemented in relation with the number of intermediaries in the supply chain and trading patterns include the following:

Moderate Impact

- Establishment of a ***Union Database***
- ***Tracking of all transactions*** *through a common registry (i.e. extending the Union Database across the entire supply chain)*
- ***Risk Assessment Tools,*** in which the audit intensity increases with increased supply chain risk
- Strengthening of **Mass Balance accounting** procedures

Supply Chain Fraud risks generally stem from the challenges associated with maintaining oversight of product traceability as material moves across very long and complex supply chains. The most effective tools to mitigate these fraud risks are those that ensure robust traceability, providing greater certainty of product type and provenance. Normal audit practices typically only allow for an auditor to see one sliver of the supply chain; however, the establishment of a ***Union Database*** is a potentially highly impactful mitigation measure. In order to mitigate the risk for fraud inherent in long and complex supply chains the Commission may consider to include all RED transactions in the Union Database, rather than just the feedstock production and biofuel production. It should be noted that some voluntary schemes are currently actively engaged with blockchain technology providers, and there is talk about how these technologies might be able to integrate into the Union Database (Direct communications).

Improvements in the rules around the implementation of Voluntary Scheme assurance systems is likely to bring benefits vis-à-vis fraud risks. For example, while a number of schemes have had risk management standards in place since their initial EU RED recognition, the systematic implementation and guidance from EU around those risk management systems has been weak and underdeveloped. However, voluntary schemes have been improving these systems recently, including in preparation for the transition to EU RED II. In May 2021, RSB announced an update to its Procedure for Risk Management (RSB-PRO-60-001), v3.3, and provided a more streamlined and sophisticated assessment tool. Likewise, ISCC has been investigating how to translate its Risk Management standard (part of ISCC EU 204), with a more streamlined assessment checklist. As operators and certification bodies become more accustomed to mass balance principles, better ways to provide robust traceability verification have emerged, for example by requesting that the mass balance documents be provided for review prior to the audit, and by conducting more frequent audits (e.g. 3 or 6 month surveillance audits) of high risk supply chains, as illustrated in the current protocol used for the EU approval of voluntary schemes (European Commission, 2020a).

9.4.2.3.2. Rule of law in producing countries

This risk relates to the difficulty of countries where feedstocks and derivatives are produced or transferred to stringently enforce laws ensuring the traceability of products and transparency of transactions, which may exacerbate the risk of fraud over the nature or origin of feedstocks and derivatives.

Mitigation measures shall therefore ensure feedstocks and derivatives, which are produced, processed and/or transferred in countries identified as having a weak rule of law undergo a higher level of scrutiny and tracking across the supply chain.

Examples of mitigation measures that have been implemented in relation to weak rule of law include the following:

High Impact

- Requirement for a **Grievance Mechanism**

- Certification Body **Oversight by the European Commission and/or Voluntary Scheme**

Moderate Impact

- Establishment of a **Union Database**

- **Risk Assessment Tools** in which the audit intensity increases with increased supply chain risk

Risks related to operating in countries with weak rule of law and high incidence of corruption would increase the chance of collusion practices, either between the economic operator and local stakeholders (e.g. regulators, etc.) or between the operator and the auditor. True corruption may be difficult to uncover without some indication of wrongdoing, so a grievance mechanism that can be utilized by a whistle-blower may be the most important mitigation measure for this risk indicator, as long as a fair and transparent investigation process is triggered.

Other important mitigation measures identified include tools that increase transparency and oversight and make it harder for either a company or their auditor to take advantage of corrupt contexts. For example, increased assurance provider oversight by the EC and/or voluntary schemes will make it more difficult for an auditor to collude with a client. Likewise, by acknowledging the increased risk associated with operating in these regions and adjusting the audit intensity accordingly (e.g. increased frequency and/or intensity), operators know that fraud is more likely to be identified and presumably will be less likely to engage in fraudulent activities due to increased scrutiny.

9.4.2.3.3. Non-EU border-crossing

This risk relates to the increased probability of intentional or non-intentional fraud across the supply chain as feedstock or derivatives transit through non-EU countries, which may lead to incompatibilities between the EU and non-EU legislation and end up with errors in the categorisation/labelling of feedstocks.

Mitigation measures shall therefore ensure feedstocks and derivatives, which are produced, processed and/or transferred in non-EU countries undergo a higher level of scrutiny and tracking across the supply chain.

Examples of mitigation measures that have been implemented related to the crossing of non-EU borders include the following:

Moderate Impact

- Publicly available information about the **geographic origin and feedstock type**
- Establishment of a **Union Database**
- **Training** of accredited assurance providers

As mentioned above, supply chain risks related to transit of material across multiple non-EU countries relates to the possibility of intentional and unintentional errors in labelling of feedstocks. Risk mitigation measures which address this are those that help to identify and establish the type of material uniformly as it passes across the supply chain. **Publicly posted information about the type of material and its origin** makes it less likely that material characteristics will change as it crosses borders and moves across the supply chain. Similarly, having **material characteristics registered in a central Union Database**, will make harder for those characteristics to be modified as they move across the supply chain.

One area of weakness among some voluntary schemes has been in ensuring **uniformity of standards implementation at a global level** due to significant discrepancies in the qualifications of auditors and their familiarity with EU RED requirements. The implementation of obligatory regular training is important to ensure assurance providers are regularly informed of standards updates, and to ensure uniformity of requirement interpretation across geographies.

9.4.2.4. Efficiency of existing measures against fraud related to the feedstock definition characteristics of feedstocks

9.4.2.4.1. Feedstock definition across countries, and feedstock classification (co-product, residue, waste)

This risk relates to the difficulty to the incompatibility or inconsistency of the definition of feedstocks across countries or of the classification of feedstocks as co-product, residue or waste across countries, which could make the implementation of sustainability/traceability rules by economic operators and/or assurance providers more challenging (e.g. by not knowing the exact nature of feedstocks, or lead to erroneous scope of compliance and/or audits between countries). For example, if a feedstock is considered as a processing residue by a country, thus requiring GHG calculations to start at the first collection point (e.g. PFAD in Finland), it would not be accepted as EU-compliant in a country where it is considered as a co-product.

Mitigation measures shall therefore ensure that the European Commission, Member States and third countries have a homogeneous and consistent definition for feedstocks, especially those on Annex IX. **Broad, generic and non-specific definitions should therefore be avoided** and/or complemented by specific lists of feedstocks, which are easily and unambiguously understood by economic operators and assurance providers.

Existing measures implemented at EU level and/or additional measures from Voluntary Schemes include:

Moderate Impact

- Improved Guidance Documents

    - While not all feedstocks are clearly defined in the RED as qualifying as a wastes or residues, some schemes have published **clear procedures for assurance providers to follow in order classify these materials**.

    - Additional guidance has been issued to help auditors with the **certification of specific feedstocks** (e.g. POME oil and EFB oil)

- Increased **auditor training**

    - Some voluntary schemes have increased auditor training requirements, with additional specific training requirements for different scopes (e.g. just for auditing Waste & Residue materials)

- Regular **standards updates and communications**

Voluntary Schemes commonly define waste as in Article 3(1) of the Waste Framework Directive 2008/98/EC (WFD), and the process for determining if a material qualifies as a waste as laid out in the Flow chart based on: EC DG Environment 2012: "Guidance on the interpretation of key provisions of Directive 2008/98/EC on waste". In practice, the process for determining whether a material may be classified as a co-product, residue, or waste has been left to the VS and assurance provider, with different interpretations possible across those entities in the industry. Certain member states have chosen to uniformly categorize certain feedstocks (e.g. Finland considers tall oil uniformly to be a residue), while other countries and schemes leave those interpretations to be classified on a case-by-case analysis.

The lack of technical specifications present in EC feedstock definitions creates ambiguities that are not easily resolved as materials can be highly variable within their category. For example, free fatty acid content and other components of tall oil can differ depending on the tree species used in the pulp process.

Voluntary Schemes have attempted to mitigate the risk of subjective definitions and regional variation by increasing auditor training requirements, including specific training for Waste/Residue audit scopes, and improved guidance for auditors to identify these materials. Nevertheless, this remains an area of significant risk, especially as new feedstocks emerge, and harmonization of definitions is increasingly of concern.

9.4.2.4.2. Cellulose/non-cellulose ratio (incl. ligno-cellulose)

This risk relates to the difficulty to consistently and accurately define the amount of cellulosic/ligno-cellulosic (covered by Annex IX, hence double-counted) and non-cellulosic/ligno-cellulosic (not-covered by Annex IX, hence single-counted and/or capped) material in feedstocks, especially when such materials are co-processed together in an integrated facility. Unclear cellulosic/ligno-cellulosic content increases the probability for a feedstock not in Annex IX to be processed and transferred without the possibility for assurance providers and/or end-users to detect the fraud early on. For instance, palm trunks contain a non-neglectable fraction of sugar, which could be processed alongside ligno-cellulose as Annex IX feedstock.

Mitigation measures shall therefore ensure that economic operators and assurance providers have practical and cost-effective means to verify and confirm the exact cellulose/non-cellulose ratio in the feedstocks used for biofuel production and the amount of end-fuels, which can be claimed as single vs double-counted.

To date, no mitigation measures specifically targeting cellulosic materials exist at the EC or voluntary schemes level. Cellulosic material and ligno-cellulosic material are currently eligible for benefits from inclusion in Annex IX under points p) and q) of Annex IX. However, there is currently no technical specifications for cellulosic materials or guidance on **how to identify the cellulosic content of materials that include both cellulosic materials and starch/sugars** (e.g. palm trunks) at the EU level. Interestingly, there is now a North American specification (ASTM E3181) for determining cellulosic content of corn fibre for ethanol. This is further discussed in the recommendations section below, however testing to determine compliance with cellulosic definitions may be challenging in the context of EU RED II, due to cost and technical feasibility at a global level.

9.4.2.5. Efficiency of existing measures against fraud related to assurance

9.4.2.5.1. Origin tracking and feedstock segregation

This risk relates to the difficulty for assurance providers to establish with certainty the exact origin of feedstocks used for biofuel/biogas production, especially in supply chains with no strict segregation of incentivised/EU-compliant feedstocks.

Mitigation measures shall therefore ensure that the European Commission, voluntary schemes, assurance providers and end-users have practical and cost-effective means to verify and confirm the origin of the feedstocks used for biofuel production, in particular the country, land type, crop/tree/process it originates from.

Existing measures implemented at EU level and/or additional measures from voluntary schemes are include:

High Impact

- **Segregated and IP Traceability Systems.** Some Voluntary Schemes allow for the use of ***Segregated Chain of Custody*** systems, in which certified and uncertified material is stored and transported separately, and some also allow for the use of ***Identity Preserved traceability systems***, in which information about the origin of the material is communicated along the supply chain.

Moderate Impact

- Publicly Available Information about the ***geographic origin and feedstock type***
- Establishment of a ***Union Database***
- ***Tracking of all transactions through a common registry (i.e. extending the UDB across the entire supply chain)***

Although they have significant benefits to allow commodity systems to operate using existing energy infrastructure, fraud risks related to the use of Mass Balance systems do exist, as oversight of the entire supply chain, to the origin of the material is in most cases not possible. Under the EU RED, feedstock country of origin and type is required to be reported along the supply chain (e.g. in "Sustainability Declarations"). However, the use of robust Segregated or Identity Preserved Chain of Custody systems, in which certified material is kept physically separate from uncertified material, goes further to strengthen the traceability system, and reduce fraud risk. Identity Preserved systems typically allow for a batch of material to be traced all the way to the specific site location from which the material was generated. In addition, the implementation of a Union Database would contribute to mitigating this fraud risk, considering that feedstock information and presumably the geographic location of its generation, will be directly entered into the database.

9.4.2.5.2. Understanding of conversion technology and Competences of assurance providers

These risks relate to auditor competencies, including challenges for assurance providers to have a very good understandings of different technologies and the conversion factors (i.e. yields) associated with them for a large range of feedstock types. Audit processes require economic operators to explain their process flows and provide internal documentation of material quantities through the various process stages, or at the very least in terms of certified feedstock in and certified material out. However, minimum requirements in terms of auditor competencies are not established (e.g. level of experience working in the field and/or minimum educational requirements), leading to significant discrepancies in auditor competencies and experience level. Fraud risks relate to challenges that auditors may have to identify fraud when they might not be aware of the red flags indicating a higher fraud risk. Given the variation in the level of subject matter expertise between assurance providers, some auditors are more likely to identify fraudulent practices than others, based on their experience and training received.

Existing measures implemented at EU level and/or additional measures from voluntary schemes related to this risk include:

High Impact

- Detailed rules regarding the **training, competences, audit process and monitoring of auditors and personnel from accredited assurance providers**, which rely, among other sources, on international ISO standards.

Moderate Impact

- EU RED II requirements for either the European Commission or voluntary schemes (through an internal monitoring system) to bypass accreditation bodies and **directly monitor the work of accredited assurance providers.**

All Voluntary Schemes interviewed require that auditors undergo training before conducting audits along with ongoing training to maintain their skills and be informed of standards updates, in line with EU requirements for approval (European Commission, 2020a). Voluntary schemes are further expected to provide oversight of the auditors to ensure that they are operating in accordance with standards requirements. However, the focus of these trainings is primarily on proper understanding of the standards themselves, rather than on the technical details of specific conversion technologies and associated yield factors. While understandable given the very large range of eligible feedstock types, the lack of technical knowledge presented means that assurance providers are largely on their own to provide technical training to their auditors to identify when yields are within or outside of normal parameters. Some schemes are already starting to address this risk; ISCC has started to conduct specific Waste & Residue trainings which are required for any auditors conducting audits of these materials. ISCC also recently released a technical guidance for public comment on EFB Oil and POME Oil, indicating typical yields that auditors can expect to find for both of these palm oil derivative materials

9.5. SUBTASK 3.6 – RECOMMENDATIONS FOR THE DEVELOPMENT AND IMPROVEMENT OF FRAUD MITIGATION MEASURES

The following sections include specific recommendations for mitigation measures that can reduce the risk associated with different fraud risk categories that have been identified. Nevertheless, it is important to keep in mind that while Voluntary Schemes rely on qualified assurance providers to ensure that biofuels qualifying for the EU RED meet their respective requirements, there is not a presumption of fraud when auditing and assurance providers are largely not expecting to find fraudulent activities when conducting audits. Indeed, **investigation of truly fraudulent activities requires skills and resources that most assurance providers do not have**. To combat fraud, it may be necessary for the Commission to consider a **dedicated fraud investigation unit for the EU RED**, which would have the required resources, including specially trained staff to investigate suspected fraud cases. A fraud investigation might be triggered by a variety of reasons, including an alert through a whistle-blower hotline, suspicious transactions noted, or other reasons. More importantly, it would avoid additional investigation costs to be borne by assurance providers and/or economic operators.

9.5.1. Physico-chemical properties and alteration of different feedstocks

Measure 1: Improved Auditor Guidelines on Typical Yields for Different Feedstocks

There is currently very little information available to auditors on typical yields that can be expected from different types of operations. For example, published typical ranges of UCO production for restaurants by size/geography would help auditors to identify if a particular economic operator was reporting significantly more volume of UCO per site than is typical for a restaurant in that part of the world, providing a red flag for auditors. The consortium found that UCO yields vary significantly by the type of restaurant that produces the oil. A study conducted in the State of Utah, USA shows that the average U.S. restaurant produces 26 gallons of UCO/month (98.4 litres/month), but that the production level varied from a low of 0.4 gallons (1.5 litres) for a delicatessen to a high of 48 gallons (182 litres) for fast food. Chinese restaurants were found to have a relatively high average production volume (37 gallons / 140 litres per month) (Miller, 2007). More research is needed; however, there are indications that per-restaurant UCO production in China may be higher on average than UCO production in North America and Europe. Guidance for auditors on UCO yields (or any other feedstocks closely related to local lifestyles, e.g. municipal waste) should therefore take geographic specificities into consideration.

Similarly, ISCC convened an expert working group on palm oil derivatives and found average ranges of palm oil mill effluent for different types of palm oil mills (ISCC, 2021).

ISCC found the following ranges for POME production for mills with horizontal and vertical sterilizers (Table 51).

Table 51 : Typical POME production from mills with horizontal and vertical sterilizers (Source: ISCC)

Description	Low Range	High Range
Mills with horizontal sterilizers		
Oil content of sterilizer condensate	0.5 kg/ton FFB	2.1 kg/ton FFB
Oil content of heavy phase	1.6 kg/ton FFB	5.5 kg/ton FFB
Total POME oil content	2.1 kg/ton FFB	7.6 kg/ton FFB
Mills with vertical sterilizers		
Oil content of sterilizer condensate	0.5 kg/ton FFB	17.4 kg/ton FFB
Oil content of heavy phase	5.5 kg/ton FFB	11.4 kg/ton FFB
Total POME oil content	6 kg/ton FFB	28.8 kg/ton FFB

The above numbers (or EU-level similar references) could therefore be used more broadly by auditors from EU-approved schemes to verify that POME yields, as reported by economic operators, are in line with industrial standards.

In another documented example, the consortium found that Palm Fatty Acid Distillate yields are directly related to the acid value (FFA content) of the Crude Palm Oil (CPO) from which it is derived. A review of two research studies found typical FFA content ranges for CPO to be 3.0 – 6.5% and 3.8 – 8.7%. Furthermore, literature review and discussion with industry experts indicated that many palm oil refineries will not accept CPO with FFA levels >5% (Japir et al., 2017; Che Man et al., 1999). Auditors can use these ranges and the 5% threshold to determine if Fatty Acid Distillate production from CPO from a particular processing unit are plausible, and in line with industry values.

The above examples show that several yield descriptions already exist for specific feedstocks, which could be used as product standards or industrial process benchmarks to support the verification work of auditors. The EU could develop a list of accepted technical descriptions and/or standards and support further research to establish similar standards when these do not yet exist. It should be noted that the relevance of such product specifications or industrial standards would be of lesser relevance for feedstocks defined by land type (e.g. degraded lands) or cultivation practices (e.g. intermediate crops), given the broad range of geographies, soils and crop types covered.

Measure 2: Physical & Chemical Testing Options

There has been a lot of discussion among voluntary schemes, assurance providers and civil society organisations about the potential for chemical testing (ie. analytical methods) to confirm if a material is indeed what it is purported to be (e.g. physico-chemical characteristics). At a practical level, analytical testing presents challenges in the context of EU RED II: Considering the global nature of feedstocks and biofuels sold into the European market, there is a large variation in accessibility to analytical equipment, and to local expertise to conduct such analysis with meaningful results. In many cases, test procedures for this type of analysis do not exist, and data interpretation would be subjective in nature. For example, some people have speculated about the possibility to conduct a test to determine palm oil content in UCO (to determine if UCO has been diluted with Crude Palm Oil). There are challenges to this, for example, in regions where palm oil is frequently used for cooking (e.g. Asia) and is therefore turned into UCO after usage; in such case, the fatty acid profile may in fact be similar between these materials. Furthermore, laboratories are unlikely to have reference materials for UCO and palm oil to compare the difference between these two materials. Similar issues exist for other feedstocks. Another issue is the ability of economic operators to collect and store samples for future spot testing upon auditor's request. While an economic operator may be able to provide an eligible material for a single test during an audit, it does not mean that there is a high degree of confidence that all material produced by them conforms to this sample. Chemical testing of materials is only highly effective if testing is conducted a very regular intervals and occasionally on a random or "spot" basis. Given the nature of how the REDII assurance system operates, this is unlikely to be feasible, especially for smaller operators.

Nevertheless, there may be opportunities to establish testing procedures to provide auditors with useful information, considering the practical constraints mentioned. For example, there may be **useful indicative tests** that auditors can use to make rapid field assessments of material they are inspecting, to at least compare certain basic parameters to industry standards. For example, visual indicators (e.g. colour using colour strips), pH level (using pH strips), and other visual and/or very basic chemical tests could be explored. While these would not be adequate to make a certification decision, they could help an auditor to assess relative risk, and to determine if further investigation is necessary.

The European Commission might also consider identifying a small number of key parameters to test for, for highly risky feedstocks, using existing analytical test procedures and providing a list of approved laboratories to conduct these tests to verify feedstocks. While a small number of tests for a small number of feedstocks would make physical/chemical analytical testing more feasible, any consideration to implement this should be approached with a high level of caution, given the issues mentioned above. Conducting random feedstock tests could fall under the remit of a fraud investigation unit (see above).

9.5.2. Land properties

Measure 3: Auditing During Farming Activities

The efficacity of auditing feedstocks grown on land with incentivised properties (e.g. polluted/degraded land, intermediate/cover crop) improves with the possibility for assurance providers to witness agricultural activities (e.g. auditing during the harvest season for annual crops). In the case of crops grown on degraded lands, it may even be advisable for assurance providers to conduct onsite audits in the 1-2 months leading up to the harvest, in order to verify anticipated yields on the cropping areas pending harvest on areas designated as having a special category, such as degraded or marginal.

While onsite visits during the farming season may be inconvenient to farmers in some cases (e.g. farmers with annual crops tend to be very busy during the harvest season), visiting sites while crops are planted/harvested, especially in the case of land with a special designation, gives assurance providers greater confidence that the reported crops were grown on the land category reported, in the yields reported.

Measure 4: Remote Sensing Tools

Feedstocks incentivised on the basis of land-use characteristics cannot be distinguished from the same feedstocks grown on non-qualifying lands, based on their physical properties. Therefore, it would be helpful to identify objective means to verify the validity of land-use data presented to ensure no material from non-qualifying lands are utilized, in addition to the verification of existing land-use requirements (e.g. the forbidden conversion of highly biodiverse forests after 2008). Remote sensing tools including satellite-based imagery has progressed to the level that it is possible to confirm the type of crop grown on specific fields around the world or whether land was under agricultural regime at a given point in time. The European Commission might consider how remote sensing tools can be used to identify qualifying lands and provide a positive verification that a particular crop was in fact grown on those lands during the period in question. While remote sensing data has limitations, remote sensing data to verify qualifying land categories paired with an onsite visit to confirm cropping systems and expected yields during an active farming period would likely provide a significant reduction in fraud risk. ISCC conducted a pilot project in the United States aimed at using remote sensing tools to classify land use status, in particular for reclaimed former mining lands converted to agriculture.

9.5.3. Number of intermediaries in the supply chain & trading patterns

Measure 5: Tracking all EU RED transactions through a common registry (i.e. extending the Union Database across the entire supply chain). As mentioned above, Supply Chain Fraud Risks generally stem from the challenges associated with maintaining oversight of product traceability as material moves across long and complex supply chains. The initiative to establish a ***Union Database*** is intended to address these risks – that longer and more complex supply chains introduce more fraud opportunity due to the increased number of actors and greater disconnect between the feedstock producers upstream and the biofuel producers downstream. Some voluntary schemes have been investigating the possibility to introduce a distributed ledger (i.e. ***Blockchain Technology***) to increase transparency in the transaction record and provide greater confidence that there is no fraud introduced anywhere along the supply chain. While the use case of Blockchain Technology is still being evaluated, the use of a common registry of all REDII transactions, as part of the Union Database would likely go along ways to mitigate against fraud insofar that the Union Database may be focused (at least initially) on the beginning of the supply chain (registering feedstock production) and the end of the supply chain (registering biofuel production). A transaction ledger would link the supply and demand sides of the Supply Chain, providing a complete traceability record that would make it difficult for fraud to be committed, and also provide a valuable tool to investigators looking into potential fraud allegations to follow the material from origin to final producer.

9.5.4. Weak Rule of Law in Producing Countries

While most experts agree that fraud is more prevalent in countries or regions with a weak rule of law, it is beyond the scope of this study and EU energy policy to address institutional weaknesses at the national or sub-national level for non-EU countries. Although *no specific mitigation measures to reduce fraud risk related to operating in a weak rule of law were identified*, it may be possible to reduce the incentive to commit fraud through activities that make fraud more difficult to commit irrespective of the risk category (e.g. more frequent or intensive audits).

9.5.5. Feedstock definition across countries, feedstock classification (co-product, residue, waste)

Measure 6: Create a Formal Process for Feedstock Definition Harmonization

The lack of harmonized technical definitions for bioenergy feedstocks means that definitions are often developed through initiatives by voluntary schemes or by member-state authorities, and without a central, harmonized process, creating room for definitional ambiguity. In addition to the existing guidance and communication, the EU should keep bringing clarity on technical specifications & definitions for feedstocks for voluntary schemes and Economic Operators. In addition, it would provide a potential opportunity to establish typical yield parameters for different feedstock types, which is an important fraud risk mitigation tool.

Technical specifications from international databases and governmental agencies for different feedstocks have been reviewed and listed in Annex G, as well as in the feedstock assessments developed during Task 2 of this project. Definitions may include technical specifications about production processes. Definitions developed during this project, along with the technical specifications listed in Annex G may form the basis of a harmonized list of feedstock technical definitions and specifications. It would be ideal for the EU to maintain a continuous formal process to collect and maintain technical definitions and specifications. Examples of definitions from Task 2 and feedstock specifications identified include the following:

<u>**Definitions from Task 2 Assessments (Examples):**</u>

Fatty acid distillates (FAD): One of the resulting products from the deodorization step in vegetable oil refining, FADs can be produced from a wide range of oilseed crops and are comprised of FFA (80%, primarily palmitic acid and oleic acid), triglycerides (5-15%) and to a lesser extent components such as vitamin E, sterols, squalene and volatiles (Golden Agri-Resources, 2020).

Brown grease: Also known as fat trap oil or trap grease, brown grease is the oily material collected from grease traps that are installed for separating insoluble and gelatinous greases from kitchen wastewater streams, which originate mainly from foodservice enterprises such as restaurants, before water enters the wastewater disposal system.

<u>Technical Specifications from Annex G (Examples):</u>

Molasses: Two documents with robust technical specifications of molasses were identified in the literature:

(1) Molasses - General Considerations, excerpt from Molasses in Animal Nutrition, 1983. A detailed description of the composition of different types of Molasses products, including both sugarcane and sugar beet derived molasses, among others, from the perspective of animal feed researchers interested in its nutritional content. Parameters reported include: Brix, Total Solids, Specific Gravity, Total Sugars, Crude Protein, Nitrogen Free Extract, Total Fat, Total Fibre, Ash, Calcium, Phosphorus, Sodium, Chlorine, Sulfur and Energy Content.

(2) United States Standards for Grades of Sugarcane Molasses, effective 16 November 1959. Provides the official U.S. technical specification for different grades of sugarcane molasses (Grade A, Grade B, Grade C, Substandard), as published in the Federal Register. Developed to assist producers in the classification of different "grades" of molasses from sugarcane. Parameters include: Color, Brix Solids, Reducing sugars, Sucrose, Total Sugar, Ash, and Sulfur Dioxide.

Sewage Sludge: CEN/TR 13097:2010(Characterization of sludges – Good practice for sludge utilisation in agriculture) is a Technical Report, which describes the characteristics of different sludge types (incl. sludges from storm water handling, night soil, urban wastewater and industrial non-hazardous sludges) and good practice for the use of sludges in agriculture (where national regulations permit). It is applicable to all of the sludges described in the scope of CEN/TC 308 (and any of the forms in which they may be presented - liquid, dewatered, dried, composted, etc.)

Used Cooking Oil (UCO): It is worth noting that an important feedstock for which there is currently no harmonized technical specification is Used Cooking Oil (UCO). There was a previously funded EU project for Aviation Biofuels (ITAKA) that identified the need for a technical specification for UCO for Sustainable Aviation Biofuels and made some initial progress towards that end, but the project has since been concluded and a commercial technical specification is still pending to be finalized (Buffi et al., 2016). A literature review did find that UCO derived from different fats/oils had different characteristics (e.g. for chemical properties related to the level of saturation). For example, UCO derived palm oil had a lower iodine value, indicating a higher saturation level and higher congealing temperature (Awogbemi et al., 2019).

Measure 7: Create a Centralized Database of Definitions

In addition to the above, the Union Database may present an opportunity for a positive feedstock list with clear definitions, such that only defined materials could be registered on the Database. The database should also include technical specifications and typical yield parameters, as they have been determined by the Voluntary Schemes and relevant Member State authorities. Providing more information about how these materials have been defined previously will help assurance providers who are less familiar with that particular material to understand how it has been classified previously. The European Commission is in a unique position to compile this information into one place, where assurance providers can more readily access it to inform certification activities.

Measure 8: Guidance on local/project-level assessments

Certain fraud risk types such as the deliberate diversion of material eligible for food/feed production to produce biofuels/biogas are specific to local economic conditions, especially local uses of feedstocks by non-energy sectors (e.g. feed or food). In these cases, a local assessment is needed. This is also the case for several elements highlighted in Task 2, such as the alignment with circular economy principles (by favouring non-energy uses, when those are economically viable) or the risk of creating local market distortions. For a local assessment to be done, technical guidance on how to conduct such local or project-level assessment is needed for economic operators, with guidance then also needed for assurance providers. Asking economic operators to report on the potential for local economically viable alternative uses of feedstock will be more difficult than many of the other criteria on which economic operators are required to report. However, within existing voluntary schemes there are criteria related to local economic conditions, such as avoiding local food impacts. The European Commission should collaborate with energy and economic experts to develop such guidance, which could be used by economic operators and assurance providers to evaluate local conditions and demonstrate that energy uses of feedstocks do not conflict with other economically viable local uses.

9.5.6. Cellulose/non-cellulose ratio

Measure 9: Development of a Technical Standard to Determine Cellulosic Content

It has become clear that an important opportunity for cellulosic ethanol is material that is co-processed with feedstock with both a sugar/starch component and a cellulosic component. One of the challenges with this approach however is that it may be difficult to accurately determine the quantity of ethanol derived from cellulosic portion, since both materials are processed in the plant in an integrated process. Since ethanol from cellulosic origin is chemically identical to ethanol from sugar/starch origins, there is no simple chemical test that can be done to identify which fraction is cellulosic-derived. In the United States, there is now a specification through ASTM International, which establishes a procedure to determine the cellulosic fraction which has been accepted by the U.S. environmental authorities (US E.P.A.). Known by its technical specification as ASTM E3181, this establishes an agreed upon procedure to quantify the cellulosic content of a combined starch/cellulosic material being simultaneously converted into ethanol. Additional procedures with more detail and similar objectives are currently under review through the ASTM International standards development process (i.e. ASTM WK63392). Developing a similar technical procedure/specification relevant for the EU market (an "EN" standard) will provide very helpful information to the market on how the Commission would like to see the cellulosic fraction of these materials calculated.

Corn ethanol is a key biofuel for which better data on cellulosic conversion ratios are of critical importance to support assurance providers, given existing risks to fraudulently mix or substitute conventional (i.e. from corn starch) and ligno-cellulosic (i.e. from corn fibres) ethanol. In the US, the largest corn ethanol producer (both conventional and ligno-cellulosic), there are at least six known providers commercializing technology to convert the cellulosic fraction of corn kernel fibre into cellulosic ethanol. Conversion technologies either use an in-situ approach whereby the cellulosic and starch fractions are converted through an integrated process (POET, Edeniq) or a separated fraction system (ICM, Cellerate, D3Max) (Cagle, 2017; Hulzen, Shon Van, 2019). The Fibreex technology by Novozymes can be used in either an integrated or separated fibre platform. Additional ethanol yield of the converted corn kernel for different technologies range from <2.5% (Edeniq) to up to 10% (ICM & D3Max). Given that assurance providers will be unable to determine the fraction of ethanol derived from the lignocellulosic versus the starch content without a very good understanding of the different technologies and their yields, there is a risk that an economic operator could count starch volumes as cellulosic, by claiming higher cellulosic conversion yields than is actually occurring. Approximately 15% of the US corn ethanol industry had implemented one of these technologies by the end of 2019, and projections are that 3% of total corn ethanol production will eventually be produced from corn fibre, equating to approximately 1.7 billion liters/year from US corn alone (Gibson, 2021), while corn ethanol in other countries (e.g. Brazil) continues to expand rapidly. As these cellulosic volumes begin to enter the EU RED market, it is critical that assurance providers have robust scientific methods to verify the real cellulosic converted fraction, given that the molecules being sold from the ethanol plant will be the same whether they were converted from starch or fibre.

9.5.7. Origin tracking and feedstock segregation

Measure 10: Preserving Origin Data in Mass Balance Accounting

Traditional Mass Balance accounting allows for the mixing of certified and uncertified materials, such that information related to the source of the material is lost as the physical product is acquired, stored and sold separately from the virtual Mass Balance inventory of claims. However, because calculated GHG values must be transferred with product documentation and cannot be averaged (they must be maintained as separate entries in the mass-balance calculation), EU RED II has essentially adopted a hybrid Mass Balance system. In this system, traditional Mass Balance principles apply, with the additional need to transfer GHG data relevant all the way back to the source of the material.

Especially for high-risk feedstocks, it may be an option to consider including upstream data on the origin of the material, for example back to the original production operations. Since GHG data is already being tracked in this way, including additional information on the company and site of the material production would provide greater transparency and traceability assurance. Including this information on the Union Database would provide additional robustness, especially in the case that a suspicion of fraud is raised after the material has already been traded, it would be possible to trace the material all the way back to the origin more easily than is currently possible under existing mass-balance rules.

9.5.8. Understanding of conversion technology

Measure 11: Improved Auditor Guidelines on Typical Conversion Yields for Different Feedstocks

As mentioned earlier, there is currently very little information available to auditors on typical feedstock conversion yields that can be expected from different types of operations. Developing a **central resource (possibly the Union Database) with information on typical yield ranges for different feedstocks**, especially wastes and residues, would be very valuable to Assurance Providers, especially when trying to determine if a particular material is being intentionally produced. Regular guidance at the EU level, in collaboration with the VSs, on typical yield ranges for different materials will provide significant benefit, especially in those cases when a material cannot be distinguished based on its physico-chemical characteristics alone.

9.5.9. Competences of assurance providers

Measure 12: Voluntary Technical Training Opportunities

While most or all Voluntary Schemes have now implemented fairly rigorous training sessions, they tend to be fairly general in nature, which is understandable and necessary given the global nature of the feedstocks and the very large range of material types auditors may deal with when implementing generic biofuel schemes such as ISCC, RSB or REDCert (as opposed to feedstock-specific schemes like Bonsucro). Nevertheless, additional voluntary training sessions on specific feedstocks (e.g. palm oil waste/residue derivatives) would be helpful to increase the technical capacities of assurance providers working in certain feedstocks regularly. Training sessions would be led by the Voluntary Schemes who operate in these high-risk materials. *Measure 13: Minimum Qualification Requirements*

Most Voluntary Schemes still do not have specific minimum experiential or technical training requirements in order for staff to qualify as an auditor. In the assessment protocol used by the European Commission for EU approval, required experience and competences from auditors are generic, with the exception of life-cycle assessments and GHG calculations, for which two years of professional experience are required. Given the complex and technical nature of assurance-related services, it may be a good idea for the European Commission to expand minimum standards for experience in auditing in order for auditors to qualify to lead an audit, and possible some familiarity with the feedstocks and/or biofuels undergoing certification. Caution should be taken here not to implement overly burdensome requirements, but rather to just recognize the need for minimum competencies and familiarity with cropping systems or chemical processing in order to be an effective and informed auditor.

9.6. CONCLUSIONS

Subtask 3.1 looked at existing fraud cases, but there is a limited number of formally documented fraud cases, either for biofuel or forestry products. In biofuels, the majority of identified fraud cases involve creating false certificates for biofuel that never existed. Some fraud cases involve importing biodiesel to the EU and claiming it to be biofuel feedstock, such as UCO, to avoid import duties. In a small number of cases, it has been confirmed through testing that biodiesel claimed to be produced from UCO was actually produced from virgin vegetable oil. However, there are suspicions that this kind of fraud may be more prevalent and undetected. There are many certification suspensions each year, but it is unknown how many of these may represent intentional fraud; it is likely that the majority are due to misunderstandings of certification requirements. The forestry fraud cases identified involve sourcing wood from illegal areas and claiming otherwise, which could be considered analogous to falsifying sustainability data for biofuels.

Subtasks 3.2 and 3.3 aimed at characterising fraud risks and developing fraud risk indicators on the basis of the documented and suspected cases of frauds explored in Subtask 3.1. Two general categories of frauds were characterised on the basis of documented fraud cases, involving either the credits to be claimed from the production/distribution of advanced biofuels, or the physical nature of feedstock. Given the limited number of documented fraud examples, the consortium also built upon the practical experience of one of its members (SCS) to explore cases where a suspicion exists that a fraud could take place, even if no such fraud case has not been documented to date. In addition, the consortium decided to cover cases of non-conformities, which would not necessarily qualify as intended frauds, but would still be seen as "honest mistakes" resulting from systemic weaknesses in the sustainability, chain-of-custody or assurance rules implemented by the European Union and/or voluntary schemes. Whether they are the results of intended frauds or honest mistakes from economic operators, breaches or violations of the rules developed by the EU and/or voluntary schemes have in common that they would result in the EU failing to achieve the expected results in terms of biofuel sustainability and renewable energy targets.

As a result, the Consortium developed 11 fraud risk indicators, which are split between primary indicators (physical characteristics of feedstocks and feedstock definition characteristics), which represent fraud incentives, and secondary fraud risk indicators (supply chain characteristics and assurance), which represent enablers or amplifiers of fraud.

It is acknowledged that not all fraud risk indicators are relevant for all feedstocks, due to their specificities. For instance, fraud risks in relation to physical characteristics are mostly relevant to feedstocks that are easily fungible with feedstocks with similar physico-chemical characteristics (e.g. waste oils and virgin vegetable oil) whereas risk indicators addressing cultivation practices or land characteristics are primarily relevant for feedstocks characterised by their production process (e.g. biomass from degraded land). This flexibility allows a robust and exhaustive coverage of potential fraud risks across all the existing Annex IX feedstocks and the feedstocks shortlisted in this study.

In subtask 3.4, the Consortium evaluated all the existing Annex IX feedstocks, as well as the feedstocks shortlisted at the end of Task 1, against the fraud risk indicators developed in subtasks 3.2 and 3.3. Feedstocks sharing similarities in their physical and/or supply chain characteristics were grouped, but distinctive features were highlighted as often as required if these would result in a different evaluation against any of the indicators. In total, 34 assessments were conducted by the Consortium, which provide a picture of where the main fraud risks lie for each feedstock category.

The following conclusions can be drawn:

- **Several feedstock categories present an overall low or low-medium fraud risk**. This is the case for:
    - The biomass fraction of wastes and residues from forestry and forest-based industries (black liquor, brown liquor, fibre sludge, lignin and tall oil);
    - Certain waste and residues from cereals (cobs cleaned from kernel, dry starch and DDGS);
    - Nut shells;
    - Husks;
    - De-oiled pomace;
    - Animal by-products;
    - Drinks, distillery and brewing products (Citrus fruit pulp and peels only);
    - Tall oil pitch;
    - Crude glycerine;
    - Animal manure
    - Brewers' Spent Grain (BSG);
    - Whey Permeate;
    - Vinasse;
    - Thin stillage;
    - Brown Grease;
    - Wastewater and derivatives.

For these feedstocks, fraud risks can be considered limited and would not immediately require specific mitigation measures beyond the existing rules implemented or being developed by the EU and/or voluntary schemes. Their status may, however, evolve if supply/demand, policy incentives and/or trading patterns change in the future.

- **High risks were detected for several feedstocks and at various levels**, which would require additional mitigation measures. These risks include, but are not limited to:

    - Risks related to the physical characteristics of feedstocks are particularly high when the physical nature of feedstocks cannot be readily distinguished from non-Annex IX materials, either visually or through chemical testing. This is the case for certain types of ligno-cellulosic materials or used cooking oil (UCO).

    - Fraud risks over feedstock definition exist for many feedstocks which are not clearly or consistently defined across member states and outside the European Union. This is the case for novel feedstocks such as residues/effluents from cereal processing (e.g. ultrafiltration retentates), feedstocks with a very broad definition (e.g. biowaste) and feedstocks, which relate to a type of land or agricultural practice (e.g. intermediate crops or crops from degraded land).

    - Fraud risk enablers (secondary indicators) related to the length/complexity of supply chains, including the number of intermediaries or (non-EU) countries through which feedstocks navigate, were also identified for several feedstock categories. This is the case for feedstocks, which are produced in multiple locations and can be easily collected and traded globally, such as oilseed (e.g. palm derivatives), waste feedstocks (e.g. UCO) and processing residues, which feed into international fuel and chemical markets (e.g. methanol).

    - Finally, the novel nature of certain feedstocks and conversion processes entails risks for assurance systems, whereby assurance providers may not have sufficient knowledge or experience of the nature and technicalities of certain feedstocks, thus not being able to detect non-compliance. In addition, the availability of testing technologies may be a limiting factor in certain countries.

    - There appears to be no significant difference between the existing Annex IX feedstocks and the feedstocks shortlisted in this study, with regards to overall fraud risk. To date, used cooking oil remains one of the feedstocks with highest risks of fraud, based on documented and suspected cases. Therefore, additional fraud risk mitigation measures, as suggested in subtask 3.6, would be beneficial to the achievements of the objectives of EU RED II (and upcoming EU RED III), even if no new feedstock is added to the Annex IX as a result of this study. Feedstocks with similarities with UCO (other waste fats and oils) are likely to face similar fraud risks, and should therefore be carefully scrutinised, should they be added to Annex IX.

Subtasks 3.5 and 3.6 respectively looked at existing and new fraud risk mitigation measures. Since the enforcement of RED I, EU rules to mitigate fraud risks have become increasingly stringent, as exemplified in the detailed chain-of-custody and assurance requirements described in the assessment protocol used for EU-approval of voluntary schemes (European Commission, 2020a). In addition to compulsory rules, some voluntary schemes decided to apply additional measures to further reduce the risks of fraud within their certified supply chains. To date, no systematic monitoring of the efficiency of anti-fraud measures has been implemented to determine whether fraud cases are effectively fewer within supply chains certified by more stringent schemes. Such monitoring would prove challenging given the very limited number of formally reported and documented fraud cases to date (See Subtask 3.1), as opposed to the numerous cases, which are suspected but were not unravelled to date.

An initial step would therefore be to increase the scrutiny and document fraud cases more systematically, which should not be limited to deliberate large-scale frauds such as the Biodiesel Kampen case, but also include repeated non-compliances building upon systemic weaknesses or grey areas. This could be done by using the reporting requirements for certification bodies and voluntary scheme to document repeated non-compliances or identified systemic weaknesses and use these to adapt anti-fraud measures at EU level.

A solid basis for fraud mitigation measures exists at EU level and among voluntary schemes already implementing good practices, as illustrated in the previous sections. Reported and suspected fraud cases nevertheless remain worrying, especially for used cooking oil, for which a significant share of the traded volumes is suspected to be fraudulent, although many such claims remained non substantiated or documented to date. Some measures were evaluated as enabling the robustness of assurance systems, and should be further developed and/or systematically applied.

- Supporting voluntary schemes, assurance providers and economic operators with the understanding of biofuel supply chains, including but not limited to:

    - The definition and identification of feedstocks as co-products, residues or waste;

    - Technical specifications, such as production processes and, typical conversion yields;

    - The evaluation of local conditions, economically viable alternative uses of feedstocks and potential risk of market distortions.

Similarly, a set of minimum competencies and standardised training should be established by the European Union to improve on the consistency of audits.

- The tracking of feedstock characteristics and origin is paramount to the avoidance of fraud. It should increasingly rely on the use of advanced technologies, such as remote sensing (e.g. to identify degraded lands) and the development of the Union Database. Such a database could ensure that all the required feedstock and biofuel characteristics (e.g. nature, origin, GHG intensity, conversion yields, etc.) are stored in one place under the control of the European Union. Challenges exist, however, to avoid that the use of technologies become discriminatory vis-à-vis smaller producers and/or non-EU countries.

- The temporality of audits was also highlighted as an important element to allow assurance providers to verify compliance with specific land characteristics or cultivation/harvesting practices. In such cases, it could be a compulsory requirement for onsite audits to take place at a given time in the crop cultivation cycle.

- The physico-chemical testing of feedstocks to verify their characteristics remains relevant to address risks of intentionally substituting or mixing incentivised (i.e. included in Annex IX) and non-incentivised (i.e. not included in Annex IX) feedstocks. Testing comes with several logistical challenges, which could represent an obstacle for smaller operators in non-EU countries, due to the lack of available technologies or extra cost. Simple tests (e.g. colour, pH, etc.) could however be envisioned, which would not entail significantly higher costs, while allowing assurance providers to decide whether further investigation is required.

It should be acknowledged that the very nature of the mechanisms incentivising the use of advanced biofuel feedstocks in EU RED II inherently create an incentive for fraud by making biofuels from residual or waste feedstocks more valuable per unit mass than biofuels from virgin feedstocks, which requires robust fraud risk mitigation measures. In turn, fraud risk mitigation measures require means of implementation, which entails a combination of policy changes, modifications in voluntary schemes' documentation, additional training for assurance providers, monitoring means and EU-level coordination activities. These tasks apply at different levels of the decision chain and their implementation must not rely solely on assurance providers, who currently have limited means and competences to systematically and efficiently detect and investigate frauds on top of their auditing routine. Assurance providers are also confronted with split incentives – on the one hand needing to provide credible assurance opinions, on the other having to manage relationships with customers who may not welcome the additional cost of more intensive audit interventions even when carefully following the rules. Some of the suggested measures would require specific investigations among economic operators, which would require extra human resources and skills. The effective implementation of the suggested fraud mitigation measures would therefore require a coordinated response and a fair division of efforts and costs among economic operators, assurance providers, voluntary schemes, member states and EU institutions.

As an immediate step, existing mechanisms could be reinforced and expanded, including but not limited to:

- *Grievance mechanisms.* All voluntary schemes are required to develop and implement a grievance mechanism, which allows any third party (including member states or EU authorities) to flag any suspected case of non-compliance among certified operators. Such mechanism is currently limited to cases of non-compliances with official EU RED sustainability or chain-of-custody requirements, but could be further expanded to cover fraud risks more broadly. A more direct process could also be developed for "whistle-blowers" to flag any suspected fraud case directly to the European Commission, which could trigger both an investigation by voluntary schemes or accreditation bodies, as well as legal investigations involving national or EU-level anti-fraud offices.

- *National anti-fraud systems.* EU Member States generally have anti-fraud offices, which are solicited for a wide range of cases. Their scope of operations and responsibilities could be further expanded to take on specific biofuel fraud suspicions, which could entail conducting *ad hoc* investigations and liaise with voluntary schemes and/or the EU over the investigation results and any required action (e.g. suspension of certificate, legal case, etc.). Collaboration and exchanges of experience between national anti-fraud offices should also be enhanced.

In addition to the above, the European Commission (and/or Member States) could consider the possibility of developing dedicated biofuel fraud investigation capacity, possibly as part of the existing anti-fraud office (OLAF) or Human Environment and Transport Inspectorate (ILT), which would be entitled to trigger additional investigations over any biofuel supply chain certified by EU-approved schemes and bear associated costs. This would also ensure a higher degree of independence and flexibility for such investigations. The exact modalities of the functioning and responsibilities of such a unit (e.g. the possibility to directly suspend a certificate or trigger an extraordinary audit) would require further investigation and discussion with assurance providers.

The detailed governance and decision process of fraud case investigations, consequences and distribution of associated costs were not included in the scope of this study and would require further investigation and discussion.

10. FINAL CONCLUSIONS AND RECOMMENDATIONS

The project successfully achieved its main objectives, namely to:

1. Establish a shortlist of potential feedstocks for inclusion in Annex IX (Task 1);
2. Assess the shortlisted feedstocks against the relevant elements of EU RED II Article 28, in support of the delegated act process coordinated by the European Commission (Task 2); and
3. Assess the shortlisted feedstocks and existing Annex IX feedstocks against a set of fraud risk indicators based on existing and theoretical fraud cases (Task 3).

The scope of the project was extended beyond initial plans due to the large number of feedstocks suggested by stakeholders during the consultation period (Task 1) organised in Phase 1 (May-June 2020), which led to a long list of 127 feedstocks, distributed across 8 categories. This long list was reduced through a preliminary assessment consisting of basic questions to identify which candidate feedstocks could be considered as already included in Annex IX or as not eligible. The resulting shortlist included 32 feedstocks.

An in-depth assessment was conducted for the 32 shortlisted feedstocks in Task 2 to determine whether they could be eligible for inclusion in Annex IX, in line with EU RED II Article 28. The Consortium used the expertise of its members, literature review and a significant amount of additional material provided by stakeholders during the first consultation or through follow-up conversations. The results from Task 2 provide a comprehensive overview of potential risks and opportunities associated with the potential inclusion of new feedstocks in Annex IX related to the enforcement of a circular economy in the European Union, the environment, the industry/market (through potential distortions) and the demand for additional land.

Task 3 complemented this evaluation by looking at potential fraud risks for both shortlisted feedstocks and those already included in Annex IX. A set of fraud risk indicators was developed by the Consortium on the basis of documented fraud cases and our expertise.

In both Task 2 and Task 3, identified risks were accompanied by recommendations from the Consortium regarding their possible mitigation, either via existing policy or technical instruments, or through the development of additional regulation or guidance. The Consortium also flagged areas of uncertainty where more research and investigation would be required to fully appraise the environmental, social and economic risks and opportunities of adding new feedstocks to Annex IX.

The results of the assessments conducted in Task 2 and Task 3 for the shortlisted feedstocks are summarised in Table 52.

The results of the Task 2 assessment are simplified as follows:

- *Feedstocks with no concern* are those for which no significant concern was found or feedstocks for which any concern would be appropriately mitigated by an EU-approved voluntary schemes (e.g. minimum GHG savings).
- *Feedstocks with some concern* are those for which the overall level of risk might be considered acceptable or where a risk would only materialise in certain conditions. In such case, existing or new policy instruments or further feedstock specification could mitigate the identified concerns.
- *Feedstocks with significant concern* are those for which the identified concerns are significant and cannot easily be addressed by an EU-approved voluntary scheme, existing/new policy instrument or further feedstock specification.

The overall fraud risk assessment (Task 3) is based on the integration of different risk levels for the indicators developed (See Section **Error! Reference source not found.** onwards for details)

It should be noted that Table 52 only represents a very simplified picture of the assessment. For details, please refer to the previous sections of this report.

Table 52: Overview of Task 2 and Task 3 assessment for shortlisted feedstocks (including Annex IX – Part A/B eligibility)

Feedstock name	T2 Assessment (EU RED II – Art 28)	T3 Assessment (Overall Fraud Risks)
Bakery and confectionery residues and waste	Some concern Part B	Medium
Drink production residues and waste	Some concern Part B	Low
Fruit / vegetable residues and waste (except tails, leaves, stalks and husks)	Some concern Part B	Medium
Potato/beet pulp	Significant concern Part A (Bioethanol) Part B (Biogas)	Medium
Starchy effluents (up to 20% dry content)	Some concern Part B	Medium-High
Dry starch from corn fractionation (formerly 'Corn processing residues')	Significant concern Part B	Low
Dextrose ultrafiltration retentate, hydrol and raffinate from sugar refining (formerly 'Sugar extraction residues and waste' or 'Sugars (fructose, dextrose) refining residues')	Some concern Part B	High
Final Molasses (formerly 'Molasses')	Significant concern Part B	High
Vinasse	Some concern (sugarcane vinasse) Part B	Low-Medium
	Significant concern (thin stillage or sugarbeet vinasse) Part B	Low-Medium
Alcoholic distillery residues and waste	Some concern Part A (fusel oils) Part B (heads and tails)	Medium
Brewers' spent grain	Some concern	Low-Medium

(formerly 'Spent grains')	Part B	
Whey permeate	Some concern Part B	Low-Medium
Olive oil extraction residues (formerly 'Olive pomace and derivatives')	Some concern (de-oiled pomace) Part B	Low
	Significant concern (non-de-oiled pomace) Part B	Medium-High
Oil palm mesocarp fibre oil ('PPF oil') (formerly 'Palm mesocarp oil')	Some concern Part B	High
Raw methanol from kraft pulping (formerly 'Raw methanol from wood pulp production')	No concern Part B (further investigation required)	Medium
Cover and intermediate crops (formerly 'Grain, starch, sugar, oil, beans and meals derived from rotation crops, cover crops and catch crops')	Significant concern Part B	Low-Medium (Niche or primarily soil-improving cover crops)
		High (Commodity crops, e.g. corn, soy, wheat)
Biomass from degraded/polluted land (Non-lignocellulosic/non-cellulosic)	No concern (Low ILUC only) Part B	High (Degraded lands) Medium (Polluted lands)
	Some concern (Others) Part B	High (Degraded lands) Medium (Polluted lands)
Damaged crops unfit for human and animal consumption (Formerly 'Damaged crops')	No concern Part B	Medium
Category 3 Animal fats (formerly 'Animal fats Cat 3')	Significant concern Part B	Low
Category 2 and 3 Animal by-products (not fats) (formerly 'Animal residues (non-fat) Cat 2-3')	Significant concern (Cat. 3) Some concern (Cat. 2) Part A (biofuels) Part B (biogas)	Low
Municipal wastewater and derivatives (other than sludge) (formerly 'Municipal wastewater and derivatives (non-sludge)')	No concern Part A (biogas >30% concentration) Part B (biogas <30% concentration and	Low

	biodiesel)	
Soapstock and derivatives	Significant concern Part B	Medium-High
Brown grease	No concern Part B	Low-Medium
Fatty acid distillates	Significant concern Part B	Medium
Technical corn oil (formerly 'Various oils from ethanol production')	Significant concern Part B	Medium
Distillers' dried grain with solubles (DDGS) (formerly 'Distillers' grain and solubles (DGS)')	Significant concern Part A	Low
High oleic sunflower oil extraction residues (formerly 'Residues from oleochemical processing of high oleic sunflower oil')	Some concern Part B	High
Other biowaste	No concern Part B	Medium
Sea algae	Some concern Part A	Medium-High
Cyanobacteria	No concern Part B	Medium-High

As illustrated in Table 52, only a few feedstock categories combine "no concern" on EU RED II Article 28 criteria (T2) and a low or low-medium fraud risk level (T3), namely:

- Municipal wastewater and derivatives (other than sludge) (formerly 'Municipal wastewater and derivatives (non-sludge)')
- Brown grease

Adding these feedstocks to Annex IX could therefore have a limited risk regarding the Article 28 eligibility criteria and regarding fraud.

On the opposite end of the spectrum, some feedstocks combine significant concerns regarding their eligibility for inclusion in Annex IX (T2) and medium-high or high fraud risks (T3), namely:

- Final molasses
- Non de-oiled olive oil pomace
- Cover and intermediate crops (non-cellulosic)
- Soapstock and derivatives

This does not necessarily mean that those feedstocks should not be considered for inclusion in Annex IX, but the conditions through which this could be possible would need to be further investigated and defined, e.g. by looking at individual feedstocks instead of broader categories, by looking at specific geographies or by adding specific rules to the EU RED compliance process.

A majority of feedstocks are situated between these two ends of the spectrum, as they were marked with some concerns regarding Article 28 eligibility criteria and/or medium to high fraud risks. As detailed in the previous sections, the identified risks could be mitigated through existing policy instruments or by developing new ones. Here again, certain feedstock categories, as established in this study, may be too broad to efficiently capture and take into consideration the specificities of individual feedstocks.

Future studies could break down feedstock categories, which may allow additional feedstocks with limited concern over EU RED Article 28 criteria and low fraud risk to be identified. This could be particularly useful for broad categories such as cover and intermediate crops, which include a large number of crops, geographies and cultivation practices. The next feedstock assessment and related delegated act could look, for instance, at specific crop rotation systems that could be certified as not leading to additional direct or indirect demand for land. Such a new type of certification could indeed provide assurance that indirect effects (such as market distortions) are limited.

An important outcome of this study is that most of the feedstocks, , if added to Annex IX, would be eligible for Part B of the Annex. Due to the cap applied to Annex IX Part B feedstocks, several feedstocks may compete with each other, which would eventually impact prices, market dynamics, investments and innovation. This could be the case, for instance, for municipal wastewater and derivatives, whose use to produce bioenergy could provide multiple sustainability benefits in line with circular economy principles. Being added to Annex IX Part B would limit the increase in production and use of this material, unless Member States decide to increase the cap on Annex IX Part B feedstocks. On the other hand, inclusion in Annex IX Part B could serve to limit the market distortion and other risks of other feedstocks associated with some or significant concerns. Several waste or residue feedstocks are in a similar situation, whereby investments in innovation and commercialisation could be disincentivised, which would have serious consequences on this segment of the biofuel/biogas industry. This concern was raised by several stakeholders. For feedstocks that can be processed via both mature and advanced technologies, one possibility would be to mention the processing technology in Annex IX (e.g. "Feedstock A processed via technology X") to help address this issue without contradicting EU RED Article 28.

Aside from feedstock-specific observations regarding fraud risks, the study delivers considerable recommendations for policy-level actions to reduce such risk. Based on the expertise of the Consortium and literature review, it should be acknowledged that documented fraud cases are an underestimation of actual fraud cases. This is partly due to the lack of clear boundaries between what could be considered as fraudulent behaviours and "honest mistakes" due to the complexity of compliance rules (sustainability, traceability, assurance, etc.) across biofuel/biogas supply chains. A distinction should also be made between the mechanisms, which create an incentive for fraud (e.g. policy-based financial incentives) and the elements in the supply chain, which make fraud more easily achievable (e.g. an inconsistent definition or classification of feedstocks). These were respectively characterised by primary and secondary fraud risk indicators throughout the assessment.

While the efforts of the European Commission to increase the level of assurance around biofuel compliance with EU RED criteria since the enforcement of EU RED I must be commended, some areas of improvement exist for the monitoring of fraud cases and anti-fraud measures. Voluntary schemes will play a key role in further strengthening assurance systems against fraud risks, but a number of actions at policy level should be continued or initiated, such as the development of the Union Database or national/EU-level anti-fraud units.

As mentioned in several parts of this report, it should be acknowledged that the level of understanding and documentation on feedstock production processes, potential impacts to the environment, techno-economics and potential fraud risks varies greatly across the feedstocks assessed in this study. Therefore, the results of these assessments should not be regarded as definitive, especially for novel feedstocks, which are insufficiently documented. Improvements in the processes implemented throughout the supply chain may also change risk levels. This should be adequately appraised in future studies, in support of EU policy developments.

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Wan Isahak, W. N. R., Che Ramli, Z. A., Ismail, M., Jahim, J. M., & Yarmo, M. A. (2015*). Recovery and purification of crude glycerol from vegetable oil transesterification.* Separation and Purification Reviews, 44(3), 250–267. Available at: https://doi.org/10.1080/15422119.2013.851696

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12. TERMS AND DEFINITIONS

The following definitions are used throughout this report, as found in EU RED II (EU 2018/2001) and the Waste Framework Directive (2008/98/EC):

- ‘agricultural, aquaculture, fisheries and forestry residues’ means residues that are directly generated by agriculture, aquaculture, fisheries and forestry and that do not include residues from related industries or processing; ‘Advanced biofuels’ means biofuels that are produced from the feedstock listed in Part A of Annex IX; ‘Agricultural biomass’ means biomass produced from agriculture;
- ‘Biogas’ means gaseous fuels produced from biomass;
- ‘Biofuels’ means liquid fuel for transport produced from biomass;
- ‘Bioliquids’ means liquid fuel for energy purposes other than for transport, including electricity and heating and cooling, produced from biomass;
- ‘Biomass’ means the biodegradable fraction of products, waste and residues from biological origin from agriculture, including vegetal and animal substances, from forestry and related industries, including fisheries and aquaculture, as well as the biodegradable fraction of waste, including industrial and municipal waste of biological origin;
- ‘Biomass fuels’ means gaseous and solid fuels produced from biomass; ‘Forest biomass’ means biomass produced from forestry;
- ‘Biowaste’ means biowaste as defined in point (4) of Article 3 of Directive 2008/98/EC, i.e. biodegradable garden and park waste, food and kitchen waste from households, restaurants, caterers and retail premises and comparable waste from food processing plants;
- ‘Food and feed crops’ means starch-rich crops, sugar crops or oil crops produced on agricultural land as a main crop excluding residues, waste or ligno-cellulosic material and intermediate crops, such as catch crops and cover crops, provided that the use of such intermediate crops does not trigger demand for additional land;
- ‘Ligno-cellulosic material’ means material composed of lignin, cellulose and hemicellulose, such as biomass sourced from forests, woody energy crops and forest-based industries' residues and wastes;
- ‘Non-food cellulosic material’ means feedstock mainly composed of cellulose and hemicellulose, and having a lower lignin content than ligno-cellulosic material, including food and feed crop residues, such as straw, stover, husks and shells; grassy energy crops with a low starch content, such as ryegrass, switchgrass, miscanthus, giant cane; cover crops before and after main crops; ley crops; industrial residues, including from food and feed crops after vegetal oils, sugars, starches and protein have been extracted; and material from biowaste, where ley and cover crops are understood to be temporary, short-term sown pastures comprising grass-legume mixture with a low starch content to obtain fodder for livestock and improve soil fertility for obtaining higher yields of arable main crops;
- ‘Recycled carbon fuels’ means liquid and gaseous fuels that are produced from liquid or solid waste streams of non- renewable origin which are not suitable for material recovery in accordance with Article 4 of Directive 2008/98/EC, or from waste processing gas and exhaust gas of non-renewable origin which are produced as an unavoidable and unintentional consequence of the production process in industrial installations;

- ‘Renewable liquid and gaseous transport fuels of non-biological origin’ means liquid or gaseous fuels which are used in the transport sector other than biofuels or biogas, the energy content of which is derived from renewable sources other than biomass;

- ‘Residue’ means a substance that is not the end product(s) that a production process directly seeks to produce; it is not a primary aim of the production process and the process has not been deliberately modified to produce it;

- ‘Waste’ means any substance or object which the holder discards or intends or is required to discard.

Annexes to the Final Report

ANNEX A – LITERATURE REVIEW (TASK 1)

Reference	Feedstocks covered
Tean, B., Sath, K., et al. (2002). Utilization by pigs of diets containing Cambodian rubber seed meal. Livestock Research for Rural Development, 14(1). Retrieved from http://lrrd.org/lrrd14/1/ly141.htm	Rubber seed
Haas, M.J., Michalski, P.J., et al. (2003). Production of FAME from acid oil, a by-product of vegetable oil refining. Journal of the American Oil Chemists' Society, 80(1), 97-102 https://www.researchgate.net/publication/225513352_Production_of_FAME_from_acid_oil_a_by-product_of_vegetable_oil_refining	Soapstock, Soapstock acid oil
Watanabea, Y., Pinsirodomb, P., et al. (2007). Conversion of acid oil by-produced in vegetable oil refining to biodiesel fuel by immobilized Candida antarctica lipase. Journal of Molecular Catalysis B: Enzymatic, 44(3-4), 99-105. Retrieved from https://www.sciencedirect.com/science/article/pii/S1381117706002797	Acid oil
Directive 2008/98. Waste Framework Directive. European Parliament, Council of the European Union.	Waste Oils and bio-waste
Directive 2009/28. Renewable Energy Directive I. European Parliament, Council of the European Union.	Ethanol Feedstocks: sugar beet, wheat, corn. Biodiesel Feedstocks: rapeseed, sunflower, soybean, palm, waste animal and vegetable oil, biogas, waste wood.
Ecometrica, Eunomia, & Imperial College of London. (2009). Methodology and Evidence Base on the Indirect Greenhouse Gas Effects of Using Wastes, Residues, and By-products for Biofuels and Bioenergy. Retrieved from http://www.globalbioenergy.org/bioenergyinfo/bioenergy-and-climate-change/detail/en/c/39211/	Molasses, Municipal solid wastes (MSW), Straw, & Tallow
Stratford, J.M., & Contreras, R.J. (2010). Chapter 5 Peripheral gustatory processing of free fatty acid. In J.P. Montmayeur & J. le Coutre (Eds.), Fat Detection: Taste, Texture, and Post Ingestive Effects. CRC	Free fatty acid

Press/Taylor & Francis.	
Decree of 23 November 2011. Decree on the list of feedstocks eligible for double counting relating to the sustainability of biofuels and bioliquids. France, Ministry of Ecology, Sustainable Development, Transportation, and Accommodation.	Same list as in RED II
Franke-Whittle I.H., Insam, H. (2013). Treatment alternatives of slaughterhouse wastes, and their effect on the inactivation of different pathogens: A review. Critical Reviews in Microbiology, 39(2), 139-151. Retrieved from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3622235/	Slaughterhouse wastes
Searle, S., & Malins, C. (2013). Availability of cellulosic residues and wastes in the EU. Retrieved from the International Council on Clean Transportation https://theicct.org/sites/default/files/publications/ICCT_EUcellulosic-waste-residues_20131022.pdf	Cellulosic fraction of waste: Paper & cardboard, wood waste, food & garden waste; crop residues; forestry residues
Tractus Asia & Ecofys. (2013). Low ILUC potential of wastes and residues for biofuels. Retrieved from Navigant (Ecofys) http://www.mvak.eu/test5674213467/Ecofys_2013_low_ILUC.pdf	Straw, bark, branches, leaves, sawdust and cutter shavings, used cooking oil, corn cob
Urbancic, N. & Grabiel, T. (2013). Waste, Residues and Co-Products for Biofuels and Bioliquids. Retrieved from Transport & Environment http://www.birdlife.org/sites/default/files/attachments/Briefing%20%20Wastes%20and%20Residues%20and%20coproducts.pdf	Agricultural residues (straw; stover, husks & cobs; Palm oil mill effluent (POME); Press cake, including rape seed cake and soybean cake; Marcs and lees, including grapes, olives and other fruits; Bagasse; Palm kernel meal; and Empty fruit bunches and nutshells) Forestry residues (Treetops; Branches; Stumps; Leaves; Sawdust; Cutter shavings and scrap wood; and Wood pulp) Aquaculture and Fisheries Residues (Algae; and Fish scales, viscera and scrap) Processing Residues (Crude glycerin; Tall oil pitch; Animal fats classified as

	category I and II in accordance with EC/1774/2002 laying down health rules concerning animal by-products not intended for human consumption) Co-products (Agricultural residues (primary and secondary); Forestry residues (primary and secondary); Animal fats classified as category III in accordance with EC/1774/2002 laying down health rules concerning animal by-products not intended for human consumption; and Animal manure.
Piloto-RodríguezI, R., MeloI, E.A., et al. (2014). Conversion of by-products from the vegetable oil industry into biodiesel and its use in internal combustion engines: a review. Brazilian Journal of Chemical Engineering, 31(2). Retrieved from https://www.scielo.br/scielo.php?script=sci_arttext&pid=S0104-66322014000200002	Soapstock, soapstock acid oil, fatty acid distillate
Rahees, K. & Meera, L. (2014). Production of biodiesel from dairy waste scum. International Journal of Scientific & Engineering Research, 5(7), 194-199. Retrieved from https://www.ijser.org/researchpaper/Production-of-Biodiesel-from-Dairy-Waste-Scum.pdf	Dairy waste scum
Sushma S., Suresh R., & Yathish K.V. (2014). Production of Biodiesel from Hybrid Oil (Dairy Waste Scum and Karanja) and Characterization and Study of Its Performance on Diesel Engine. International Journal of Engineering Research & Technology, 3(7), 686-690, Retrieved from https://www.ijert.org/research/production-of-biodiesel-from-hybrid-oil-dairy-waste-scum-and-karanja-and-characterization-and-study-of-its-performance-on-diesel-engine-IJERTV3IS070674.pdf	Dairy waste scum and karanja oilseeds
Baral, A., & Malins, C. (2014). Comprehensive carbon accounting for identification of sustainable biomass feedstocks. Retrieved from the International Council on Clean Transportation https://theicct.org/sites/default/files/publications/ICCT_carbonaccounting-biomass_20140123.pdf	Short-rotation temperate forestry, stump removal, slash removal, reduced-impact logging (Brazil), forest thinning, switchgrass, corn stover, willow, Miscanthus

Toop, G., Alberici, S., et al. (2014). Trends in the UCO market. Retrieved from Navigant (Ecofys) https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/307119/trends-uco-market.pdf	Used cooking oil (UCO)
E4tech (UK) Ltd. (2014). Advanced Biofuel Feedstocks –An Assessment of Sustainability. Retrieved from Department for Transportation in the UK https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/277436/feedstock-sustainability.pdf	Crude tall oil, Black & brown liquor, tall oil pitch, Category III animal fats, Category I & II animal fats; small round-wood/pulp wood, sugarcane trash; bagasse; bark, branches & leaves; olive pits, Carbon Capture and Utilization (CCU) for transport purposes; Renewable liquid and gaseous fuels of non-biological origin; bacteria; bio-fraction of MSW, bio-fraction of commercial & industrial waste, straw, corn stover, animal manure, sewage sludge, POME, empty palm fruit bunches, crude glycerin; grape marcs & wine lees; nut shells, cobs, husks; saw dust & cutter shavings; UCO, Miscanthus, short rotation coppice, micro & macro algae
Alberici, S., Toop, G., & Weddige, U. (2014). Status of the tallow (animal fat) market. Retrieved from Navigant (Ecofys) https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/307110/status-tallow-market.pdf	Tallow, animal fats
Ling, K.C. (2014). Whey to Ethanol: A Biofuel Role for Dairy Cooperatives? Retrieved from the USDA Rural Development https://www.rd.usda.gov/sites/default/files/RR214.pdf	Whey permeate
Mullen, A., Alvarez, C., et al. (2015). Chapter 2 Classification and target compounds. In C. M. Galanakis (Eds.), Food Waste Recovery: Processing Technologies and Industrial Techniques (pp. 25-58). Academic Press.	Oil crop and oilseed processing wastes, fishery byproducts, meat byproducts, root wastes, dairy processing wastes, cereals
Directive 2015/1513. Indirect Land-Use Change Directive. European Parliament, Council of the European Union.	Straw, animal manure, sewage sludge, palm oil, tall oil pitch, crude glycerin, bagasse, grape marc, nut shells, husks, corn cobs, forestry biomass, non-food cellulosic material, non-biological renewable liquid and gaseous, used cooking oil, animal fats

Fine, F., Lucas, J.L., et al. (2015). Food losses and waste in the French oil crops sector. Oilseeds & fats Crops and Liquids (OCL), 22(3), Retrieved from https://www.ocl-journal.org/articles/ocl/full_html/2015/03/ocl150012-s/ocl150012-s.html	Free fatty acid, oilseed pressing waste
ICF International. (2015). Waste, Residue and By-Product Definitions for the California Low Carbon Fuel Standard. Retrieved from https://theicct.org/sites/default/files/publications/ICF_LCFS_Biofuel_Categorization_Final_Report_011816-1.pdf	Corn, sugarcane, wheat, sugar beet, cassava, soybean, rapeseed/canola, palm, cellulosic biomass, soybeans, Jatropha, soy oil, palm fruit, animal carcass for tallow, UCO, tallow, miscanthus, acid ester, Brown/sulphite liquor, dried distillers grains with solubles (DDGS), corn oil, crude tall oil, glycerol, Meal from virgin oil, molasses, palm fatty acid distillate, palm kernel oil, palm oil olein, palm stearin, POME, sugar beet pulp, arboricultural residues, bagasse, cob, forestry residue, husk, nut shell, straw, brown grease, cashew nut shell liquid, food waste, grape marc, starch slurry, manure, MSW, animal waste, acid ester, tall oil pitch, short rotation coppice, end-of-life tyre, sewage sludge, soapstock acid oil contaminated with sulphur, spent bleaching earth, free fatty acid, rapeseed residue
Parashar, A., Jin, Y., et al. (2016). Incorporation of whey permeate, a dairy effluent, in ethanol fermentation to provide a zero-waste solution for the dairy industry. Journal of Dairy Science, 99(3), 1859-1867. Retrieved from https://www.sciencedirect.com/science/article/pii/S0022030215009480	Whey permeate
Yuvaraj, D., Bharathiraja, B., et al. (2016). Production of biofuels from fish wastes: an overview. Biofuels, 10(3), 301-307. Retrieved from https://www.tandfonline.com/doi/abs/10.1080/17597269.2016.1231951?journalCode=tbfu20	Waste fish oil
Harsono, S.S., Setyobudi, R.H., & Zeemani, T. (2016). Biodiesel production from waste fish for zero waste concept in remote area of Eastern of Java, Indonesia. Jurnal Teknologi (Sciences and Engineering, 78(2-4), 215-219. Retrieved from http://repository.unej.ac.id/bitstream/handle/123456789/79701/11%2	Waste fish oil

0%20UTM%20Biodiesel%20Ikan.pdf?isAllowed=y&sequence=1	
European Court of Auditors. (2016). The EU system for the certification of sustainable biofuels [pursuant to Article 287(4), second subparagraph, TFEU]. Retrieved from the European Court of Auditors https://www.eca.europa.eu/Lists/ECADocuments/SR16_18/SR_BIOFUELS_EN.pdf	None. Report focuses on verification and certification of biofuels, and shortcomings of RED
Paltseva, J., Searle, S., & Malins, C. (2016). Potential for advanced biofuel production from palm residues in Indonesia. Retrieved from the International Council on Clean Transportation https://theicct.org/sites/default/files/publications/Indonesia%20Palm%20Oil%20White%20Paper_vFinal.pdf	Palm oil, palm residues, palm fronds, trunks, empty fruit brunches, palm press fiber, palm kernel shells
Hillairet, F., Allemandou, V., & Golab, K. (2016). Analysis of current development of household UCO collection systems in the EU. Retrieved from International Council on Clean Transportation https://theicct.org/sites/default/files/publications/Greenea%20Report%20Household%20UCO%20Collection%20in%20the%20EU_ICCT_20160629.pdf	Used cooking oil (UCO)
Visser, C.L.M de, & Ree, R. van. (2016). Small-scale Biorefining. Retrieved from Wageningen University & Research https://library.wur.nl/WebQuery/wurpubs/fulltext/405718	Wet agro-crops (grass, beets, maize, etc.), agro-residues (leaves/foliage), food processing residues and aquatic biomass (microalgae, duckweed, etc.).
Hamelinck, C., & Zabeti, M. (2016). Low carbon biofuels for the UK. Retrieved from Navigant (Ecofys) https://epure.org/media/1418/ecofys-2016-low-carbon-biofuels-for-the-uk.pdf	UCO

Chudziak, C., & Haye, S. (2016). Indirect emissions from rendered animal fats used for biodiesel. Retrieved from Navigant (Ecofys) https://ec.europa.eu/energy/sites/ener/files/documents/Annex%20II%20Case%20study%202.pdf	Animal fats
Searle, S., & Malins, C., & Christopher, J. (2016). Waste and residue availability for advanced biofuel production in EU Member States. Biomass and Bioenergy, 89(2016), 2-10. Retrieved from https://pubag.nal.usda.gov/catalog/5267579	Agricultural residues (barley, maize, oats, olives, rapeseed, rice, rye, soybeans, sunflower, triticale, wheat, and sugar beet), forestry residues (unused portions of felled trees, including tops and limbs, but exclude the below-ground parts of stumps), and biogenic wastes (paper and cardboard, wood, animal and mixed food, animal feces, urine, and manure, household wastes, sorting residues, common sludge)
United Kingdom Department of Transportation. (2017). Feedstocks including wastes and residues [RTFO Guidance valid from 15 April 2017 to RTFO Year 10]. Retrieved from https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/687475/list-of-wastes-residues-year-10.pdf	Acid ester, brown liquor, DDGS, corn oil, crude tall oil, glycerol from virgin oils, molasses, palm fatty acid distillate (PFAD), palm oil, slaughter products, starch slurry, sugar beet, tallow, bagasse, cobs, forestry residues, husks, nut shells, straw, brown grease, crude glycerin, food waste, manure, MSW, rapeseed residue, sewage sludge, soapstock acid oil, tall oil pitch, used cooking oil, waste wood, miscanthus, yellow grease
Elberson, W., Lammens, T.M., et al. (2017). Chapter 3 - Lignocellulosic Biomass Quality: Matching Characteristics with Biomass Conversion Requirements. In C. Panoutsou (Eds.), Modeling and Optimization of Biomass Supply Chains: Top-Down and Bottom-up Assessment for Agricultural, Forest and Waste Feedstock (pp. 55-78). Academic Press.	Lignocellulosic biomass
Peters, D., & Stojcheva, V. (2017). Crude Tall Oil low iLUC risk assessment. Retrieved from Navigant (Ecofys) https://www.upmbiofuels.com/siteassets/documents/other-publications/ecofys-crude-tall-oil-low-iluc-risk-assessment-report.pdf	Crude tall oil

Malins, C. (2017). Waste not want not. Retrieved from the International Council on Clean Transportation https://theicct.org/sites/default/files/publications/Waste-not-want-not_Cerulogy-Consultant-Report_August2017_vF.pdf	Animal fats, tall oil, tall oil pitch, glycerin, Sawdust and cutter shavings, black liquor, distillers' corn oil, Palm fatty acid distillate (PFAD)
El Takriti, S., Searle, S., & Pavlenko, N. (2017). Indirect impacts of EU ethanol derived from molasses. Retrieved from the International Council on Clean Transportation https://theicct.org/sites/default/files/publications/EU-molasses-ethanol-emissions_ICCT-working-paper_27092017_%20vF.pdf	Molasses, MSW, straw, tallow
Department for Transport. (2016). Decide if a material is waste or not: general guide [updated version of part 2 of original full document]. Retrieved from UK DFT https://www.gov.uk/government/publications/legal-definition-of-waste-guidance/decide-if-a-material-is-waste-or-not	MSW
Searle, S., Pavlenko, N., et al. (2017). Potential greenhouse gas savings from a 2030 greenhouse gas reduction target with indirect emissions accounting in the European Union. Retrieved from the International Council on Clean Transportation https://theicct.org/sites/default/files/publications/RED-II-Analysis_ICCT_Working-Paper_05052017_vF.pdf	Feedstock for Annex IX
Elbersen, B. S., Forsell, N., et al. (2017). Chapter 2 - Existing modeling platforms for biomass supply in Europe. In C. Panoutsou (Ed.), Modelling and Optimization of Biomass Supply Chains: Top down and bottom up assessment for agricultural, forest and waste feedstock (pp. 25-54). Academic Press. https://doi.org/10.1016/B978-0-12-812303-4.00002-1	Agricultural and forest residues

Ramirez Almeyda, J., Elbersen, B.S, et al. (2017). Chapter 9 - Assessing the Potentials for Nonfood Crops. In Panoutsou, C. (Eds.), Modeling and Optimization of Biomass Supply Chains: Top Down and Bottom Up Assessment for Agricultural, Forest and Waste Feedstock (pp 219-251). Academic Press.	Non-food crops
E4tech (2014-2017). Individual feedstock assessment reports prepared by E4tech for the UK Department for Transport (DfT)	Starch slurry, waste tires, waste oil and palm oil co-products
Directive 2018/2001. Renewable Energy Directive II. European Parliament, Council of the European Union.	Part A: Algae, if cultivated on land in ponds or photobioreactors; Biomass fraction of MSW from unsorted household waste; Bio-wastes separately collected from households; Biomass fraction of agro-industrial waste not fit for food or feed; straw; animal manure; sewage sludge; Palm oil mill effluent and empty palm fruit bunches; Tall oil pitch; crude glycerin; Bagasse; Grape marcs and wine lees; nut shells; husks; Cobs cleared of kernels of corn; Waste and residues from forestry and forest industries: bark, branches, precommercial thinnings, leaves, needles, tree tops, saw dust, cutter shavings, black liquor, brown liquor, fiber sludge, lignin, and tall oil; Other non-food cellulosic material, including for instance perennial grasses, but also non-starchy cover crops before and after main crops as well as ley crops. This category also includes industrial residues after the extraction of vegetable oils, sugars, starches and proteins.; Other ligno-cellulosic materials, including for instance woody short rotation crops, pulp logs and other forest-based biomass, but excluding veneer logs and saw logs. Part B: Used cooking oil; Animal fats with high risk for human health (Category 1) and animal fats suitable for soil enhancement and chemical industry (Category 2)
Royal Decree 235/2018. Calculation methods and information requirements in relation to the intensity of greenhouse gas emissions from fuels and energy in transport. Spain, Ministry of Energy, Tourism and Digital Agenda.	Feedstocks as in the iLUC Directive, i.e. +/- the same as in RED II, but with RFNBOs, RCFs and bacteria included.
Housel, T. (2018). Synthetic Esters: Engineered to Perform. Retrieved from Lexolube https://directory.lubesngreases.com/media/4C958A3A-E9CA-629B-156D-1D38513AAE05.pdf	Acid ester

Nieuwenhuis, E., Post, J., et al. (2018). Statistical modelling of Fat, Oil and Grease (FOG) deposits in wastewater pump sumps. Water Research, 135(2018), 155-167. Retrieved from https://www.sciencedirect.com/science/article/pii/S0043135418301313	Sewage FOG
Bonilla-Méndez, J.R., & Hoyos-Concha, J.L. (2018). Methods of extraction refining and concentration of fish oil as a source of omega-3 fatty acids. Corpoica Ciencia y Tecnología Agropecuaria, 19(3), 645-668. Retrieved from http://www.scielo.org.co/scielo.php?script=sci_arttext&pid=S0122-87062018000300645	Fish oil
Navigant (Ecofys) & Stockholm Environment Institute. (2019). Technical assistance in realization of the 2018 report on biofuels sustainability. Retrieved from European Commission https://ec.europa.eu/energy/sites/ener/files/documents/technical_assistance_in_realisation_of_the_2018_report_on_biomass_sustainability-final_report.pdf	Woody residues, straw, UCO, animal fats (tallow), crude tall oil, fatty acids
E4tech internal report on conformity of crude tall oil with RED low iLUC requirements (confidential).	Crude tall oil (CTO)
Baldino, C., Pavlenko, N., et al. (2018). The potential for low-carbon renewable methane in heating, power, and transport in the European Union. Retrieved from the International Council on Clean Transportation https://theicct.org/sites/default/files/publications/Renewable_Gas_EU-28_20181016.pdf	Livestock manure, Sewage sludge, Municipal and industrial solid waste; Crop residues, Logging residues
Von Cossel, M., Lewandowski, I., et al. (2019). Marginal Agricultural Land Low-Input Systems for Biomass Production. Energies, 12(2019). Retrieved from https://www.mdpi.com/1996-1073/12/16/3123/htm	Biomass sorghum, camelina, cardoon, castor, crambe, Ethiopian mustard, giant reed, hemp, lupin, miscanthus, pennycress, poplar, reed canary grass, safflower, Siberian elm, switchgrass, tall wheatgrass, wild sugarcane, and willow

Ranta, Liisa. (2020). Climate Positive Fuel for transport decarbonization. Retrieved from UPM Biofuels https://www.upmbiofuels.com/siteassets/documents/upm-biofuels-climate-positive-fuels-2020.pdf	Brassica carinata
Zanettia, F., Isbell, T.A., et al. (2019). Turning a burden into an opportunity: Pennycress (Thlaspi arvense L.) a new oilseed crop for biofuel production. Biomass and Bioenergy, 130(2019), 1-7. Retrieved from https://www.sciencedirect.com/science/article/pii/S0961953419303034?via%3Dihub	Pennycress (*Thlapsi arvense*)
E4tech (2019). Desk Study on Technical Corn Oil. Report for the Dutch Ministry of Infrastructure and Water Management. Retrieved from: https://zoek.officielebekendmakingen.nl/blg-879000.pdf	Technical corn oil
Baldino, C., Rosalie, B., et al. (2019). Advanced alternative fuel pathways: Technology overview and status. Retrieved from The International Council on Clean Transportation https://theicct.org/sites/default/files/publications/ICCT_advanced_alt_fuel_pathways_20190723.pdf	Generic feedstock description. Conversion routes to biofuels is the focus of the report
ISCC. (2018). Lists of material eligible for ISCC EU certification. Retrieved from https://certificates.iscc-system.org/cert-pdf/EU-ISCC-Cert-ES216-20183041.pdf	Animal fat (category 1), Animal fat (category 2), Animal fat (category 3), Animal fat (uncategorized), Bagasse, Brown grease / grease trap fat, Camelina, Cashew Nut Shell Liquid (CSNL), Corn / Maize cobs, Cotton seed, Crude glycerin, Crude tall oil, Empty palm fruit branches, (Free) Fatty Acids (specification of raw material/crop), Fish Oil Ethyl Ester (FOEE), Food waste, Forestry residues, Forestry processing residues, Giant cane, Grape marc, Grass, Husks, Jatropha, Manure, Mustard/Carinata, Nut shells, Oat, Oil palm fresh fruit bunches, Organic MSW, Palm Fatty Acid Distillate (PFAD), Palm kernel, Palm oil mill effluent (POME), Poultry feather acid oil, Rapeseed/Canola, Renewable component of end-of-life tyres, Roadside grass cuttings, Rye, Sewage sludge, Shea nuts, Short Rotation Coppice, Soapstock acid oil, Sorghum, Soybean, Spent bleaching earth, Waste starch slurry, Straw, Sugar beet, Sugar beet residues, Sugar cane, Sunflower, Tall oil pitch, Technical corn oil, Triticale, Used cooking oil (UCO) entirely of veg origin, Used cooking oil (UCO) entirely or partly of animal origin, Waste pressings (from production of vegetable oils), Waste/residues from processing of alcohol, Waste/residues from

	processing of vegetable or animal oil (specification of raw material or crop), Waste wood, Whey permeate, Wine lees
Smoliński, A., Karwot, J., et al. (2019). The Bioconversion of Sewage Sludge to Bio-Fuel: The Environmental and Economic Benefits. Materials, 12(15). Retrieved from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6696038/	Sewage sludge
United Kingdom Department of Transportation. (2020). Renewable Transport Fuel Obligation [List of Feedstocks including wastes and residues]. Retrieved from https://www.gov.uk/government/publications/renewable-transport-fuel-obligation-rtfo-guidance-2020/rtfo-guidance-feedstocks-including-wastes-and-residues	Products: Acid ester, Brown/sulphite liquor, Corn or wheat dried distillers grains with solubles (DDGS), Corn oil, Crude tall oil, Glycerol (refined) from virgin oils, Meal from virgin oil production, Molasses, Palm fatty acid distillate (PFAD), Palm kernel oil, Palm oil olein, Palm stearin, Slaughter products (category 3), Starch slurry regular, Sugar beet pulp, animal fats category 2, animal fats category 3, Uncategorized tallow, Virgin oils Agricultural residues: Arboricultural residues, Bagasse, Cobs, Forestry residues, Husks, Nut shells, Straw Wastes and processing residues: Brown grease, Cashew nut shell liquid, Crude glycerin, Empty palm fruit bunches, Ethanol used in the cleaning / extraction of blood plasma, Food waste (unsuitable for animal feed), Grape marc and wine lees, Manure, Organic municipal solid waste (MSW), Palm oil mill effluent (POME), Poultry feather acid oil, Rapeseed residue, Renewable component of end-of-life tyres, Roadside grass cuttings, Sewage sludge, Sewage system FOG, Soapstock acid oil contaminated with sulphur, Spent bleaching earth, Sugar beet tops, tails, chips and process water, Tall oil pitch, Tallow (processed animal fats) category 1, Used cooking oil (UCO), Waste pressings from production of vegetable oils, Waste slurry from the distillation of grain mixtures, Waste starch slurry, Waste wood

	Non-food cellulosic and ligno-cellulosic material: Miscanthus, Short rotation coppice (SRC) Renewable fuels of non-biological origin: CO2, water Other materials: Free fatty acids or acid oils or soapstocks, Used cooking oil (UCO) mixed with animal fats, Yellow grease
Baldino, C., Searle, S., & Zhou, Y. (2020). Alternative Uses and Substitutes for Wastes, Residues, and By-products Utilized in Alternative Fuel Production in the United States. (In Press)	Fats, oils, and greases (FOGs); PFADs; POME; forestry and paper industry by-products; glycerin; food wastes

Annex B – Preliminary Feedstock Assessment (Task 1)

1. Food-Feed Processing Residues and Waste

Subcategory	Examples	Biomass?	Food/feed crop?	Covered in Annex IX?	Shortlisted	Additional remarks
Bakery and confectionery residues and waste	Residues and waste from bread, biscuits, wafer, pastas, etc.	**Yes**	**No**	**Inconclusive.** Feedstock cannot be unequivocally considered as biowaste (Part A d)	**Yes.** Current Annex IX coverage could not be unequivocally established.	2nd consultation did not lead to clear conclusion with regards to non-energy uses
Drink production residues and waste	Citrus peel and pulp (pressing)	**Yes**	**No**	**Inconclusive.** Feedstock cannot be unequivocally considered as biowaste (Part A d)	**Yes.** Current Annex IX coverage could not be unequivocally established.	2nd consultation did not lead to clear conclusion with regards to non-energy uses
Drink waste	Waste wine and beverage (unfit for human consumption) Spent alcohols	**Yes**	**No**	**Yes.** Annex IX Part A d).	**No.** One preliminary assessment criterion not fulfilled.	Feedstock raised stakeholders' concerns regarding fraud risks, which require further investigation in T3 (Existing annex IX feedstocks will also be evaluated).
Fruit / vegetable residues and waste	Defective fruit /vegetables Waste from fruit / vegetable processing	**Yes**	**No**	**Inconclusive.** Feedstock cannot be unequivocally considered as biowaste (Part A d)	**Yes.** Current Annex IX coverage could not be unequivocally established.	2nd consultation did not lead to clear conclusion with regards to non-energy uses
	Potato/beet pulp	**Yes**	**Inconclusive.** Pulp could be considered	**Inconclusive.** Feedstock cannot	**Yes.** Current food/feed	Usable as feed

Subcategory	Examples	Biomass?	Food/feed crop?	Covered in Annex IX?	Shortlisted	Additional remarks
			a primary product from beet and potato cultivation.	be unequivocally considered as biowaste (Part A d)	crop match and Annex IX coverage could not be unequivocally established.	
	Tails Tops/leaves Stalks Husks	**Yes**	**No**	**Yes.** Annex IX Part A d).	**No.** One preliminary assessment criterion not fulfilled.	Different from the same material collected from cereals.
Bean shells, silverskin, and dust	Cocoa Coffee Hazelnut	**Yes**	**No**	**Yes.** Annex IX Part A d) and p)	**No.** One preliminary assessment criterion not fulfilled.	Cocoa bean shells may have other uses, but these remain marginal.
Shells/husks and derivatives	Nutshells Soy hulls	**Yes**	**No**	**Yes.** Annex IX Part A l) and p)	**No.** One preliminary assessment criterion not fulfilled.	
Starchy effluents (up to 20% dry content)	Starch slurry Steepwater	**Yes**	**No**	**Inconclusive.** Qualification as biowaste (part A d) could not be clearly established, due to potential other uses.	**Yes.** Further investigation of potential conflicts of use required.	Starch and other nutrients could theoretically be extracted for food/feed purposes. However, rapid degradation remains an issue (+ considered advanced in UK & NL)
Corn processing residue	Dry starch	**Yes**	**Inconclusive.** Although the company claims for	**No**	**Yes.** Further investigation required over	Different from starchy effluents. This is obtained from a process

Subcategory	Examples	Biomass?	Food/feed crop?	Covered in Annex IX?	Shortlisted	Additional remarks
			starch to be a residue, it may as well be considered a primary product.		potential uses and environmental performance.	called dry fractionation process, which aims to extract protein feeds and corn oil as its main purpose.
Sugars extraction residues and waste	Ultrafiltration retentate Monohydrate hydrol	**Yes**	**No**	**Inconclusive.** Cannot be clearly qualified as biowaste.	**Yes.** Further investigation about potential markets required.	These residues can currently be treated and reinjected in the process.
Molasses	Molasses	**Yes**	**Inconclusive.** Although molasses are a residue from sugar refining, they still contain high level of sugar content and can be used as food / feed.	**No**	**Yes.** Given lack of consensus over potential double counting, Task 2 evaluation will allow reaching more robust and impartial conclusions.	
Vinasse	Vinasse Thin Stillage	**Yes**	**No**	**No**	**Yes**	Possible other uses as fertiliser or adhesive for feed require further investigation.
Alcoholic distillery residues and waste	Heads and tails fusel alcohols/oils Technical ethanol	**Yes**	**No**	**Inconclusive.** Cannot be clearly qualified as biowaste.	**Yes.** Further investigation about potential markets	Could be considered as waste from spirits distillation (Ref 200/532/EC). Documented uses as

Subcategory	Examples	Biomass?	Food/feed crop?	Covered in Annex IX?	Shortlisted	Additional remarks
					required.	lubricant / solvent but exact demand unclear.
Spent grains	Brewers' spent grain/ spent grain (brewery)	**Yes**	**No**	**Inconclusive.** Cannot be clearly qualified as biowaste	**Yes.** Further investigation about conflicting uses and available amounts.	Possible use as food/feed requires further investigation
Residues and waste from production of hot beverages	Spent coffee grounds Spent tea leaves	**Yes**	**No**	**Yes.** Annex IX Part A b), c) and d	**No.** One preliminary assessment criterion not fulfilled.	Not part of EU Feed Catalogue. Other uses mentioned (e.g. mushroom medium) but demand appears limited compared to available material.
Dairy waste scum	Dairy waste scum	**Yes**	**No**	**Yes.** Annex IX Part A b), c) and d)	**No.** One preliminary assessment criterion not fulfilled.	Limited to dairy waste scum, which is not part of EU Feed Catalogue.
Food waste oil	Oil extracted from waste food from households and industry	**Yes**	**No**	**Yes.** Annex IX Part A b) and d).	**No.** One preliminary assessment criterion not fulfilled.	
Whey permeate		**Yes**	**No**	**No**	**Yes**	Several food/feed uses
Non-edible cereal residues and waste from grain milling and	Wheat Corn Barley	**Yes**	**No**	**Yes.** Annex IX Part A d).	**No.** One preliminary assessment criterion not	Non-edible means improper for use as food AND feed. Residues which are not fit for

Subcategory	Examples	Biomass?	Food/feed crop?	Covered in Annex IX?	Shortlisted	Additional remarks
processing	Rice				fulfilled.	human, but usable as feed are not covered under this definition.
Olive oil extraction residues and waste	Olive pomace	**Yes**	**No**	**No**	**Yes**	Several food use of pomace exist, which require further investigation in Task 2.
	Olive stones	**Yes**	**No**	**Yes.** Annex IX Part A d).	**No.** One preliminary assessment criterion not fulfilled.	

2. Agricultural / Forestry Residues And Waste

Subcategory	Examples	Biomass?	Food/feed crop?	Covered in Annex IX?	Shortlisted	Additional remarks
Agricultural harvesting residues	Straws Stems Stalks Shells (not nuts) Hulls (not soy)	**Yes**	**No**	**Yes.** Annex IX Part A p).	**No.** One preliminary assessment criterion not fulfilled.	
Palm harvesting residues	Palm fronds, palm trunk	**Yes**	**No**	**Yes.** Annex IX Part A p) and q).	**No.** One preliminary assessment criterion not fulfilled.	
	Palm mesocarp	**Yes**	**No**	**Yes (Fibre).**	**Yes (oil)**	Mesocarp fibers used to produce ligno-cellulosic

Subcategory	Examples	Biomass?	Food/feed crop?	Covered in Annex IX?	Shortlisted	Additional remarks
				Annex IX part A p). **No (Oil).** Cannot count as agriculture or processing residue.	**No (Fibre)**	fuels would be covered under Annex IX part p) Mesocarp oil used for biodiesel is currently being used and traded, but has a lower grade than CPO.
Cotton seeds		**Yes**	**Yes.** In several regions, cotton seeds and derivatives represent a significant source of income, relative to fibre.	**No**	**No.** One preliminary assessment criterion not fulfilled.	In spite of geographic disparities, seeds and oil can be considered as co-products.
Wood processing residues	Crude tall oil	**Yes**	**No**	**Yes.** Annex IX Part A o).	**No.** One preliminary assessment criterion not fulfilled.	
	Raw methanol from wood pulp production	**Yes**	**No**	**No.** Not listed in Annex IX Part A (o).	**Yes**	

3. Intermediate crops

Subcategory	Examples	Biomass?	Food/feed crop?	Covered in Annex IX?	Shortlisted	Additional remarks

Grain, starch, sugar, oil, beans and meals derived from rotation crops, cover crops and catch crops	Camelina Carinata Castor Silphium perfoliatum Tall wheat grass Tobacco	**Yes**	**No**	**No**	**Yes**	Intermediate crops are excluded from the definition of food and feed crops. The Consortium will look specifically at the production system used, first for intermediate crops generically, after which if necessary, the consortium will consider specific cases.

4. Landscape care biomass

Subcategory	Examples	Biomass?	Food/feed crop?	Covered in Annex IX?	Shortlisted	Additional remarks
Biomass from fallow land	Hay Legumes Grass	**Yes**	**No**	**No.** Cellulosic material is covered by Annex IX Part A p), but not grain, fruits or seeds.	**Yes**	
Biomass from degraded/ polluted land		**Yes**	**No**	**No**	**Yes**	
Biomass from maintenance operations	Roadsides Environmental protection areas Harvesting of invasive species Bush encroachment	**Yes**	**No**	**Yes.** Annex IX Part A c), o), p), q)	**No.** One preliminary assessment criterion not fulfilled.	Annex IXA part c) for parks o) for forest maintenance operations p/q) for bushes and grasses from other ecosystems.

Subcategory	Examples	Biomass?	Food/feed crop?	Covered in Annex IX?	Shortlisted	Additional remarks
Biomass harvested from mixture meadow	Timothy grass, tall fescue and clover/legumes	**Yes**	**No**	**No.** Cellulosic material is covered by Annex IX Part A p), but not grain, fruits or seeds.	**Yes**	
Damaged trees	Trees made improper for use as log grade due to diseases or other natural events	**Yes**	**No**	**Yes.** Covered under Annex IX Part A q).	**No.** One preliminary assessment criterion not fulfilled.	
Damaged crops	Food / feed crops made inedible due to diseases or other natural events	**Yes**	**No**	**No.** Cellulosic material is covered by Annex IX Part A p), but not grain, fruits or seeds.	**Yes**	High risk of fraud reported by stakeholders (to be investigated in Task 3)
Unused feed/fodder from ley		**Yes**	**No**	**Yes.** Annex IX Part A p).	**No.** One preliminary assessment criterion not fulfilled.	Ley crops grown for feed / fodder are covered in the definition of non-food cellulosic material.

5. Animal residues and waste

Subcategory	Examples	Biomass?	Food/feed crop?	Covered in Annex IX?	Shortlisted	Additional remarks
Animal fat (Cat 3)	Beef tallow Poultry fat Swine fat	**Yes**	**No**	**No**	**Yes**	

Animal residues (Non-fat; category 2, 3)	See EC Regulation 1069/2009	**Yes**	**No**	**No**	**Yes**	
Waste fish oil		**Yes**	**No**	**Yes.** The different fish oil categories are covered by different parts of Annex IX (See remarks)	**No.** One preliminary assessment criterion not fulfilled.	Food-grade fish oil would qualify as Animal by-product cat 3, hence already shortlisted (see previously). Cat 1-2 fish oil are already covered in Annex IX B.
Animal fat (Cat 1-2)	Beef tallow Poultry fat Swine fat	**Yes**	**No**	Covered in Annex IX Part B	No	Currently processed via conventional technologies (cannot fit under Annex IX A).
Other slaughterhouse waste *(Animal residues – Non-fat Category 1)*	Inedible animal tissues other than fat (organs, integument, ligaments, tendons, blood vessels, feathers, bone) derived from the production of meat	**Yes**	**No**	**Yes.** Covered in Annex IX A part d)	**No.** One preliminary assessment criterion not fulfilled.	Cat 1 material needs to be disposed of, either by incineration or as a fuel for combustion.
Manure and derivatives	Wet manure Dry manure Manure washwater	**Yes**	**No**	**Yes.** Annex IX Part A f).	**No.** One preliminary assessment criterion not fulfilled.	

6. Wastewater and derivatives

Subcategory	Examples	Biomass?	Food/feed crop?	Covered in Annex IX?	Shortlisted	Additional remarks

Municipal wastewater and derivatives (non-sludge)	Wastewater FOGs extracted from sewage	**Yes**	**No**	**No**	**Yes**	Municipal wastewater is outside the scope of the Waste Framework Directive (WFD), which Annex IX A b) and c) refer to for biowaste and mixed municipal waste.
Municipal wastewater (sewage) sludge		**Yes (Biogenic fraction)**	**No**	**Yes.** Annex IX Part A f).	**No.** One preliminary assessment criterion not fulfilled.	
Industrial wastewater and derivatives	Biodiesel wastewater Potato sludge Olive mill wastewater Food processing wastewater	**Yes**	**No**	**Yes.** Annex IX Part A d).	**No.** One preliminary assessment criterion not fulfilled.	All these materials are reportedly discarded.
Palm oil mill effluent (POME)		**Yes**	**No**	**Yes.** Annex IX Part A g)	**No.** One preliminary assessment criterion not fulfilled.	
Palm sludge oil		**Yes**	**No**	**Yes.** Annex IX Part A g).	**No.** One preliminary assessment criterion not fulfilled.	PSO is a residue that is removed in the same stream as POME but just before release in the POME ponds.

7. Fats, oils and greases (FOGs)

Subcategory	Examples	Biomass?	Food/feed crop?	Covered in Annex IX?	Shortlisted	Additional remarks
Soapstock and derivatives	Soapstock Acid oil Free fatty acids PSK-Keto	**Yes**	**No**	**No**	**Yes**	
Brown grease		**Yes**	**No**	**Partly** (Annex IX Part A d)	**Yes**	Partly covered (Industrial fryers) in Annex IXA part d) but not for restaurants and households. Could also fit under Annex IX B (along with UCO).
Industrial storage settlings	FAME storage settlings FAME distillation residues Waste tank bottom oil	**Yes**	**No**	**Yes.** Annex IX part A d)	**No.** One preliminary assessment criterion not fulfilled.	
Fatty acid distillates	PFADs Oilseed FADs	**Yes**	**Inconclusive.** FADs may be considered among primary products due to high value	**No**	**Yes.** Given lack of consensus over potential double counting, Task 2 evaluation will allow reaching more robust and impartial conclusions.	
Used vegetable ester and oil (waste stream)		**Yes**	**No**	**Yes.** Annex IX Part A d)	**No.** One preliminary assessment criterion not	Obtained via the segregation of bio-based products (e.g. lube) at

Subcategory	Examples	Biomass?	Food/feed crop?	Covered in Annex IX?	Shortlisted	Additional remarks
					fulfilled.	the end of life

8. Others

Subcategory	Examples	Biomass?	Food/feed crop?	Covered in Annex IX?	Shortlisted	Additional remarks
Biogenic fraction of municipal solid waste, refuse and compostable waste	Municipal Solid Waste Refuse Derived Fuels Biostabilized material & compost Biodegradable bio-based plastics	**Yes**	**No**	**Yes.** Annex IX Part A b, c) and d)	**No.** One preliminary assessment criterion not fulfilled.	Annex IXA part b)= MSW/Refuse from households c) = biostabilized material and compost d) = industrial waste and refuses
Plastic waste		**No.** Fossil fraction cannot qualify.	**No**	**No**	**No.** One preliminary assessment criterion not fulfilled.	Biodegradable fraction of bio-based plastic covered in previous category.
Biogenic fraction of end-of-life tyres	Oil from EOL Tyres	**Yes**	**No**	**Yes.** Annex IX Part A d).	**No.** One preliminary assessment criterion not fulfilled.	Energy recovery appears as the main use of EOL Tyres oil. Considered advanced in UK and Netherlands.
Various oils from ethanol production	Technical / Distillers Corn Oil	**Yes**	**No**	**No**	**Yes**	

Subcategory	Examples	Biomass?	Food/feed crop?	Covered in Annex IX?	Shortlisted	Additional remarks
Distillers grain and solubles (DGS)	Corn DDGS Wheat DDGS	**Yes**	**Inconclusive.** DGS may be considered a primary product, due to high economic value.	**No**	**Yes.** Given lack of consensus over potential double counting, Task 2 evaluation will allow reaching more robust and impartial conclusions.	May qualify as food/feed crop
Trees / bushes (Not sawlog/veneer grade)	Black locust Pongamia[16] Silvopastoral crops	**Yes**	**No**	**Yes.** Annex IX Part A p)	**No.** One preliminary assessment criterion not fulfilled.	
Recycled/waste wood	Wood from demolition and construction waste	**Yes**	**No**	**Yes.** Annex IX Part A (q).	**No.** One preliminary assessment criterion not fulfilled.	
Ligno-cellulosic crops or fraction of crops	Energy cane Energy crops and grasses (incl. Virginia mallow) Grass pulp Bagasse	**Yes**	**No**	**Yes.** Annex IX Part A c), j) or p).	**No.** One preliminary assessment criterion not fulfilled.	

[16] Pongamia seeds would not be shortlisted, as they would fit the food/feed crop definition, unless cultivated on degraded land (see previous categories).

Subcategory	Examples	Biomass?	Food/feed crop?	Covered in Annex IX?	Shortlisted	Additional remarks
Opuntia ("prickly pear")	Cactus that grows in semi-arid regions	**Yes**	**Yes.** It is considered that opuntia fruits are the primary product of the plant.	**No**	**No.** One preliminary assessment criterion not fulfilled.	
Humins	Residues from bio-based FDCA	**Yes**	**No**	**Yes.** Annex IX Part A d).	**No.** One preliminary assessment criterion not fulfilled.	No evidence provided of any ongoing use. Not part of EU Feed Catalogue
Residues from oleochemical processing of high oleic sunflower oil	High boiling vegetable fraction (FAV) Keto	**Yes**	**No**	**No**	**Yes**	Mostly composed of glycerides and carboxylic acids
Spent bleaching earth		**Yes (Biogenic fraction)**	**No**	**Yes.** Annex IX Part A d).	**No**	Bleaching earth per se is not biomass but may contain some. The earth part has no energy content
Waste biogenic CO2 and CO2 from Direct Air capture		**No**	**No**	**No**	**No**	Biogenic CO2 does not fit the definition of biomass since it is not biodegradable. Furthermore, it is not an energy carrier. Therefore CO2-derived fuels qualify either as Renewable Fuels from Non-Biological Origins (RFNBOs) or Recycled Carbon Fuels (RCFs).

Subcategory	Examples	Biomass?	Food/feed crop?	Covered in Annex IX?	Shortlisted	Additional remarks
Other biowaste	Biowaste as defined in point (4) of Article 3 of Directive 2008/98/EC	**Yes**	**No**	**No**	**Yes**	These are neither from households nor from industries (e.g. restaurants), hence not covered by Annex IXA d).
Sea algae		**Yes**	**No**	**No.** Only algae cultivated on land (open ponds/PBRs) are included in Annex IX.	**Yes**	
Cyanobacteria	*Arthrospira platensis*	**Yes**	**No**	**No**	**Yes**	

ANNEX C – EVALUATION OF FEEDSTOCK PROCESSING TECHNOLOGIES

Process	Input	Output	Mature or Advanced	TRL	CRL
Biogas:					
Anaerobic digestion (AD)	Feedstock	Biogas	Mature	9	5
Biogas upgrading	Biogas	Biomethane	Mature	9	5
Pre-treatment of lignocellulosic material for AD	Lignocellulosic feedstock	Treated feedstock	Advanced	5-8	1-2
Bioethanol/biofuels from sugars:					
Pre-treatment + enzymatic hydrolysis + Fermentation	Lignocellulosic feedstock	Bioethanol	Advanced	7-8	1-2
Fermentation	Sugars	Bioethanol	Mature	9	5
Aqueous phase reforming	Sugars	Fuels (e.g. jet)	Advanced	4-5	1
Biodiesel/FAME & HVO from oils:					
Oil extraction + Refining of oil + Transesterification	Feedstock	FAME (biodiesel)	Mature	9	5
Hydrotreating	Feedstock	HVO (Renewable diesel)	Mature	9	3
Refinery hydrotreater co-processing	Oils	Refined fuels	Mature	9	3
Biofuel routes through syngas:					
Gasification + Conditioning + Fischer-Tropsch (FT) + Upgrading	Feedstock	FT fuels	Advanced	5-6	1
Gasification + Methanol synthesis	Feedstock	Methanol	Advanced *	7-8	1-2
DME synthesis	Methanol	DME	Advanced	5	1
Methanol to ethanol	Methanol	Ethanol	Mature	8-9	2-3
Alcohol catalysis (e.g. MTG)	Alcohols (e.g. methanol)	Fuels (e.g. gasoline)	Advanced	5-6	1
Gasification + Conditioning + Methanation + Purification	Feedstock	BioSNG	Advanced	7-8	1-2
Gasification + Syngas	Feedstock	Bioethanol	Advanced	5-7	1

fermentation					
Refinery hydrocracker co-processing	FT wax	Refined fuel	Advanced	3-4	1
Other thermochemical BTL routes:					
Fast Pyrolysis	Feedstock	Pyrolysis oil	Advanced/ Mature*	8	2
Hydrothermal liquefaction	Feedstock	Bio-crude	Advanced	5-6	1
Catalytic upgrading (e.g. hydroprocessing)	Bio-crude, pyrolysis oil	Refined fuel	Advanced	3	1
Refinery FCC co-processing	Pyrolysis oil	Refined fuel	Advanced	5-6	1

Annex D – Shortlist of feedstocks to be assessed in Task 2 and Task 3

Category	Feedstock sub-category/examples
Food-feed processing residues and waste	Bakery and confectionery residues and waste
	Drink production residues and waste
	Fruit / vegetable residues and waste (except tails, leaves, stalks and husks)
	Potato/beet pulp
	Starchy effluents (up to 20% dry content)
	Corn processing residues
	Sugar extraction residues and waste
	Molasses
	Vinasse
	Alcoholic distillery residues and waste
	Spent grains
	Whey permeate
	Olive pomace and derivatives
Agricultural / Forestry residues and waste	Palm mesocarp oil
	Raw methanol from wood pulp production
Intermediate crops	Grain, starch, sugar, oil, beans and meals derived from rotation crops, cover crops and catch crops
Landscape care biomass	Biomass from fallow land (Non-lignocellulosic/non-cellulosic)
	Biomass from degraded/polluted land (Non-lignocellulosic/non-cellulosic)
	Biomass harvested from mixture meadow (Non-lignocellulosic/non-cellulosic)
	Damaged crops
Animal residues and waste	Animal fats Cat 3
	Animal residues (non-fat) Cat 2-3
Wastewater and derivatives	Municipal wastewater and derivatives (non-sludge)
Fats, oils and greases (FOGs)	Soapstock and derivatives
	Brown grease
	Fatty acid distillates
Others	Various oils from ethanol production
	Distillers grain and solubles (DGS)
	Residues from oleochemical processing of high oleic sunflower oil
	Other biowaste
	Sea algae
	Cyanobacteria

ANNEX E – INDIVIDUAL FEEDSTOCK EVALUATIONS (TASK 2)

Bakery and confectionary residues and waste

1. TECHNICAL DESCRIPTION

Feedstock description

Bakery and confectionery residues and waste are raw or baked material, primarily composed of carbohydrates (incl. starch, glucose, fructose, etc.), with variable amounts of proteins, fats and cellulose.

Bakery residues and waste are generated during the **production** of bread, pasta, wafer, dough and commercially supplied products containing bread or dough, such as sandwiches, pizzas or pies. Examples of bakery residues and waste include flour, dough, breadcrumbs, bread crust, fermentation residues, wastewater etc.

Confectionery residues and waste are generated during the **production** of sweets, including chocolate and sugar confectionery and gum products. Examples include cocoa residues, nuts, sugar, wastewater etc.

Bakery and confectionery residues and waste are also generated at the **distribution/retail stage** when businesses (e.g. supermarkets, bakeries and restaurants) discard unsold/expired products before they reach the end consumer.

In this assessment, a distinction is made between bakery and confectionery residues and waste, which may be used for **human food** purposes, those which may be used for **animal feed** purposes and those which may be **neither used for food or feed purposes** (e.g. as chemical ingredient or energy). It is, however, important to assess the economic feasibility of reusing bakery residues and waste as food or feed, especially to guarantee that they meet food safety standards, which may only apply for a fraction of the material, and in some situations.

Bakery and confectionery residues and waste generated by **households** are not considered in this category, since they are already covered in Annex IX category b) and c).

Production process

Bakery and confectionery residues and waste are generated at various points of the manufacturing of the main products, as exemplified in Figure 6 and Figure 7.

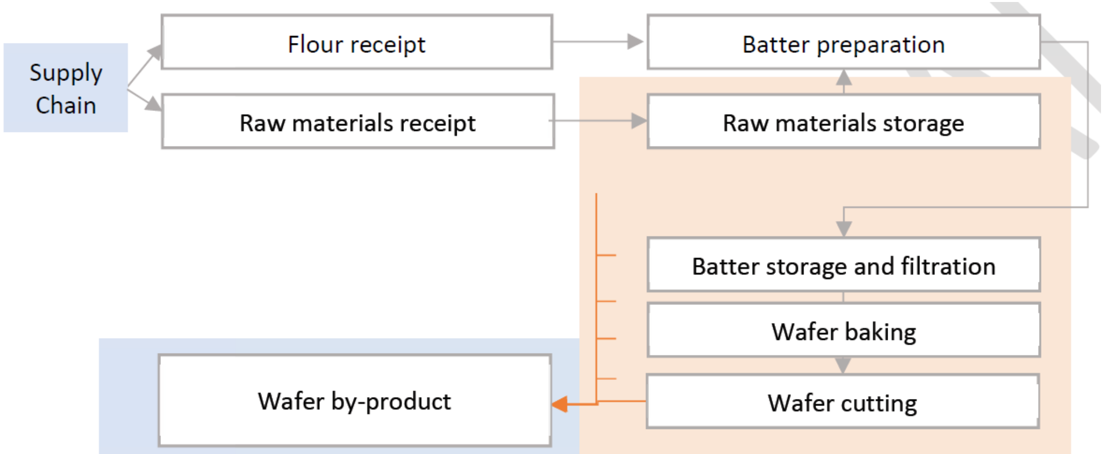

Figure 6: Example of bakery residues ("Wafer by-product") – Source: Ferrero (2020)

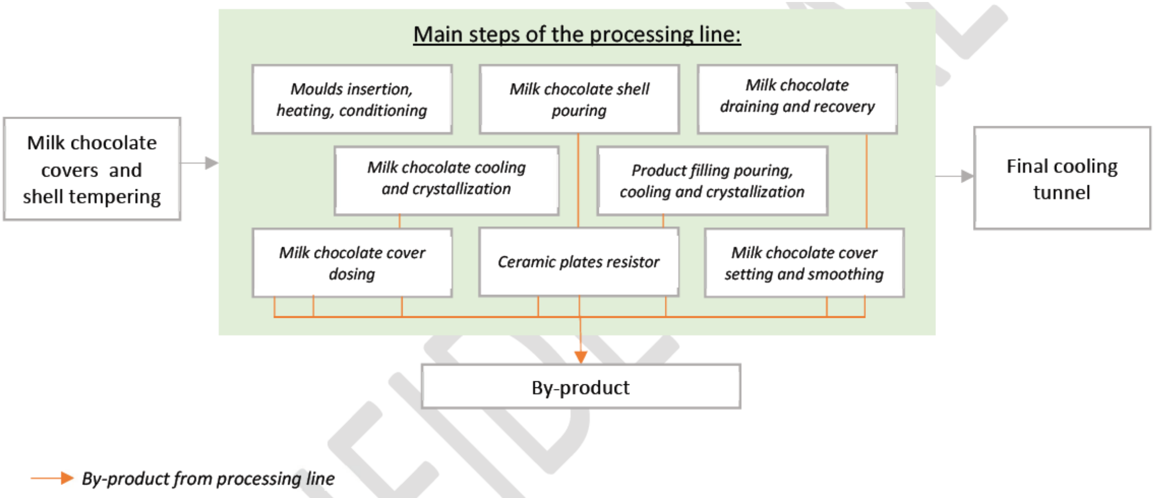

Figure 7: Example of confectionery residues ("By-product") – source: Ferrero (2020)

Possible uses

- Bakery and confectionery residues and waste from **production:**
    - Commercial producers of bakery and confectionery products participating in the stakeholder consultation organised in Phase 1 (Ferrero, 2020; European Biogas Association, 2020) report that bakery and confectionery residues and waste are used to produce **biogas via anaerobic digestion**, as they have "characteristics unsuitable for marketing and human consumption" and are "not even reusable within the production cycle, although [they have] good quality and hygiene characteristics". Additional communication from these stakeholders confirmed their view that that the processes required to make bakery and confectionery residues or waste suitable for re-use in the food production cycle would involve high sanitization costs. This would mean that this option was not economically attractive compared to using those residues for biogas production. Bakery and confectionery residues and waste can also be co-digested in combination with energy crops and manure. Biogas digestate can be used as fertiliser (IEA, 2018). Biogas may be further upgraded into biomethane.
    - According to the European Commission (2007), bakery and confectionery "by-products" (considered here equivalent to "residues"), have nutritional characteristics similar to the raw materials from which they originated and are **suitable for animal feed**, once integrated with other nutrients. Heuzé et al. (2018) report that 10-25% of bakery waste is used as animal feed.
    - No documented use of bakery and confectionery residues and waste for **human food purposes** was found in this study, although some of these residues and waste could meet human food quality standards if further treated for that purpose (Ferrero, 2020).
- Bakery and confectionery residues and waste from **distribution/retail:**
    - Significant amounts of bread and other bakery/confectionery products are discarded by businesses before being purchased by end-customers because they reached their expiry date or do no longer meet standards of freshness. Brancoli et al. (2020) establishes a hierarchy of uses for bread returned from retail, including the possible donation of bread, which still meets human food consumption standard, followed by use as feed. The Guardian (2018a) reports that Gail's Bakery reuses breadcrumbs from leftover loaves to produce porridge

and sourdough. Heuzé et al. (2018) report frequent use as animal feed but report challenges when using returned bread as feed, due to animal health concerns, moisture content, and nutrient variability. Several beer companies are also using surplus bread from sandwich factories as feedstock for brewing beer (The Guardian, 2018b).

- Several documented examples exist of returned bread and bakery products being used for energy purposes:
  - For fuel ethanol production via fermentation (St1 Oy, 2020; Wessberg & Eerola, n.d.; Bacovsky, 2020), with liquid animal feed and biogas generated as co-products (See Figure 8);
  - For biogas production via anaerobic digestion, possibly as part of combined heat and power unit (Veolia, 2017). Biogas digestate can be used as fertiliser; and
  - As biodiesel feedstock, although no evidence could be found of a commercially viable implementation to date (Hull Live, 2011).

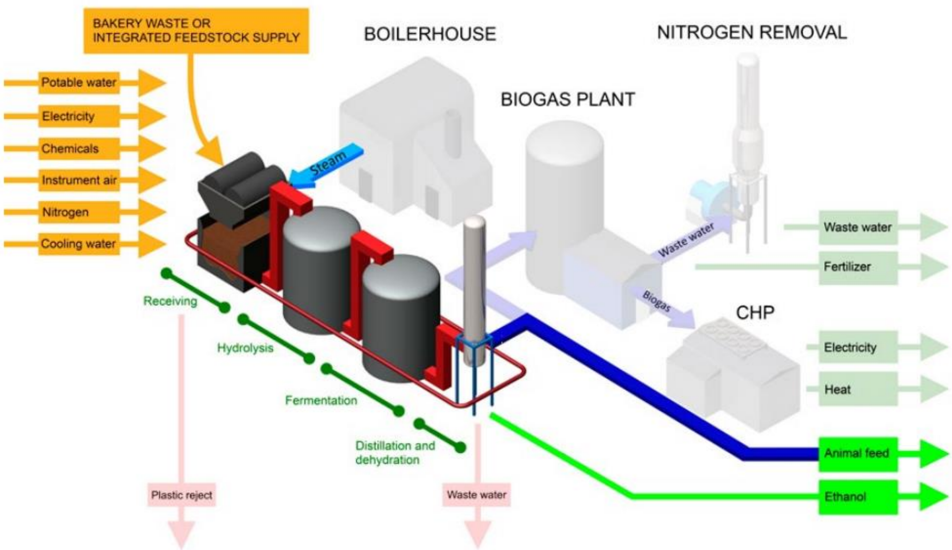

Figure 8: Ethanol production (Etanolix®) based on bakery residues and waste (Source: St1)

- The BREAD4PLA project (European Commission, 2010) establishes the optimal conditions to produce poly-lactic acid (PLA) from bakery residues and waste. No documented evidence exists that bakery or confectionery residues and waste are used commercially to produce bio-based chemicals.

Possible uses of bakery and confectionery residues and waste are summarised in Table 53.

Table 53 : Summary of possible uses of bakery and confectionery residues and waste

	Food use	Feed use	Other uses
Bakery and confectionery **production** residues and waste	No documented evidence of commercial implementation. Lack of economic attractiveness compared to energy uses.	Documented evidence of commercial implementation.	Biogas/biomethane: Documented evidence of commercial implementation. PLA: Possible in theory. No documented evidence of commercial

			implementation.
Bakery and confectionery **distribution / retail** residues and waste	Return schemes exist whereby unsold bread can be donated for food use. Documented evidence of commercial use to produce porridge and sourdough. Documented evidence of use for beer making.	Documented evidence of commercial implementation.	Biogas (+ compost): Documented evidence of commercial implementation. Bioethanol: Documented evidence of commercial implementation. Biodiesel: Possible in theory. No documented evidence of commercial implementation. PLA: Possible in theory. No documented evidence of commercial implementation.

2. Circular economy and waste hierarchy

Result from the Circular economy and waste hierarchy assessment.

2.1. Classification of the feedstock as a co-product, residue or waste

On the basis of the feedstock description provided in sub-section 0, its possible uses in sub-section 0, stakeholder feedback and additional references, bakery and confectionery residues and wastes can be classified as residues or wastes as described below.

Table 54 : Classification of bakery and confectionery residues and waste

Evaluation question	Answer	Rationale
Is the feedstock the primary aim of the production process?	No	Bakery / confectionery products are the primary aim of the production process.
Does the feedstock have any economic value, but is not the primary aim of the process, and therefore a residue?	Variable	Material that is suitable for food/feed (European Commission, 2013) and is currently used for generating energy such as bioethanol or biogas combined with cogeneration (IEA, 2018; St1 Oy, 2020; Veolia, 2017) or fertilizer by composting (IEA, 2018) or biochemicals like PLA and succinic acid (European Commission, 2010; Zhang, 2013) is considered to have economic value. Such feedstock can be defined as **residue.** Note: This material can be mixed with material that is inedible for both humans and animals, such as, rejected chocolates and sweets that are not suitable for sale or reprocessing (Confectionery Production, n.d.). Mouldy bread that is inedible for humans can be fed to pigs, however, if they feed on this regularly then it is said to reduce the quality of their meat (The Pig Site, 2011). A large portion of feedstock, which would in theory be suitable for food/feed or energy generation or
Is the feedstock normally discarded, and therefore a waste?	Variable	

		fertilizers or biochemicals, is discarded and sent to landfill (Southey, 2020; IEA, 2018) or incinerated without energy recovery (IEA, 2018). This feedstock can be mixed with material that is inedible for both humans and animals. These constitute a **waste.**

2.2. Is the use of feedstock to produce biofuel/biogas in line with circular economy principles?

- **Does the feedstock have non-energy (re)uses, which could extend its life or sequester carbon for longer?**

Answer: No.

Rationale: Residues generated during the production process or distribution may theoretically be reused to produce food/feed items (Mwai, n.d.; Baker Group, 2011). However, contributions from industries to the stakeholder consultation state that bakery/confectionery residues are often sold to biogas producers, rather than being reused in the food production process, which would not be economically attractive. Evidence of the commercial use of bakery and confectionery residues and waste from both production and distribution/retail as feed are documented. Therefore, the economic viability of non-energy uses may change in different geographic and economic contexts. In any case, use for food/feed would not constitute a significant extension of the life-time. It would only temporarily extend the life-time of the material, which eventually exits the circular chain by being released into the environment (air, soil and water) through human or animal metabolism, even when manure is collected for biogas production.

Inedible waste cannot be used as food/feed but can be used for energy recovery as well as production of fertilizers and bio-based chemicals (Zhang, 2013), which would sequester their carbon over a longer period than if these are used to produce biofuel or biogas. However, no evidence exists of commercial application.

- **Does its use as biofuel/biogas feedstock contribute to nutrient recovery?**

Answer: Variable.

Rationale: Anaerobic digestion of bakery and confectionery residues and waste generates a digestate, which retains C, N, P and other important nutrients and can be used as fertiliser, thus contributing to decreasing the need for industrial fertiliser production (IEA, 2015; European Commission, 2019).

Bioethanol or biodiesel derived from bakery or confectionery residues and waste have no documented contribution to nutrient recovery.

- **Does its use as biofuel/biogas feedstock contribute to a more efficient use of resources by avoiding primary material extraction?**

Answer: Variable.

Rationale: As with all other biomass feedstocks, biofuels and biogas derived from bakery/confectionery residues and waste displace fossil fuels and natural gas, thus reducing the need for primary material extraction. When economically feasible, reusing food/feed-grade bakery or confectionery residues in food/feed chains (rather than as bioenergy) would, however, reduce the need for primary production (e.g. sugar, cereals) as well. It should be noted that the nutritional value may or may not be at par with conventional food/feed. Furthermore, it is important to assess whether it meets safety standards for food/feed.

Finally, comparative benefits of using edible residues for energy rather than in food chains through avoided primary material extraction should be further explored to assess which use should be prioritised at policy level.

- **Does its use as biofuel/biogas feedstock contribute to reducing waste generation, especially food waste?**

Answer: Variable.

Rationale: Transforming bakery/confectionery residues and waste into energy, which eventually displaces fossil fuels, has higher environmental benefits than if these residues/wastes were discarded or landfilled. Industry stakeholders reported that bakery/confectionery residues were sold to biogas producers, thus generating additional revenues, which could constitute an incentive against trying to improve food chain efficiency to reduce the share of residues or waste. It is, however, unclear whether such extra revenues would be higher than if those were re-used in food/feed chains. Whenever selling residues or waste for energy recovery is the only alternative to discarding these materials, using them as biofuel/biogas feedstock does indeed contribute to reducing waste generation.

It should be noted, however, that including bakery and confectionery residues in Annex IX could further incentivise their use as biofuel at the expense of the desirable increase in use as feed or food.

2.3. Is the use of this feedstock for biofuel/biogas production in line with the waste hierarchy?

The following questions apply to bakery and confectionery waste.

- **Contribution to increasing waste?**

Answer: No.

Rationale. No evidence exists that using bakery or confectionery residues and waste for biogas or biofuel production would generate more waste. However, there could be a broader risk to create an incentive against reducing waste by offering an extra source of income to manufacturers of bakery or confectionery products.

- **Can this feedstock be potentially reused?**

Answer: No.

Rationale: The documentation received during the stakeholder consultation and additional references indicate that bakery and confectionery residues and waste can be used, primarily as feed and, to a lesser extent, in food chains (incl. using waste bread as a baking ingredient by tailored lactic acid fermentation – See Immonen, 2020). This cannot, however, be considered as "reuse" given that no primary use of the feedstock was made.

- **Can this feedstock be potentially recycled?**

Answer: No.

Rationale: Recycling does not apply to food material.

2.4. Conclusion

Contribution to circular economy

There is no demonstrated commercial use of bakery or confectionery residues for material/chemical purposes, which could ensure a significantly longer life time and/or carbon sequestration than energy uses (biogas, bioethanol and biodiesel). Using bakery or confectionery residues for energy does neither contribute to, nor contravene circular economy principles or the waste hierarchy.

With regards to contributing to waste reduction, it can be expected that further encouraging the use of bakery or confectionery residues for biogas or biofuel risks incentivising producers against improving processes and reducing the amount of residues being generated, and/or being detrimental to non-energy uses (food or feed) of these feedstocks, should these be economically and technically feasible.

Alignment with the waste hierarchy

Using bakery/confectionery waste for biogas/biofuel is in line with the waste hierarchy under the following conditions:

- Waste do not meet food or feed quality standards.
- Waste, for which a food or feed use is not economically viable for the economic operator or the logistical chains to collect and/or process residues and waste into food or feed chains are not in place, and could not be readily put in place.

Whenever using bakery or confectionery waste as food or feed ingredient is both logistically and economically possible, using these feedstocks for energy purposes (biogas, bioethanol and biodiesel) is not in line with the waste hierarchy.

One possibility could be for EU-approved voluntary schemes to include a requirement for assurance providers to assess whether the opportunity to use bakery/confectionery waste as food or feed ingredient exists in the context of an economic operator, as part of the audit and certification of biofuel/biogas produced out of bakery/confectionery waste. Economic operators may be required to demonstrate that food/feed use was logistically and/or economically difficult. The exact modalities of adding such requirement to the existing scope of EU-approved voluntary schemes would, however, require further discussion and guidance for implementation, given that this would entail gathering and analysis complex economic data, which all economic operators may not be able to access.

3. SUSTAINABILITY AND GREENHOUSE GASES

3.1. Union sustainability criteria

None of the union sustainability criteria are applicable to bakery or confectionery residues or waste.

3.2. GHG Savings Criteria

Two conversion processes are considered in this section: biomethane via anaerobic digestion and biogas upgrading; and bioethanol via fermentation.

No default value exists in REDII for **biomethane derived from bakery or confectionery residues and waste**. Nevertheless, default values for biomethane production from biowaste can be considered an acceptable proxy, given that biowaste includes, among other things, food and kitchen waste from food processing and restaurants[17].

Based on the values available in REDII for biowaste, GHG emission savings of biomethane derived from bakery and confectionery residues would range between 20 and 80%, depending on whether digestate is stored in an open or a closed tank and whether the off-gas is vented or combusted (see Figure 9). Therefore, to be eligible with the 65% minimum GHG saving threshold, operators producing biomethane from bakery and confectionery residues and waste should ensure that the resulting digestate is maintained in a closed infrastructure and off-gas combustion is applied.

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17 As per Directive 2008/98/EC, ‘biowaste’ means biodegradable garden and park waste, food and kitchen waste from households, restaurants, caterers and retail premises and comparable waste from food processing plants

BIOMETHANE FOR TRANSPORT (*)			
Biomethane production system	Technological options	Greenhouse gas emissions savings – typical value	Greenhouse gas emissions savings – default value
Biowaste	Open digestate, no off-gas combustion	43 %	20 %
	Open digestate, off-gas combustion	59 %	42 %
	Close digestate, no off-gas combustion	70 %	58 %
	Close digestate, off-gas combustion	86 %	80 %

(*) The greenhouse gas emissions savings for biomethane only refer to compressed biomethane relative to the fossil fuel comparator for transport of 94 g CO_2eq/MJ.

Figure 9. Default GHG emissions savings values provided in REDII for biomethane from biowaste (proxy for bakery residues and waste)

No default value exists in REDII for **bioethanol derived from bakery or confectionery residues and waste**, but it can be estimated as follows:

$$E = e_{ec} + e_l + e_p + e_{td} + e_u - e_{sca} - e_{ccs} - e_{ccr}$$

Where

E = total emissions from the use of the fuel;
e_{ec} = emissions from the extraction or cultivation of raw materials;
e_l = annualised emissions from carbon stock changes caused by land-use change;
e_p = emissions from processing;
e_{td} = emissions from transport and distribution;
e_u = emissions from the fuel in use;
e_{sca} = emission savings from soil carbon accumulation via improved agricultural management;
e_{ccs} = emission savings from CO_2 capture and geological storage; and
e_{ccr} = emission savings from CO_2 capture and replacement.

In line with Annex V in RED II, bakery and confectionery residues and waste are considered "to have zero life-cycle greenhouse gas emissions up to the process of collection of those materials irrespectively of whether they are processed to interim products before being transformed into the final product." For the purpose of this calculation, it is assumed that no CO2 capture and storage/replacement (CCS/CCR) is implemented. Finally, emissions in use are assumed to be zero for any biofuel and bioliquid.

Therefore the above formula can be simplified as:

$$E = e_p + e_{td}$$

No disaggregated default value could be found for processing ethanol from bakery or confectionery residues and waste (e_p), either in RED II, JEC's Well-to-Tank report (Prussi et al., 2020), GREET or academic literature. Disaggregated default values for processing in RED II for sugarcane, sugar beet, corn and wheat ethanol range from 1.8 g CO_2eq/MJ (sugarcane ethanol) to 42.5 g CO_2eq/MJ (other cereals with lignite as process fuel in CHP Plant). The disaggregated default value for transport and distribution (e_{td}) in RED II Annex V ranges between 2.2 and 2.3 g CO_2eq/MJ (the default value for sugarcane ethanol was deliberately ignored, since it assumes transatlantic shipping, which would not occur in the case of ethanol derived from bakery/confectionery residues or waste).

Total GHG emissions for bioethanol derived from bakery/confectionery residues or waste would therefore range between 4 g CO_2eq/MJ and 44.8 g CO_2eq/MJ, which would represent between 52% and 96% GHG savings (using RED II fossil comparator of 94 g CO_2eq/MJ). When using any e_p value (processing) without lignite as processing fuel, the maximum GHG emissions obtained are 31.5 g CO2eq/MJ (using "other cereals excluding maize ethanol (natural gas as process fuel in conventional boiler" as proxy), i.e. minimum 66% savings, which is above the required 65% savings for biofuels, biogas (biomethane) consumed in the transport sector, and bioliquids produced in installations starting operation from 1 January 2021. Therefore, the risk of bioethanol derived from bakery/confectionery residues and waste of not complying with the GHG savings requirement in REDII is considered to be low.

3.3. Other environmental impacts

Bakery/Confectionery residues and waste do not require dedicated land cultivation and therefore have no land management impact. The evaluation of risks of adverse effects on soil, water, air and biodiversity is not applicable.

4. MARKET EFFECTS AND 2030/2050 POTENTIAL

4.1. Market effects

Bakery and confectionery residues are produced in large amounts in the European Union, which is the largest world exporter of processed agricultural products (European Commission, 2021). Given the rapid degradation of food residues, it is assumed that bakery and confectionery residues are primarily used locally; therefore any market effect will rather be triggered by local supply and demand patterns, rather than EU-wide or global supply and demand. No specific statistics could be found on the exact production of bakery and confectionery residues and waste in the European Union or in the rest of the world, due to incomplete and heterogeneous dataset. In 2012, food waste generated at processing and wholesale/retail levels in the European Union was estimated at 21.5 million tonnes, which includes bakery and confectionery residues and waste (Stenmarck et al., 2016). While the market for bakery products is expected to keep growing through 2025 in Eastern Europe, markets in Western Europe are deemed saturated and are not expected to grow in the coming years. Therefore, it can be expected that volumes of bakery and confectionery residues generated in the European Union will either stagnate or undergo a moderate growth in the foreseeable future. The supply of bakery and confectionery residues can be considered as rigid, as it is dependent on the production of bakery and confectionery products.

As described in Section 1, a limited amount (10-25%) of bakery residues and waste are currently being used as animal feed (Heuzé et al., 2018), thus leaving a significant amount (75-90%, i.e. approx. 16.1 to 19.3 million tonnes in the EU, based on current food waste at processing and wholesale/retail) potentially available for other uses, including energy production in the coming decades. Therefore, the risk of market distortion of the animal feed market appears limited. A risk exists that inclusion in Annex IX and subsequent double counting may prevent an increase in food/feed uses.

Stringent policies to reduce the amount of bakery and confectionery residues and waste at processing and retail/wholesale levels and incentives to increase food and/or feed uses may however reduce the amounts of feedstock locally available for energy uses. This could create local competition between food/feed use and biogas or bioethanol production and local market distortions, although there is no evidence that such competition would create market distortions at a larger scale.

Considering the current use of bakery and confectionery residues, there is low risk of distortion of the animal feed market if this feedstock was to be added to Annex IX.

4.2. 2030/2050 Potential

The future potential for bakery and confectionery residues in the European Union will depend on how the market for bakery and confectionery products develops, which itself depends on the evolution of the EU population and lifestyle. As mentioned in Section 4.1, a limited growth in this sector is expected in the coming years, mostly in Eastern Europe. Meanwhile, the population in the European Union is expected to decline by 2050, compared to current levels (European Commission, 2012). On this basis, production levels for bakery and confectionery residues will likely remain stable, although a number of parameters would require additional investigations, namely:

- The effects of climate change on EU cereal productions and imports, which directly affects EU bakery products;
- The effects of climate change and other geopolitical elements on EU capacity to import raw materials used in confectionery products (e.g. cocoa, coconut and sugar);
- Changes in lifestyle, which could increase/reduce the consumption of bakery and confectionery products in the EU;
- EU policies on the reduction of food waste, which could reduce the supply of bakery and confectionery residues in the EU.

It can be expected that the availability of bakery residues and waste in the rest of the world will keep growing, following the combined growth in population and lifestyle improvement. Report Linker (2020) estimates a 3.8% global growth rate in the bakery product market between 2021 and 2027 (7.1% in China). As a result, large amounts of bakery and confectionery residues will be available around the world, thus adding to the EU potential.

Based on the limited evidence gathered in this study, the availability of bakery and confectionery residues and waste in the EU for biogas and biofuel production would likely remain significant (between 16.1 and 19.3 million tonnes, based on current food waste at processing and wholesale/retail) in both 2030 and 2050.

5. Additional demand for land

5.1. Assessment of additional demand for land

As identified in Section 4, there is large supply of bakery and confectionery residues and waste in the EU, which will likely remain unchanged in the coming decades. Although the supply of bakery and confectionery residues and waste can be considered rigid, a limited fraction of this feedstock is currently being used as feed, thus leaving significant amounts available for biogas or bioethanol production. Although future policies may attempt to drastically reduce the amount of food being wasted at processing and wholesale/retail levels in the EU, there is no evidence that this would create sufficient competition with feed uses, except when both energy and feed uses are located in the same region. Therefore the risk for bakery and confectionery residues to create additional land demand appears limited, based on the evidence gathered for this study.

Final result for bakery and confectionery residues and waste: Low risk for additional demand for land.

6. Processing technologies

6.1. Evaluation of processing technology (mature vs advanced)

Stakeholder consultation (Ferrero, 2020) reveals that bakery and confectionery residues and waste are most commonly converted into biogas via anaerobic digestion. Biogas may then be upgraded into biomethane for transport. Anaerobic digestion and biogas upgrading are **mature technologies** (TRL 9, CRL 5) which would mean this feedstock to be suitable to be added to Part

B of Annex IX. When used to produce bioethanol, as illustrated in the Etanolix® process (St1 Oy, 2020), bakery and confectionery residues and waste appear to be converted via hydrolysis (not enzymatic), followed by fermentation and distillation, which correspond to a TRL 9 and CRL 5 levels. Thus, bioethanol production out of bakery and confectionery residues and waste would also be considered as a **mature technology.**

7. Conclusions

Nomenclature:

- No concern = the evaluation did not reveal any significant concern about this feedstock.
- Some concern = the evaluation identified limited conditions under which some concerns may exist, i.e. using this feedstock for biofuel/biogas production could be in contradiction with this criterion.
- Significant concerns = the evaluation reveals that using this feedstock for biofuel/biogas production would be in contradiction with this criterion in most circumstances.
- Not applicable = this criterion is not applicable to the feedstock.

Table 55: Summary of evaluation results

	Evaluation Result	Rationale
Circular economy (applied to bakery and confectionery residues and waste)	Some concern	No commercial uses exist, which can extend product life and sequester carbon for longer than energy uses. Therefore, using bakery/confectionery residues and wastes for biogas/biofuel does neither contribute to, nor contravene circular economy principles or contravene the waste hierarchy. <u>Under which circumstances could this feedstock be problematic?</u> Using feedstocks which could be used for food/feed purposes would not contravene circular economy principles, but would not be aligned with the waste hierarchy. <u>How to mitigate this concern?</u> New policy developments would be required to ensure that food residues that could be locally used for food/feed purposes are not used for biofuel production whenever supply is limited. For instance, evaluating whether such use is logistically and economically viable could be added by EU-approved voluntary schemes to the scope of compliance verified by assurance providers (modalities to be further discussed).
Union sustainability	Not applicable	These criteria are **not applicable** to bakery and confectionery

criteria		residues and waste, as this feedstock is neither primary agricultural biomass or agricultural field residue or forest biomass. The feedstock is classified as a process residue or waste.
Sustainability GHG	No concern	To be eligible with the 65% minimum GHG saving threshold, operators producing **biomethane** from bakery and confectionery residues and waste should ensure that the resulting digestate is maintained in a closed infrastructure and off-gas combustion is applied. To be eligible with the 65% minimum GHG saving threshold, operators producing **bioethanol** from bakery and confectionery residues and waste should not use lignite as process energy. <u>How to mitigate this concern?</u> Failure to meet the minimum GHG savings will be efficiently addressed throughout the certification process by an EU-approved voluntary or national scheme.
Sustainability Others	Not applicable	Bakery/Confectionery residues and waste do not require dedicated land cultivation and therefore these criteria are **not applicable**.
Market distortion	Some concern	Bakery and confectionery residues and waste are currently used as animal feed and have a rigid supply. Therefore, diverting these from feed to energy production has a **risk** of having distortive effect on the animal feed market. However, as it is estimated that 75-90% is available; therefore, this risk is considered as **low.** <u>Under which circumstances could this feedstock be problematic?</u> An incentive to decrease food waste and increase the use of bakery and confectionery residues/waste for food/feed purposes could increase the risk of local competition with energy uses and create local market distortions. However, the inclusion of bakery and confectionery residues in Annex IX could also prevent an increase

		in food/feed uses at local level. <u>How to mitigate this concern?</u> Inclusion in Annex IXB (See below) would limit the amount of feedstock being used for biofuel/biogas production. Auditors should check that facilities are producing an expected ratio of main product (e.g. bread, dough, wafers, etc.) to other materials. The auditor should have access to historical data to be able to determine that the ratio of process streams has not materially changed over time. New policy developments would also be required to evaluate local markets and demonstrate that no local demand exists from the feed sector and/or that available supply largely exceeds the demand from the feed sector.
2030/2050 Potential	2030: 16.1-19.3 million tonnes (i.e. 5.46-6.5 million tonnes of ethanol or 3.1-3.7 million tonnes of biogas), based on current food waste at processing and wholesale/retail 2050: 16.1-19.3 million tonnes (i.e. 5.46-6.5 million tonnes of ethanol or 3.1-3.7 million tonnes of biogas), based on current food waste at processing and wholesale/retail	No specific data could be found for the 2030 and 2050 production of bakery and confectionery residues and waste. Current food waste at processing and wholesale/retail was used as proxy. Production levels are expected to remain comparable to the current levels.
Land demand	Some concern	Should market distortions occur, substituting bakery/confectionery waste and residues would pose a medium risk for additional demand for land for cereals. The overall risk is considered **low-medium**. How to mitigate this concern? See “Market distortion”
Processing Technologies	Mature (biogas) Mature (bioethanol)	The conversion technologies of bakery and confectionery residues and waste into biogas or bioethanol are considered to be **mature**, due to high TRL (9) and CRL (5).

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Drink production residues and waste

1. TECHNICAL DESCRIPTION

1.1. Feedstock description

Drink production residues and waste are generated during the production of non-alcoholic drinks, including but not limited to fruit pulp and peeling (e.g. citrus). The assessment will be about the material obtained from the processing of non-alcoholic drinks in general while referring to the citrus pulp and peel feedstock as an example.

Citrus pulp is the material generated during the industrial processing of citrus fruits and consists of peel and pulp, with a high moisture content of more than 80% (Italian Government, 2020). Citrus peel and pulp contain water-soluble sugars, fibres, organic acids, amino acids and proteins, minerals, oils and lipids. Essential oils can be extracted from citrus pulp and peel which contain a mixture of bioactive compounds with useful properties (Shirahigue et al., 2020). Phenols are a major class of bioactive compounds that include flavonoids, phenolic acids, tannins, stilbenes and lignans (Chockchaisawasdee et al., 2017).

1.2. Production process

Citrus pulp and peel are generated during the processing of the fruit as shown in **Figure 10**.

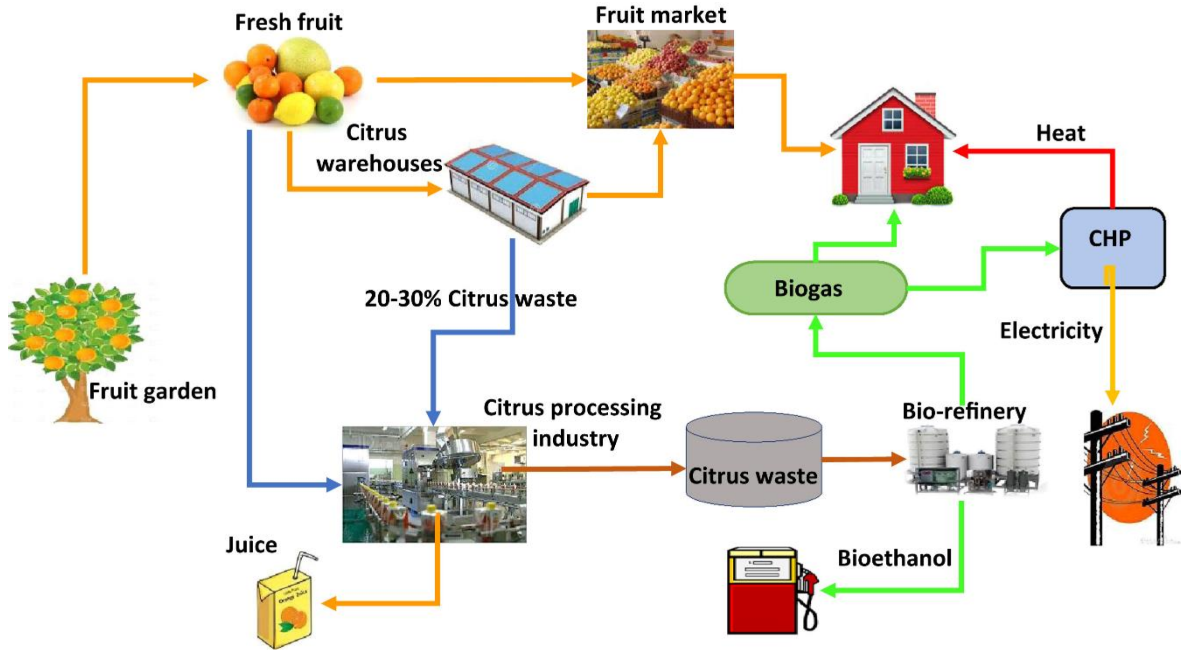

Figure 10: Citrus fruit supply chain and waste valorization (Taghizadeh-Alisaraei et al. 2017)

1.3. Possible uses

The high fibre content of citrus pulp makes it suitable for use as animal feed (Italian Government, 2020). While such use is technically feasible, it only makes economic sense when there are livestock settlements located near to the processing industries due to the degradation of this material (Zema et al., 2018). Citrus pulp has a high moisture content (more than 80%) (Patsalou et al., 2019) which makes transportation and storage expensive. Drying processes reduce the weight of citrus peel being transported and therefore results in lower transportation costs. Furthermore, it has been reported that transportation of wet citrus peel costs on average six times more than transportation of dry peel (Zema et al., 2018).

In addition, feed use might be limited due to the production standard for high quality food products, which may prohibit the use of fruit pulp or peel as feed in certain Member States (Italian

Government, 2020). Finally, the animal feed produced via the thermal dehydration of citrus pulp and peel has a low protein and high sugar content, which makes it less attractive from a nutritional point of view (Patsalou et al., 2019). Drying costs must also be considered for the production of feed pellets (Italian Government, 2020).

Despite citrus peel and pulp not being widely used in the food industry, there are examples of citrus peel being used in the Gin industry and distillery trade. The lemons and oranges remaining after the fruit harvest can be collected and the peels used for Gin production. However, the peel generated from the processing of juice drinks may not be suitable for this application in terms of quality. Gin distillers are particular about the peel used in making Gin and emphasise that the peel used in Gin production is separate from the peel generated during juice production (Beacon Commodities, 2021).

The bioactive components in drink residues/waste makes it suitable for a range of health and cosmetic applications. These include nutrient supplements; flavouring agents in food processing; preservatives; health and power drinks; skin, hair, and nail cosmetic formulations; antifungal and antibacterial lotions; soaps; and perfumes. More specifically citrus peel contains flavonoids, essential oils, and various other components that can be used in teas, aroma oils, antiseptics, digestives, mouth rinse, and soaps. Citrus pulp contains substances that can be used in supplements for ethanol and vinegar production (Mahato et al., 2017). However, the use of citrus pulp and peel in the food, cosmetic, and pharmaceutical industries, is not currently economically favourable because the processing costs are high and only small amounts of the compounds desired are produced (Calabro et al., 2017).

The use of drink residues/waste in anaerobic digestion to produce biogas allows a more 'traceable' use and produces organic fertiliser, as well as renewable energy. The organic fertiliser has a higher humidification index which is important where soil carbon loss is constant and often less than 1% organic matter (Italian Government, 2020). High volumes of organic matter are processed in anaerobic reactors by some researchers, however, there are various parameters that must be controlled including the concentration of toxic components present in drink residues/waste (Rosas-Mendoza et al., 2017).

Pyrolysis of drink residues/waste can produce fuels in the form of char, bio-oil and gases. The temperatures used influences the product composition. Temperatures between 400-650 °C achieves a bio-oil yield in the range of 36-39%. This yield can be increased to 75% using flash or fast pyrolysis reactors in comparison to normal (e.g. fixed-bed) reactors (Tagizadeh-Alisaraei, et al., 2017).

It has been reported that although pyrolysis of citrus pulp and peel is technically feasible, it is not efficient in terms of both energy and economics. The same can be said for gasification and incineration of citrus pulp and peel too. The drying step is expensive due to the high moisture content of the pulp and peel. Another drawback is the large concentrations of nitrous oxide produced during combustion of the organic material (Calabro et al., 2017).

Possible uses of drink residues/waste are summarised in Table 56.

Table 56 : Summary of possible uses of drink production residues and waste

	Food use	Feed use	Other uses
Drink production residues and waste	Potential application in Gin and distillery trade but quality of peel limits commercial implementation.	More widely practised application but limited economic viability compared to energy use and poor nutritional value.	Biogas: not common practice at scale due to presence of toxic components. Biofuel: not common practice at scale due to high drying costs. Compost: digestate from anaerobic digestion proven

			to provide nutritional benefits to soil. Health and personal care: high cost of processing restricts the viability of this application at scale.

2. Circular economy and waste hierarchy

2.1. Classification of the feedstock as a co-product, residue or waste

On the basis of the feedstock description provided in sub-section 0, it's possible uses in sub-section 1.3, stakeholder feedback and additional references, drink production process materials can be classified as residues as described below.

Table 57 : Classification of drinks production residues and waste

Evaluation question	Answer	Rationale
Is the feedstock the primary aim of the production process?	No	The primary aim of the process is to produce drinks. The process is not modified to produce drink residues/waste.
Does the feedstock have any economic value, but is not the primary aim of the process, and therefore a residue?	Yes	The feedstock matches the definition of "residue"; it isn't a co-product. The feedstock has a much lower economic value than the main product. The feedstock isn't the result of a technical choice; the manufacturer couldn't have produced the primary products without producing this feedstock.
Is the feedstock normally discarded, and therefore a waste?	No	The feedstock is not considered a waste as per Directive 2008/98/EC. In Italy, a clear legislative framework has allowed the creation of local virtuous circuits for the recovery of residual biomass from feed-food chains, remaining outside the waste context. The production of high-quality food, environmental sustainability, and an agricultural sector integrated with biogas, have contributed to this (Zanetti, 2017).

2.2. Is the use of feedstock to produce biofuel/biogas in line with circular economy principles?

The following questions apply to drink production residues.

- **Does the feedstock have non-energy (re)uses, which could extend its life or sequester carbon for longer?**

Answer: Variable.

Rationale: Residues from drinks made of fruits can potentially be used in health and cosmetics products because they contain bioactive components, which extend feedstock lifetime, compared to energy uses. However, extracting the bioactive components for use in healthcare products is considered a niche application due to economic barriers limiting the commercial attractiveness. Use as animal feed is possible, but these are comparable to energy recovery with respect to the lifetime being extended by a short time.

The organic material in drink residues provides potential as a fertiliser to enrich soils which would sequester carbon for longer.

- **Does its use as biofuel/biogas feedstock contribute to nutrient recovery?**

Answer: Yes.

Rationale: Digestate is produced during anaerobic digestion of drink residues (fruit pulp and peel) to biogas. The digestate can be applied to soil as an organic fertiliser. This is considered a fundamental process to certain regions in Southern Europe (Italian Government, 2020).

Production of biofuel via pyrolysis can produce biochar as a co-product which can be applied to land, enriching the soil, contributing to nutrient recovery (Tagizadeh-Alisaraei, et al., 2017).

- **Does its use as biofuel/biogas feedstock contribute to a more efficient use of resources by avoiding primary material extraction?**

Answer: Variable

Rationale: Using drink residues for biofuel/biogas production displaces the requirement to extract fossil fuels and natural gas. However, drink residues have other potential uses including animal feed and healthcare products which would require alternative materials that may not avoid primary material extraction.

- **Does its use as biofuel/biogas feedstock contribute to reducing waste generation, especially food waste?**

Answer: Variable.

Rationale: Using drink residues for biofuel/biogas production displaces fossil fuels. However, generating additional revenues through selling drinks residues to biofuel/biogas producers may deter from improving the drinks production value chain towards less waste being generated. If the only alternative is to discard these residues, using them as biofuel/biogas feedstock does contribute to reducing waste generation.

2.3. Is the use of this feedstock for biofuel/biogas production in line with the waste hierarchy?

The feedstock is considered a process residue for the purpose of this assessment and therefore assessment against the waste hierarchy is not necessary.

2.4. Conclusion

Contribution to circular economy

Using drink residues for biofuel/biogas contributes to a circular economy, especially as its use for biogas production would produce a digestate, which can be applied to soil contributing to nutrient recovery.

From now on the feedstock will be referred to as drink residues because it is no longer considered to be waste.

3. Sustainability and Greenhouse gases

3.1. Union sustainability criteria

Drink residues are derived from the processing of fruit; therefore, the Union sustainability criteria does not apply.

3.2. Potential GHG savings

There is no default value in RED II for the GHG savings associated with biogas from drinks production residues. The GHG savings criteria requires savings of at least 65% for new installations.

The GHG savings range from 20-80% for biogas used for transport, produced from biowaste (**Figure 11**). The technology option would need to correspond to the close digestate, off-gas combustion in order to comply with GHG savings criteria.

BIOMETHANE FOR TRANSPORT (*)			
Biomethane production system	Technological options	Greenhouse gas emissions savings – typical value	Greenhouse gas emissions savings – default value
Biowaste	Open digestate, no off-gas combustion	43 %	20 %
	Open digestate, off-gas combustion	59 %	42 %
	Close digestate, no off-gas combustion	70 %	58 %
	Close digestate, off-gas combustion	86 %	80 %

(*) The greenhouse gas emissions savings for biomethane only refer to compressed biomethane relative to the fossil fuel comparator for transport of 94 g CO_2eq/MJ.

Figure 11: Default GHG emissions savings for biogas for transport from biowaste (RED II)

Peel and pulp residue acts as a cereal substitute in animal feed so the default GHG intensity for corn ethanol was also considered as a proxy for the GHG emissions for this feedstock. The emissions associated with cultivation were excluded from the calculation due to this feedstock being a process residue.

The default value for the emissions associated with processing (e_p) was between 2.6-40.1 gCO_2e/MJ, dependent on the process fuel used.

Biofuel and bioliquid production pathway	Greenhouse gas emissions – typical value (g CO_2eq/MJ)	Greenhouse gas emissions – default value (g CO_2eq/MJ)
corn (maize) ethanol (natural gas as process fuel in conventional boiler)	20,8	29,1
corn (maize) ethanol, (natural gas as process fuel in CHP plant (*))	14,8	20,8
corn (maize) ethanol (lignite as process fuel in CHP plant (*))	28,6	40,1
corn (maize) ethanol (forest residues as process fuel in CHP plant (*))	1,8	2,6

Figure 12: Default GHG emissions associated with processing of corn ethanol (RED II)

The default value for the emissions associated with transport and distribution (e_{td}) was 2.2 gCO_2e/MJ for all process fuel types.

Biofuel and bioliquid production pathway	Greenhouse gas emissions – typical value (g CO_2eq/MJ)	Greenhouse gas emissions – default value (g CO_2eq/MJ)

corn (maize) ethanol (natural gas as process fuel in CHP plant (*))	2,2	2,2
corn (maize) ethanol (natural gas as process fuel in conventional boiler)	2,2	2,2
corn (maize) ethanol (lignite as process fuel in CHP plant (*))	2,2	2,2
corn (maize) ethanol (forest residues as process fuel in CHP plant (*))	2,2	2,2

Figure 13: Default GHG emissions associated with transport and distribution of corn ethanol (RED II)

The emissions of the fuel in use is taken to be 0 gCO_2e/MJ for biofuels. The fossil fuel comparator for biofuels is taken as 94 gCO_2e/MJ. The total emissions from the disaggregated default values for biofuel produced from corn ethanol, excluding cultivation emissions, is therefore between 4.8-42.3 gCO_2e/MJ depending on the process fuel used. This implies there would be GHG savings ranging from 55-95% from using drinks production residues for biofuel production. The process fuel used in the biofuel production plant will determine whether the feedstock pathway is compliant with GHG savings criteria.

3.3. Other environmental impacts

Drink residues, such as citrus pulp and peel, are secondary processing residues and therefore have no land management impact. The evaluation risks of the other environmental impacts (adverse effects on soil, water, air and biodiversity) are not applicable to this feedstock.

4. Market effects and 2030/2050 potential

4.1. Market effects

Animal feed

The supply of drink residues is rigid because it is the demand for the fruit that dictates the supply of peel and pulp. Citrus pulp and peel have a low protein content (Patsalou, 2019) and so the application of drink residues in animal feed is a possible substitute for other low protein materials. These substitutes may include cereal grains such as wheat, corn, or barley. The demand for animal feed remains relatively stable throughout the year. There is variability in the supply and demand for peel and pulp because feed is influenced by costs and availability of alternative feed. In addition, the quantity of fruit available for industrial processing to peel and pulp varies inter-annually and is dependent on climate conditions, agricultural yields, and market trends for fresh fruit (European Commission, 2020). If drink residues were diverted to biofuel/biogas production, cereal grains could potentially substitute drink residues in animal feed.

Health and personal care

Substances extracted from drink residues can have application in pharmaceutical and cosmetic products, although these are niche uses. This route is of growing interest to improve circularity of food waste, but research has found there is a negative perception of the product quality amongst consumers which creates a large barrier for this industry (Matthews, 2020). In contrast, there is increasing demand for aromas and flavourings from natural sources (Sagar et al., 2018).

There are alternative fruit, vegetables and grain materials that can provide the bioactive components demanded by the cosmetic and pharmaceutical industries (Shirahigue et al., 2020). The phenolic compounds mentioned in 0, like other bioactive components, can be found in different feedstocks. However, the concentrations of the different bioactive components vary between feedstocks (Chockchaisawasdee et al., 2017), therefore the chemical properties of the resulting products may not be comparable to the cosmetics products derived from drink residues. For example, the composition of apple skin may not be adapted to replace citrus peel in certain pharmaceutical applications.

The high moisture content of drink residues makes transportation of the feedstock expensive (Patsalou et al., 2019) so there are limitations on the distance this feedstock could be transported, suggesting there would be minimal impact on global supply for industries such as healthcare. The cost of extraction of the bioactive components is another economic barrier to using drink residues in pharmaceutical products (Calabro et al., 2017). Therefore, drink residues are unlikely to impact the healthcare markets due to limited application.

Composting

Composting of drink residues provides nutritional benefits to the soil quality. However, the market is currently limited to intensive high-income crops due to the current sale price and the land spreading cost (Calabro et al., 2017).

Energy use

There is an increasing trend to utilise crops and agro-food industry residues for energy production. The location of the feedstock production and the processing plant is an important consideration to reduce transport and storage costs, ensuring economic viability of the process (Calabro et al., 2017).

The supply of drink residues is likely to exceed the demand considering the competition and transportation costs limiting application in the feed industry and the high volume of feedstock available. For example, the global production of citrus fruits is 121 million tonnes each year, with 50% of the weight being attributed to pulp and peel (Patsalou et al., 2019).

As highlighted already, extracting the bioactive components from drink residues in the pharmaceutical industry is considered a niche application and so displacement from feed application will be the focus for assessing the market impacts. Alternative materials, such as cereal crops, may substitute the use of drink residues in animal feed which could have distortive effects on the markets. Directing drink residues to energy uses would therefore imply **medium risk of market distortion**.

4.2. 2030/2050 Potential

Citrus production in the European Union is estimated to be ~11.4 million tonnes with oranges, tangerines, and mandarins accounting for 85%. Brazil is the top producer of oranges (16.9 million tonnes) while China produces the most tangerines/mandarins and grapefruits (23.1 million tonnes and 5.0 million tonnes, respectively) and Mexico produce the highest number of lemons/limes (2.9 million tonnes) followed by the European Union (1.6 million tonnes). Weather conditions and harvested areas are key factors that impact production yields (USDA, 2021).

The production of **oranges** in the European Union is expected to remain stable at ~6.5 million tonnes to 2030 while global fruit and vegetable availability is estimated to increase at an annual rate of 1.3% (European Commission, 2020; Mason-D'Croz et al., 2019). Applying this 1.3% increase and considering 50% of the fruits weight is waste, this results in an estimated **6.5 million tonnes of pulp and peel residues produced in the European Union by 2030**. However, while the processing sector is expected to decline to 17% of the share of production by 2030, health concerns are expected to drive consumer demand for fresh **oranges**. Consumption of fresh **oranges** is expected to increase while the consumption of processed **oranges** is expected to decrease by -1.6% by 2030 due to health concerns over their high sugar content (European Commission, 2020).

The projected decline in the processing sector implies there will be a decline in the pulp and peel residues feedstock available. However, consumption of freshly squeezed **orange** juice from stores is expected to increase, which suggests there will be feedstock available from commercial retailers but access to this type of feedstock may be more difficult if collection schemes are not well established.

Imports of fresh **oranges** are expected to increase by 1.4% by 2030 driven by a strong increase in demand. Despite the projected increase in European Union exports of fresh **oranges**, the quantities will remain lower than those being imported resulting in the European Union net trade balance for fresh **oranges** becoming more negative.

The production of medium-protein crops for feed use is expected to increase by 18.7% between 2020 and 2030 (European Commission, 2020) which increases competition with citrus peel and pulp residues for animal feed. This will potentially reduce the demand for citrus pulp and peel in animal feed and increase the availability for biogas production. The higher methane potential of citrus peel compared to other crop residues and the increasing development for this biogas process (Calabro et al., 2017) promotes the use of this type of feedstock for future energy production.

Climate change is likely to affect the global production of fruits due to fluctuating temperatures and more frequent droughts impacting the quality and quantity of crop yields. By 2050, water scarcity is likely to be a huge problem which will affect crop production on a global scale. Agronomic management and improvements in water-use efficiency can ensure measures are taken to avoid adverse effects to fruit production (Shafqat et al., 2021). The feedstock production potential by 2050 will therefore be highly dependent on technology development and agricultural management. Assuming the same average annual increase of 1.3% to fruit availability would lead to an estimated **8.5 million tonnes** of pulp and peel residues produced in the European Union in 2050.

5. ADDITIONAL DEMAND FOR LAND

5.1. Assessment of additional demand for land

A large supply of drink residues was identified in Section 4. There is a limited amount of this feedstock being used in pharmaceutical and cosmetic products and the high moisture content of citrus peel makes composting difficult and results in a blend of peel at ~17% with another organic material (Calabro et al., 2017). This suggests that a large volume of citrus pulp and peel can be better utilised for alternative applications. Therefore, focusing on application in animal feed, cereal crops, such as wheat, corn, or barley, are examples of low protein feed that may substitute drink residues. These substitute materials correspond to a medium risk category for additional demand for land.

Therefore, a medium risk on additional land demand was identified for diverting drink residues to energy uses.

6. PROCESSING TECHNOLOGIES

6.1. Evaluation of processing technology (mature vs advanced)

Anaerobic digestion of drink residues produces biogas. When using citrus pulp and peel as the feedstock, the biogas produced contains 60-70% methane. The technology is used commercially for the treatment of agricultural wastes, food wastes, and sewage sludge, and treats more than 10% of organic wastes in a number of European countries.

Fruits have low total solid waste and high volatile solids which results in them easily decomposing via anaerobic digestion (Tagizadeh-Alisaraei, et al., 2017). The presence of limonene reduces biogas yields and needs to be separated from the feedstock before anaerobic digestion. Limonene is an antimicrobial compound which inhibits the formation of methane forming bacteria which can result in the accumulation of volatile fatty acids, decreasing the production of methane. A solution to this problem has been to perform the anaerobic digestion process in two separate stages: acid formation and methane formation (Milati et al., 2018).

The maturity level of anaerobic digestion (TRL 9, CRL 5) means that drink residues can be processed to produce biogas using a mature technology.

7. Conclusions

Overall compliance, areas of uncertainty, need for further research, etc.

Nomenclature:

- No concern = the evaluation did not reveal any significant concern about this feedstock.
- Some concern = the evaluation identified limited conditions under which some concerns may exist, i.e. using this feedstock for biofuel production could be in contradiction with this criterion.
- Problematic = the evaluation reveals that using this feedstock for biofuel production would be in contradiction with this criterion in most circumstances.
- Not applicable = this criterion is not applicable to the feedstock.

Table 58 : Summary of evaluation results

	Evaluation Result	Rationale
Circular economy	No concern	No commercial uses exist, which can extend product life and sequester carbon for longer than energy uses. Furthermore, using citrus peel and pulp residue for biofuel/biogas production contributes to a circular economy, since it produces digestate which can be applied to soil contributing to nutrient recovery.
Union sustainability criteria	Not applicable	These criteria do not apply to drink production residues because they are process residues therefore this feedstock is neither of the following: a primary agricultural biomass, an agricultural field residue, or a forest biomass.
Sustainability GHG	No concern	Under which circumstances could this feedstock be problematic? To comply with GHG savings criteria, the technology option of close digestate, off-gas combustion would need to be applied for the production of biogas from drinks production residues. The reference used for biofuel production returned GHG savings that would comply with this criteria. How to mitigate this concern? Failure to meet the minimum GHG savings will be efficiently addressed throughout the certification process by an EU-approved voluntary or national scheme.
Sustainability Others	Not applicable	Drink production residues are process residues. These criteria are **not applicable** as this feedstock has no land impact.
Market distortion	Some concern	There is a large supply of drink residues available with limited application in healthcare products and composting.

		Under which circumstances could this feedstock be problematic? Diverting drink residues from animal feed to biofuel/biogas production would be at **medium risk of market distortion**. How to mitigate this concern? Inclusion in Annex IXB (see below) would limit the amount of feedstock being used for biogas production. Auditors should check that facilities are producing an expected ratio of main product (e.g. fruit juice) to other materials. The auditor should have access to historical data to be able to determine that the ratio of process streams has not materially changed over time. New policy developments would also be required to evaluate local markets and demonstrate that no local demand exists from the feed sector and/or that available supply largely exceeds the demand from the feed sector.
2030/2050 Potential	2030: 6.5 million tonnes [i.e. 1.2 million tonnes of biogas] 2050: 8.5 million tonnes [i.e. 1.6 million tonnes of biogas]	EU citrus production estimated to be 11.4 million tonnes. Assuming 50% by weight waste and an average increase in fruit availability of 1.3% citrus pulp and peel residues would reach 6.5 million tonnes in the EU by 2030. Applying the same 1.3% annual increase would estimate 8.5 million tonnes of citrus pulp and peel residues available by 2050. However, there may be less feedstock available due to climate change affecting production yields.
Land demand	Some concern	Under which circumstances could this feedstock be problematic? There would be **medium risk** on additional demand for land if the cereal crops such as wheat, corn or barley displaced the use of drink residues in animal feed. How to mitigate this concern? See "Market distortion".
Processing Technologies	Mature (biogas)	Anaerobic digestion can be used to convert drink production residues to biogas which is considered a **mature processing technology**.

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Fruit and vegetable residues and waste

1. TECHNICAL DESCRIPTION

1.1. Feedstock description

Fruit and vegetable residues and waste includes materials generated through the processing (e.g. peeling, chopping, pressing) of fruits and vegetables into food items, such as sauces, yogurts, soups, ice creams, etc. Fruits and vegetables that have been processed and are considered defective and unfit for human consumption are also included in this assessment, along with other residues as defined below. To note this does not include damages to fruit and vegetables prior to processing, i.e. at the cultivation/harvesting stage.

Examples of other residues include the following:

- Residues and parts of raw materials that are generated along the processing lines and accumulate in the equipment and/or along the conveyor belts.

- Raw materials and/or semi-finished products collected during the cleaning of bins, containers, silos and containers in general, once emptied, are deemed unsuitable for the food chain.

Products classed as defective and unfit for human consumption are those that do not conform to the standards for end-use in the food chain. This could be due to undesirable physical characteristics including weight, shape, and damage during production, or incorrect chemical composition. These types of products could still be suitable for use as animal feed provided that they comply with feed safety legislation (European Commission, 2018).

Fruit and vegetable residues and waste contain bioactive components that have anti-inflammatory, antioxidant, anticarcinogenic and cardioprotective properties. Potatoes, onions, citrus fruits, carrots, and bananas are among those with a good source of polyphenols; citrus fruits contain D-Limonene; carrots and pumpkins consist of beta-carotene; and lycopene is present in tomato peels and pomace (Esparza et al., 2020). The carbohydrate content is strawberries is ~8.3% whereas it is ~24% for bananas. Lettuce has a low carbohydrate content of ~2.8% compared to ~27.3% in sweet potatoes. Generally, the water content in fruit and vegetables is over 70%, the protein content will be less than 3.5% and the fat content will not be greater than 0.5% (FAO, 1995). For biogas production, methane yields are generally higher for fruits than for vegetable due to the difference in carbohydrate, protein, lignin and cellulose contents (Esparza et al., 2020).

1.2. Production process

Fruit and vegetable residues and wastes are generated from the selection, preparation and processing of fruit and vegetables for food products as described in 0. The consumption stage generates the greatest amount of food waste in the supply chain (European Commission, 2020a).

1.3. Possible uses

The bioactive components in fruit and vegetable residues and waste makes this feedstock suitable for a range of applications in the **food, cosmetic, and pharmaceutical industries**, to produce high value products. There is growing demand for many of these bioactive components including pectin which is used in the medical and pharmaceutical industries for drug delivery, wound healing, and tissue engineering. However, there are drawbacks to the extraction required to obtain these bioactive components, including long extraction times, solvent costs, selectivity issues, and low yields, meaning the technologies remain at lab-scale (Esparza et al., 2020; European Commission, 2020a).

The feedstock can also be used in pyrolysis plants to produce **biochar, bio-oil, or syngas** (Esparza et al., 2020). The biochar acts as an intermediate in **bioethanol** production. Biochar can also be used as fertiliser and to remove pollutants from contaminated bodies of water (Kumar et al., 2020). Thermochemical liquefaction is another technique to produce **bio-oil** from fruit and vegetable residues and waste, however this technology is more complex and expensive (Muangrat, 2013). Gasification of the feedstock can produce **syngas** which can be used in synthesis of chemical or fuel for power and/or heat generation. However, the high moisture content of the feedstock means high energy input is required for the drying step which is costly and reduces the thermal efficiency of the process. The use of fruit and vegetable residues and waste to produce biochar, bio-oil and gases in these thermal treatments is still in the early stages of development due to technical, economic, and legal barriers (Esparza et al., 2020).

The feedstock has a high level of organic matter so is suitable for **biogas** production from anaerobic digestion which accepts wet or dry feed (Soldano et al., 2012). The raw biogas can be used for cooking and once upgraded, the purified biogas can generate electricity, heat, and steam, be used in transport fuel, or injected into the natural gas grid (Gonçalves Neto et al., 2021). This reduces the dependency on using dedicated energy crops for energy generation (Soldano et al., 2012). Mango, banana, cabbage, and carrot peels are examples of fruit and vegetable derivatives used in studies for biogas production via anaerobic digestion (Esparza et al., 2020). Slow start up of the biodigesters has been observed for citrus pulp as well as other types of food waste due to the high acidity content, requiring addition of alkali reagents to control the pH (Soldano et al., 2014; Gonçalves Neto et al., 2021).

The digestate produced from anaerobic digestion of fruit and vegetable residues and waste, can be used in compositing as a soil amendment and nutrient source in agriculture. Water retention is encouraged through soil amendment which reduces irrigation needs, however, contaminants in the feed can be problematic. Vermicomposting is a recent practice for the production of biofertilisers. Earthworms and microorganisms are used to stabilise waste organic matter. Composting of fruit and vegetable waste is promoted in European Union legislation over landfilling, and the management of municipal waste through composting has almost doubled from 2000 to 2016 (Esparza et al., 2020).

The presence of toxic components such as organochlorine residues in root vegetables and cucurbits (e.g. pumpkins, squash, marrows), and more generally chemical residues on skins of fruit and vegetables, means that this feedstock may be unsuitable for use as **animal feed** (New South Wales, 2019). In the European Union, animal feed needs to comply with feed safety legislation (European Commission, 2018). Certain food wastes can also only be given to certain animals, and in some Member States it is illegal to use food waste in animal feed. In addition, the transport and storage costs, and low value product, result in this route not being economically viable (Esparza et al., 2020). The feedstock production is also strongly seasonal which makes continuous use throughout the year very difficult (Italian Government, 2020).

There are other more niche applications for fruit and vegetable residues and waste in the early stages of development including use in **carbon dots, nanoparticles, and bio sorbents** (Kumar et al, 2020).

Possible uses of fruit and vegetable residues and waste are summarised in **Table 59**.

Table 59 : Summary of possible uses of fruit and vegetable residues and waste

	Food use	Feed use	Other uses
Fruit and vegetable residues and waste	No documented evidence of commercial implementation.	Partial substitution of conventional feed found to have health and environmental benefits, but feedstock also reported as unsuitable for feed for certain animals, as well as legal issues and economic viability.	Biogas: not common practice at scale due to presence of toxic components. Biofuel: not common practice at scale due to high drying costs. Composting: digestate from anaerobic digestion proven to provide

			nutritional benefits to soil. Health and personal care: no evidence of commercial use due to cost of extraction.

2. Circular economy and waste hierarchy

2.1. Classification of the feedstock as a co-product, residue or waste

On the basis of the feedstock description provided in sub-section 0, its possible uses in sub-section 0, stakeholder feedback and additional references, fruit and vegetable residues and waste can be classified as residues as described below.

Table 60 : Classification of fruit and vegetable residues and waste

Evaluation question	Answer	Rationale
Is the feedstock the primary aim of the production process?	No	The primary aim of the process is to produce feed. The process is not modified to produce fruit and vegetable residues and waste.
Does the feedstock have any economic value, but is not the primary aim of the process, and therefore a residue?	Yes	The feedstock has a much lower economic value than the main product.
Is the feedstock normally discarded, and therefore a waste?	No	The feedstock is not considered a waste as per Directive 2008/98/EC. In Italy, a clear legislative framework has allowed the creation of local virtuous circuits for the recovery of residual biomass from feed-food chains, remaining outside the waste context. The production of high-quality food, environmental sustainability, and an agricultural sector integrated with biogas, have contributed to this (Zanetti, 2017).

2.2. Is the use of feedstock to produce biofuel/biogas in line with circular economy principles?

The following questions apply to fruit and vegetable residues.

- **Does the feedstock have non-energy (re)uses, which could extend its life or sequester carbon for longer?**

  Answer: Variable.

  Rationale: Fruit and vegetable residues can be utilised to produce biochar via pyrolysis which, when used as a fertiliser, can enhance carbon storage in soils. Biofuel/biogas would also be produced as co-products during the pyrolysis process so could still contribute to energy uses. However, the cost of the drying step limits the development of these thermal technologies to treat fruit and vegetable residues.

  Other uses of this feedstock in the food, cosmetic and pharmaceutical industries have limited commercial attractiveness due to high extraction costs and would only extend the lifetime by a short period of time.

- **Does its use as biofuel/biogas feedstock contribute to nutrient recovery?**

  Answer: Yes.

  Rationale: Digestate produced during the anaerobic digestion of fruit and vegetable residues to biogas can improve the nutrients of soils by acting as an organic fertiliser. Biochar is a co-product of biofuel produced during pyrolysis of the feedstock. This biochar can also enrich the soil, contributing to nutrient recovery (Tagizadeh-Alisaraei, et al., 2017).

- **Does its use as biofuel/biogas feedstock contribute to a more efficient use of resources by avoiding primary material extraction?**

  Answer: Variable.

  Rationale: The biofuel/biogas produced from processing this feedstock could displace the need to extract fossil fuels and natural gas. However, if fruit and vegetable residues have potential uses in healthcare products, diverting this feedstock towards biofuel/biogas production may require primary material extraction of alternative feedstocks.

- **Does its use as biofuel/biogas feedstock contribute to reducing waste generation, especially food waste?**

  Answer: Variable

  Rationale: Using fruit and vegetable residues for biofuel/biogas production displaces fossil fuels. However, generating additional revenues through selling fruit and vegetable residues to biofuel/biogas producers may deter from improving the fruit and vegetable value chain towards less waste being generated. If the only alternative is to discard these residues, using them as biofuel/biogas feedstock does contribute to reducing waste generation.

2.3. Is the use of this feedstock for biofuel/biogas production in line with the waste hierarchy?

The feedstock is considered a process residue for the purpose of this assessment and therefore assessment against the waste hierarchy is not necessary.

2.4. Conclusion

Contribution to circular economy

Utilising fruit and vegetable residues for biofuel/biogas production contributes to a circular economy because it reduces the generation of waste and can contribute to nutrient recovery.

From now on the feedstock will be referred to as fruit and vegetable residues because it is no longer considered to be waste.

3. Sustainability and Greenhouse gases

3.1. Union sustainability criteria

The fruit and vegetable residues in this assessment are derived from the processing of fruit and vegetables into food items, therefore the Union sustainability criteria does not apply to this feedstock.

3.2. GHG Savings Criteria

There is no default value in RED II for the GHG savings associated with biogas from fruit and vegetable residues.

As an initial estimate, default values provided in the RED II for biowaste are considered. The GHG savings range from 20-80% for biomethane used for transport, produced from biowaste (**Figure 14**). The technology option would need to correspond to the close digestate, off-gas combustion in order to comply with GHG savings criteria.

BIOMETHANE FOR TRANSPORT (*)			
Biomethane production system	Technological options	Greenhouse gas emissions savings – typical value	Greenhouse gas emissions savings – default value
Biowaste	Open digestate, no off-gas combustion	43 %	20 %
	Open digestate, off-gas combustion	59 %	42 %
	Close digestate, no off-gas combustion	70 %	58 %
	Close digestate, off-gas combustion	86 %	80 %

(*) The greenhouse gas emissions savings for biomethane only refer to compressed biomethane relative to the fossil fuel comparator for transport of 94 g CO_2eq/MJ.

Figure 14: Default GHG emissions savings for biomethane for transport from biowaste (RED II)

Therefore, it can be inferred that utilising fruit and vegetable residues for biogas production via anaerobic digestion, would result in GHG savings. Moreover, sending this feedstock to landfill or incineration creates environmental problems due to the high biodegradability and high moisture content of the organic material (Neto, 2021). These properties make this feedstock well suited to anaerobic digestion (Seswoya, 2019).

Fruit and vegetable residues can substitute cereal crops in animal feed and so the default GHG intensity for corn ethanol was also considered as a proxy for the GHG emissions for this feedstock. The emissions associated with cultivation were excluded from the calculation due to this feedstock being a process residue.

The default value for the emissions associated with processing (e_p) was between 2.6-40.1 gCO_2e/MJ, dependent on the process fuel used.

Biofuel and bioliquid production pathway	Greenhouse gas emissions – typical value (g CO_2eq/MJ)	Greenhouse gas emissions – default value (g CO_2eq/MJ)
corn (maize) ethanol (natural gas as process fuel in conventional boiler)	20,8	29,1
corn (maize) ethanol, (natural gas as process fuel in CHP plant (*))	14,8	20,8
corn (maize) ethanol (lignite as process fuel in CHP plant (*))	28,6	40,1
corn (maize) ethanol (forest residues as process fuel in CHP plant (*))	1,8	2,6

Figure 15: Default GHG emissions associated with processing of corn ethanol (RED II)

The default value for the emissions associated with transport and distribution (e_{td}) was 2.2 gCO_2e/MJ for all process fuel types.

Biofuel and bioliquid production pathway	Greenhouse gas emissions – typical value (g CO_2eq/MJ)	Greenhouse gas emissions – default value (g CO_2eq/MJ)
corn (maize) ethanol (natural gas as process fuel in CHP plant (*))	2,2	2,2
corn (maize) ethanol (natural gas as process fuel in conventional boiler)	2,2	2,2
corn (maize) ethanol (lignite as process fuel in CHP plant (*))	2,2	2,2
corn (maize) ethanol (forest residues as process fuel in CHP plant (*))	2,2	2,2

Figure 16: Default GHG emissions associated with transport and distribution of corn ethanol (RED II)

The emissions of the fuel in use is taken to be 0 gCO_2e/MJ for biofuels. The fossil fuel comparator for biofuels is taken as 94 gCO_2e/MJ. The total emissions from the disaggregated default values for biofuel produced from corn ethanol, excluding cultivation emissions, is therefore between 4.8-42.3 gCO_2e/MJ depending on the process fuel used. This implies there would be GHG savings ranging from 55-95% from using fruit and vegetable residues for biofuel production. The process fuel used in the biofuel production plant will determine whether the feedstock pathway is compliant with GHG savings criteria.

3.3. Other environmental impacts

Fruit and vegetable residues are secondary process residues and therefore have no land management impact. The evaluation of risks of adverse effects on soil, water, air and biodiversity is not applicable.

4. Market effects and 2030/2050 potential

4.1. Market effects

Animal feed

The demand for animal feed remains relatively stable throughout the year (European Commission, 2020b). The low protein content of fruit and vegetable residues (Patsalou, 2019) means that this feedstock could substitute other low protein materials in animal feed, such as wheat, corn, or barley. However, directing fruit and vegetable residues to animal feed may not always be the most feasible option because some of these residues are unsuitable for certain animals, transmission of diseases through consumption of toxic compounds can be problematic, and there are costs associated with transportation and conservation (Esparza et al., 2020).

Composting

Composting is a suitable method for the utilisation of fruit and vegetable residues due to the high organic content, however this relies on source separation of this type of biogenic feedstock from other household and commercial waste (Esparza et al., 2020). In addition, the cost involved in spreading fruit and vegetable residues over land results in the composting market being limited to intensive high-income crops (Calabro et al., 2017). The additional sorting requirements and costs associated with composting restrict the economic viability of this end-use process.

Health and personal care

There is increasing demand for pectin which can be recovered from fruit and vegetable residues in the medical and pharmaceutical industries. The trade value of pectin surpassed $850 million in 2013 and continues to increase (Esparza et al., 2020). Consumer demand for aromas and flavours from natural sources, including fruit and vegetable residues, has increased. Vanillin which can be extracted from pineapple waste is an example of one flavouring that has high application in the food, cosmetic and pharmaceutical industries. Extraction of enzymes from these wastes is another highly desired product for use in these industries (Sagar et al., 2018).

However, extraction of bioactive components in fruit and vegetable residues is a relatively niche application due to the costs of extraction and transportation limiting the commercial attractiveness (Calabro et al., 2017).

Energy use

The amount of food waste generated per year in the European Union is over 88 million tonnes with fruit and vegetables being amongst the highest contributors and this value is expected to increase by 40% over the following years (Esparza et al., 2020; Sagar et al., 2018).

There is an increasing trend in the use of agro-food industry residues for energy production (Calabro et al., 2017). Diverting fruit and vegetable residues to biofuel/biogas production is unlikely to have a high impact on the composting and healthcare industries. There would be **medium risk of market distortion** if cereal substitutes displaced fruit and vegetable residues in animal feed.

4.2. 2030/2050 Potential

The supply and demand for certain types of fruit and vegetables is likely to differ depending on climate conditions and consumer behaviour and lifestyle. There is expected to be a decline in processed fruits in line with the drop in demand for juices. Increased health awareness is expected to result in an increase in the consumption of certain fruit and vegetables, including apples, smaller sized tomatoes and canned products considered to be higher value-added products.

The European Union exports of fresh **apples** is expected to decline by 19% by 2030 compared to 2019 which in part will be due to Russia, who used to be the largest European Union export market, becoming more self-sufficient. Imports to the European Union are expected to remain stable to meet the demand in the summer months and due to the high quality of imports (European Commission, 2020b).

The increased consumer demand for fruit and vegetables will increase the availability of the waste feedstock. However, competition with the food, cosmetic and pharmaceutical industries will impact the potential for biofuel/biogas production processes. Alternative feedstocks that are sustainable and meet the consumers' needs will be necessary to avoid risk of market distortion if fruit and vegetable residues are diverted to biofuel/biogas production.

The majority of fruits and vegetables generate 25-30% waste and a study found that ~55 million tonnes of fruit and vegetable waste was produced from India, Philippines, the US and developed parts of China (Sagar et al. 2018). The Sustainable Development Goal (SDG) to halve the volume of waste generated in the European Union by 2030 (WWF-WRAP, 2020) will impact the volume of feedstock available for energy use. The global production of fruit and vegetables in 2019 was 1.8 billion tonnes, which has remained relatively stable over the previous 5 years (Fepex, 2021). The increasing population and consumer demand for fruit and vegetables suggests a rise in the waste produced from this type of feedstock over the next ten years.

The average fruit and vegetable availability per person is estimated to be 640 g/day in 2030 and 760 g/day in 2050, according to modelling by Mason-D'Croz et al. The global population is projected to increase at an average annual rate of 0.73% reaching 9.2 billion in 2050 (Mason-D'Croz et al., 2019). The population in 2030 would reach ~8.4 billion when the average population increase of 0.73% is applied. Assuming 25% of the fruit and vegetables produced is waste, this results in estimates of **490 million tonnes and 638 million tonnes of waste generated by 2030 and 2050 respectively**.

Climate change will have an impact on fruit and vegetable production leading up to 2050 which will in turn affect the volumes of waste available for energy use applications. Measures will need to be taken to mitigate these impacts and adapt agricultural systems through technology development and agronomic management (Shafqat et al., 2021).

5. ADDITIONAL DEMAND FOR LAND

5.1. Assessment of additional demand for land

Increased use of fruit and vegetable residues for biogas and biofuel production would result in demand for substitute materials to meet the needs of other industries. In line with the market assessment, use of fruit and vegetable residues in animal feed is likely to be substituted by other low protein feed such as wheat, corn, or barley. These substitute materials correspond to a medium risk category for additional demand for land.

Therefore, a **medium risk** on additional land demand was identified for diverting fruit and vegetable residues to energy uses.

6. PROCESSING TECHNOLOGIES

6.1. Evaluation of processing technology (mature vs advanced)

Anaerobic digestion is a mature technology for treating food waste such as fruit and vegetables, but it can be challenging if a suitable pre-treatment is not applied (Esparza et al., 2020). The maturity level of anaerobic digestion and subsequent biogas upgrading (TRL 9, CRL 5).

7. CONCLUSIONS

Overall compliance, areas of uncertainty, need for further research, etc.

Nomenclature:

- No concern = the evaluation did not reveal any significant concern about this feedstock.
- Some concern = the evaluation identified limited conditions under which some concerns may exist, i.e. using this feedstock for biofuel production could be in contradiction with this criterion.
- Significant concern = the evaluation reveals that using this feedstock for biofuel production would be in contradiction with this criterion in most circumstances.
- Not applicable = this criterion is not applicable to the feedstock.

Table 61: Summary of evaluation results

	Evaluation Result	Rationale
Circular economy	No concern	No commercial uses exist that can extend product life and sequester carbon for longer than energy uses. Utilising fruit and vegetable residues for biofuel/biogas production contributes to a circular economy because it reduces the generation of waste and can contribute to nutrient recovery.
Union sustainability criteria	Not applicable	These criteria do not apply to this feedstock because they are process residues, therefore this feedstock is neither of the following: a primary agricultural biomass, an agricultural field residue, or a forest biomass.
Sustainability GHG	No concern	<u>Under which circumstances could this feedstock be problematic?</u> To comply with GHG savings criteria,

		the technology option of close digestate, off-gas combustion would need to be applied for the production of biogas from fruit and vegetable residues. The reference used for biofuel production returned GHG savings that would comply with this criteria. <u>How to mitigate this concern?</u> Failure to meet the minimum GHG savings will be efficiently addressed throughout the certification process by an EU-approved voluntary or national scheme.
Sustainability Others	Not applicable	The fruit and vegetable residues are derived from the processing of fruits and vegetables into food items, therefore these criteria are **not applicable** as this feedstock has no land impact.
Market distortion	Some concern	There is a large supply of fruit and vegetable residues with limited application in healthcare products and composting. <u>Under which circumstances could this feedstock be problematic?</u> There would be **medium risk of market distortion** if this feedstock was diverted away from use in animal feed. <u>How to mitigate this concern?</u> Inclusion in Annex IXB (see below) would limit the amount of feedstock being used for biogas production. Auditors should check that facilities are producing an expected ratio of main product (e.g. fruit, vegetables) to other materials. The auditor should have access to historical data to be able to determine that the ratio of process streams has not materially changed over time. New policy developments would also be required to evaluate local markets and demonstrate that no local demand exists from the feed sector and/or that available supply largely exceeds the demand from the feed sector.
2030/2050 Potential	2030: 490 million tonnes [i.e. 93.1 million tonnes of	An estimated 490 million tonnes of fruit and vegetable residues could be available in 2030 considering the increasing population and changes in

	biogas] 2050: 638 million tonnes [i.e. 121 million tonnes of biogas]	consumer behaviour. There may potentially be less feedstock available moving to 2050 due to the effects of climate change on crop production. However, mitigation measures may suppress these impacts, and an increasing population is likely to result in increased demand.
Land demand	Some concern	Under which circumstances could this feedstock be problematic? There would be **medium risk** on additional demand for land if fruit and vegetable residues were displaced by cereal crops such as wheat, corn or barley in animal feed. How to mitigate this concern? See "Market distortion".
Processing Technologies	Mature (biogas)	Anaerobic digestion can be used to convert fruit and vegetable residues to biogas which is considered a **mature processing technology**.

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Potato and sugar beet pulp

1. TECHNICAL DESCRIPTION

1.1. Feedstock description

Potato pulp is one of the resulting products from the production of potato starch. It contains starch, cellulose, hemicelluloses, pectin, proteins, free amino acids and salts (Mayer et al., 1997).

Sugar beet pulp is a resulting product from sugar production from sugar beets. Sugar beet pulp consists of carbohydrates, proteins and minerals (Duraisam et al., 2017).

1.2. Production process

In potato starch production, potatoes are washed, rasped, and then separated into starch slurry, protein water solubles and pulp (see Figure 17). For every 100 kg of potato starch production, 3-3.5 kg of dried potato pulp is produced (Feedipedia, n.d.).

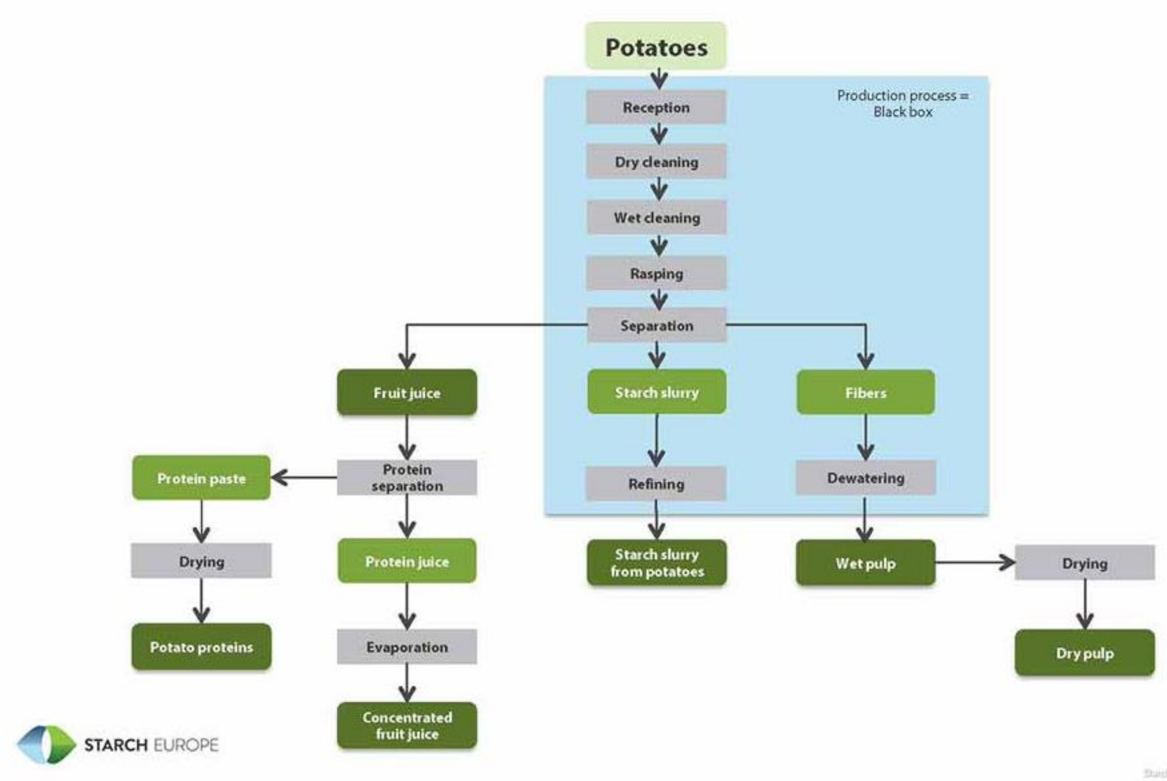

Figure 17. Process diagram of potato starch production (Source: Starch Europe, 2014).

Sugar beet pulp is the residual material generated after extracting the raw juice from sugar beet cossettes (elongated slices of sugar beet). In sugar mills, it is typically pressed, dehydrated, and pelletised, and accounts for 30%–40% of overall energy costs of the mill. The processing of 100 kg of sugar beet typically produces 50 kg[6] of wet pulp and 7 kg[5] of dry sugar beet pulp (Tomaszewska et al., 2018).

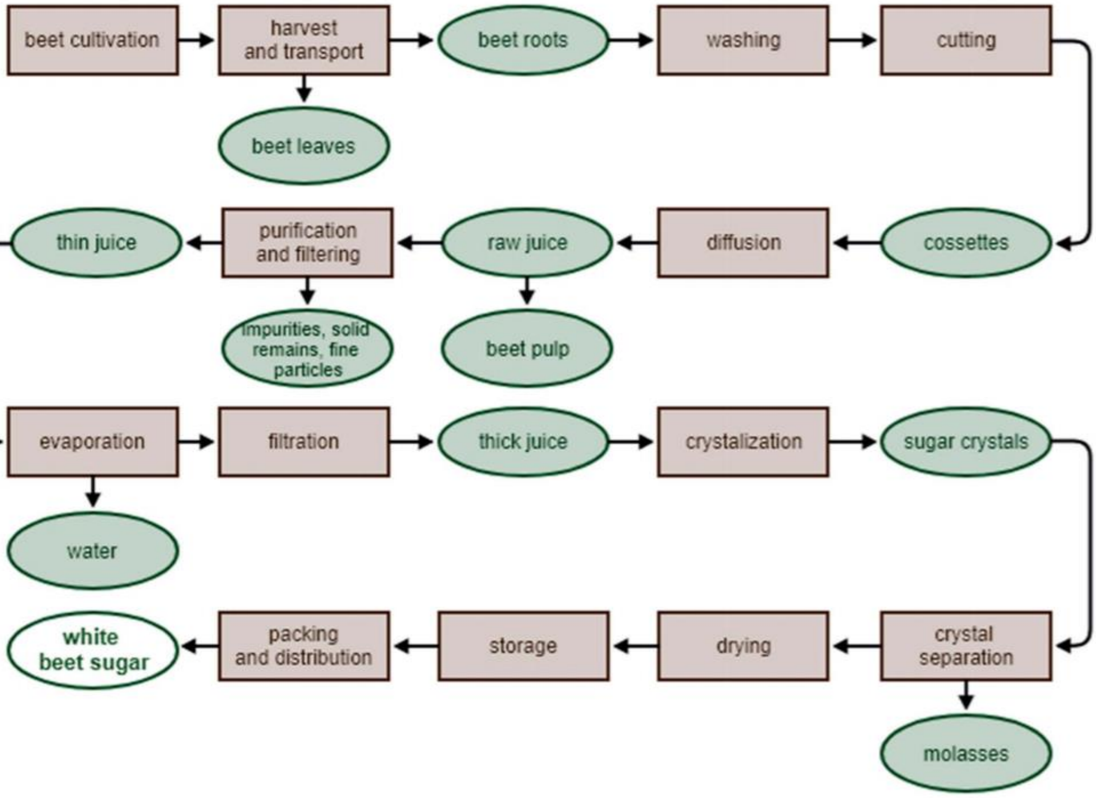

Figure 18. Process diagram of sugar production from sugar beet (Source: Tomaszewska et al., 2018).

1.3. Possible Uses

Potato pulp is currently used as animal feed, in the food industry and to a lesser extent beverage production (Transparency Market Research, 2018). The utilisation of potato pulp to make preservatives, flavouring agents and emulsifiers in the food industry is because of its high protein and fibre content compared to other vegetables. Potato pulp can also be applied to fields as compost or as raw material to provide nutritional benefits, improving the quality of the soil (Muter et al., 2014). In terms of bioenergy, the composition of potato pulp suggests it has potential for the production of bioethanol or biogas (Marzo et al., 2019; Transparency Market Research, 2018). Anaerobic digestion can be used to convert potato pulp to biogas however studies highlight the challenges with regards to inefficient performance (Chen et al., 2021).

Sugar beet pulp is primarily used for feed, either as a straight feed or as an ingredient in compound feed, and represents 2% of the 267 million tonnes of feed consumed in the EU by livestock (Farm Europe, 2018). The pulp can either be sold as wet or dried and pelleted (termed sugar beet pulp pellets), often with molasses (ED&F Man, n.d.). In Russia, sugar beet pulp has a limited market as animal feed domestically and so the majority of it is dehydrated, pelleted and exported (FAO Investment Centre, 2013).

Sugar beet pulp is particularly used in ruminant feeding due to its high fibre content (up to 25% in the dry matter). It has the potential to replace significant quantities of cereals in concentrate mixtures for dairy cattle. Incorporation rates of 30% in the dry matter of diets for dairy cows and 50% for beef cattle are possible (ED&F Man, n.d.).

Other applications for sugar beet pulp have also been investigated; for example, pectin can be extracted from the pulp and used as a food additive. Carboxymethyl cellulose can also be derived from cellulose from the pulp and used in the food, cosmetics, pharmaceuticals, and detergents industries. In terms of bioenergy, sugar beet pulp has been most studied for the production of bioethanol, but could also be theoretically used for biogas production through anaerobic digestion (Tomaszewska et al., 2018).

Table 62: Summary of possible uses of Potato and Sugar beet pulp

Feedstock	Food use	Feed use	Other uses
Sugar beet pulp	Pectin as food additive	Animal feed	Carboxymethyl cellulose (pharmaceutical or detergent)
Potato pulp	Beverage production, food preservatives, flavouring agent, and emulsifier	Animal feed	Compost

2. CIRCULAR ECONOMY AND WASTE HIERARCHY

2.1. Classification of the feedstock as a co-product, residue or waste

Table 63 : Classification of potato and sugar beet pulp.

Evaluation question	Answer	Rationale
Is the feedstock the primary aim of the production process?	No	White sugar is the primary aim of sugar beet processing and potato starch is the primary aim of potato processing.
Does the feedstock have any economic value, but is not the primary aim of the process, and therefore a residue?	Variable	Sugar beet pulp has an economic value and is a traded commodity (as dried pellets). The economic ratio of sugar beet pulp to white sugar is ~30% (Tomaszewska et al., 2018), therefore sugar beet pulp can be considered as a **co-product** in the sugar production process. Potato pulp isn't the result of a technical choice, the manufacturer couldn't have produced the primary products without producing this feedstock. The limited availability of data on the economic value of potato pulp also implies the low commercial value of this feedstock. Therefore, this feedstock can also be considered as a **residue**.
Is the feedstock normally discarded, and therefore a waste?	No	Sugar beet is normally used as animal feed and potato pulp is used as animal feed and beverage production.

2.2. Is the use of feedstock to produce biofuel/biogas in line with circular economy principles?

- **Does the feedstock have non-energy (re)uses, which could extend its life or sequester carbon for longer?**

  Answer: Variable.

Rationale: Use of these feedstocks in animal feed, food, cosmetic and pharmaceutical industries would only extend the lifetime by a short period of time. Composting provides potential for fertiliser applications to enrich soils which would promote carbon sequestration.

- **Does its use as biofuel/biogas feedstock contribute to nutrient recovery?**

  Answer: Variable.

  Rationale: The potential for anaerobic digestion of potato and sugar beet pulp to generate biogas could also produce digestate which can improve the nutrients of soils by acting as an organic fertiliser.

- **Does its use as biofuel/biogas feedstock contribute to a more efficient use of resources by avoiding primary material extraction?**

  Answer: Variable.

  Rationale: The biogas/biofuel produced from processing these feedstocks could displace the need to extract fossil fuels and natural gas. The food, cosmetic and pharmaceutical applications of potato and sugar beet pulp may result in negative impacts if this feedstock is diverted to biofuel/biogas production because the alternative inputs may require primary material extraction.

- **Does its use as biofuel/biogas feedstock contribute to reducing waste generation, especially food waste?**

  Answer: No

  Rationale: Potato and sugar beet pulp are not normally discarded.

2.3. Is the use of this feedstock for biofuel/biogas production in line with the waste hierarchy?

Potato pulp and sugar beet pulp are considered a residue and co-product respectively for the purpose of this assessment and therefore assessment against the waste hierarchy is not necessary.

2.4. Conclusion

Contribution to circular economy

No evidence of commercial use as material/chemical could be found. Therefore, using potato or beet pulp for energy purposes does neither contribute to, nor contravene circular economy principles. Biogas production can contribute to nutrient recovery due to the generation of digestate from the anaerobic digestion process. If potato and sugar beet pulp are diverted away from other applications, primary material extraction may be required which could have negative impacts on the environment, however this is variable and may not always be the case.

3. Sustainability and Greenhouse gases

3.1. Union sustainability criteria

The Union sustainability criteria relate to agricultural field residues (Article 29(2)), agricultural biomass (Articles 29 (3) to (5)) and forestry biomass (Articles 29 (6) and (7)), and therefore do not apply to potato pulp which is classified as residue. Since sugar beet pulp is a co-product, these criteria do need to be considered (see Table 64).

Table 64 : Assessment of Sugar beet pulp.

Criterion (all land status assessed in 2008)	Assessment
(2) for wastes and residues derived from agricultural land operators or national	As a co-product, this does not apply to sugar beet pulp.

authorities have monitoring or management plans in place in order to address the impacts on soil quality and soil carbon	As a processing residue, this also does not apply to potato pulp.
(3) bioenergy from agricultural biomass shall not be made from raw material obtained from land with a high biodiversity value	Expansion of sugar beet on highly biodiverse land is possible since expansion of sugar beet has been observed since 2017 when the EU sugar production quotas were abolished (CBS, 20178).
(4) bioenergy from agricultural biomass shall not be made from raw material obtained from land with high-carbon stock in January 2008 if the status of the land has changed	Expansion of sugar beet on land with high-carbon stock is possible since expansion of sugar beet has been observed since 2017 when the EU sugar production quotas were abolished (CBS, 2018).
(5) bioenergy from agricultural biomass shall not be made from raw material obtained from land that was peatland in January 2008, unless evidence is provided that the cultivation and harvesting of that raw material does not involve drainage of previously undrained soil.	Expansion of sugar beet on peatland is possible but not likely to occur as this crop can grow in a large range of soil types (Yara, n.d.).

3.2. Potential GHG savings

The potential GHG savings are analysed for the pathway of sugar beet pulp to ethanol. Default values of sugar beet ethanol from the REDII are used as a proxy as this closely mirrors the sugar beet pulp ethanol pathway (without an additional hydrolysis pre-treatment step). If sugar beet pulp is considered a co-product and energy allocation is used, and the additional processing compared to sugar beet resulted in ~8 gCO_2/MJ, the estimated GHG savings are 68%.[18] This indicates that sugar beet pulp ethanol would likely meet a minimum of 65% GHG emission savings.

No data could be identified for potato pulp to ethanol. However, since it is considered a residue (from processing), it is also expected to meet the minimum GHG emissions savings.

3.3. Other environmental impacts

An overview of the potential environmental impacts from sugar beet production (from which sugar beet pulp is derived) are highlighted in Table 65. Potato pulp is a process residue so these risks do not need to be evaluated.

Table 65: Overview of evaluation of risks for adverse effects on soil, water, air and biodiversity for Sugar beet pulp

Type of risk to be reviewed	Risk indicator	Risk level	Rationale and sources
Adverse impacts on soil quality	2.1 Soil Organic Matter: decline should be avoided	High risk	Row cultivation and relatively long periods of bare soils associated with sugar beet production make it a high erosion risk crop (soil and
	2.2 Nutrient and	High	

[18] GHG emissions from land use change, soil carbon accumulation, carbon capture and storage, and carbon capture and replacement are considered to be zero in this example. For processing, disaggregated values from no biogas from slop, and natural gas as process fuel in CHP plant used.

Type of risk to be reviewed	Risk indicator	Risk level	Rationale and sources
	phosphate balance: a disturbance of the balance leading to strong leaching of nutrients should be avoided	risk	wind), and soil organic matter loss (Diaz-Chavez et al., 2013). Sugar beet is a root crop, meaning that it requires significant disturbance to extract it from the soil during harvest, hence the potential risks associated with wind erosion. This may also be exacerbated by its tendency to prefer relatively light/medium soils (Diaz-Chavez et al., 2013). Sugar beet cultivation presents high soil compaction risks, particularly on clay soils. This is due to a higher depth of tillage and the greater weight of harvesters for sugar beet than for cereals. Furthermore, the harvesting period is later for sugar beet than for cereals and generally, where sugar beet is grown in northern Europe, the soil is wetter than during the cereal harvest (Diaz-Chavez et al., 2013). Herbicides and fungicides are used to control weeds and pathogens during early stages of growth and there are pollution risks to soil associated with pesticide run-off (Diaz-Chavez et al., 2013). Depending on soil and preceding crop type, its nitrogen demand of 230kg/N ha is comparable to rapeseed, leading to a risk of nitrogen compound fertiliser run-off (Diaz-Chavez et al., 2013).
	2.3 Soil erosion: should be minimised	High risk	
	2.4 Soil structure: soil compaction and waterlogging should be avoided	High risk	
	2.5 Soil biodiversity: contamination of soils with metals and other toxic component, disturbance of soil structure and decline in soil organic carbon may all lead to a decline in biodiversity and this should be avoided	Medium risk	
Adverse impacts on water quality	3.1 Water quality: ground and surface water quality should not decline through increased leaching and run off of N, P from fertilization and of other contaminants from fertilization and weed and pest control.	Medium risk	Herbicides and fungicides are used to control weeds and pathogens during early stages of growth and there are pollution risks to water associated with pesticide run-off (Diaz-Chavez et al., 2013). Depending on soil and preceding crop type, its nitrogen demand of 230kg/N ha is comparable to rapeseed, leading to a risk of nitrogen compound fertiliser run-off (Diaz-Chavez et al., 2013).
Adverse impacts on water quantity	4.1 Water quantity: excessive water consumption in agriculture should not lead to	Medium risk	Sugar beet are often grown in irrigated systems, particularly in arid and semi-arid areas (Diaz-

Type of risk to be reviewed	Risk indicator	Risk level	Rationale and sources
	depletion of sweet water resources and salinization.		Chavez et al., 2013).
Adverse effects on air quality	5.1 GHG emissions: GHG emissions from cropping should be minimized	Low risk	The main air quality risk associated with sugar beet is related to agrochemical spray drift. EU regulations should control this, but outside EU this is not regulated.
	5.2 Ammonia and NOx emissions: should be minimized	Low risk	
	5.3 Air pollution through spreading of herbicides and pesticides should be minimized	Medium risk	
Adverse effects on biodiversity	6.1 Crop diversity: large scale monocultures decreasing crop diversity strongly in a region should be avoided	Medium risk	The maintenance of sugar beet in crop rotations may have beneficial agronomical and environmental effects for cereals that follow in the rotation (Diaz-Chavez et al., 2013).
	6.2 Biodiversity: Direct adverse impacts on flora and fauna should be avoided	Medium	
	6.3 Pollination: Direct adverse impacts on pollinators and their habitats should be avoided	Medium	
	6.4 Invasive species: use of biomass crops that are invasive should be banned	Low	

4. Market effects and 2030/2050 potential

4.1. Market effects

Sugar beet pulp

Globally, the EU is the leader of sugar beet production, representing about 50% of the global sugar beet market, with Russia and the U.S. as the next largest producers (European Commission, 2017). Sugar beets are grown mainly in northern Europe, where climate and soil are best suited. The most productive regions are northern France, Germany, Poland, the United Kingdom, the Netherlands and Belgium. In the Southern hemisphere the only grower is Chile (ED&F Man, n.d.).

Sugar beet is made into an array of different products, including white sugar, pulp, bioethanol and sugar syrups for the chemical industry. Of the 140 million tonnes of sugar beet harvested in the EU in 2016-17, 16.7 million tonnes of white sugar were produced, 5 million tonnes of dehydrated sugar beet pulp, 1.6 million tonnes of sugar syrup for bioethanol production and 0.8 million tonnes of sugar syrup for the chemical industry (Farm Europe, 2018).

Sugar beet pulp is either sold dried as pellets or on a wet/pressed basis. The global production of dried sugar beet pulp pellets is estimated to be approximately 7.5 million tonnes while the worldwide output of wet beet pulp exceeds 10 million tonnes. The five largest producing countries of dried sugar beet pulp pellets are France, Germany, Russia, USA and Egypt (together producing 66% - equivalent to around 5 million tonnes - of the global supply) compared to large outputs of wet beet pulp in primarily The Netherlands, Belgium, Poland, Turkey, Russia/Ukraine and Iran (Beet&Feed, n.d.).

The supply of sugar beet pulp is rigid, as an increased demand for pulp would not increase its supply. Rather, it is the demand for the main product, white sugar, that dictates the supply of pulp. Since sugar beet pulp has such a strong existing use as animal feed, this would imply that adding the feedstock to Annex IX is very likely to have distortive effects on the animal feed market.

In addition, adding sugar beet pulp to Annex IX could have negative environmental effects due to substitution. Sugar beet pulp is a possible substitute for cereal grains such as barley or maize, thus the inverse could also be imaginable (Evans and Messerschmidt, 2017; Cordiez et al., n.d.). A thorough assessment would need to be performed to assess the range of products that could possibly substitute sugar beet; however, if sugar beet pulp was diverted from animal feed to biofuel production, this could potentially cause sugar beet pulp to be substituted with other crops such as cereal grains, which would require additional cultivation of these crops. This could subsequently lead to negative environmental impacts by increasing water demand, fertilizer use, soil erosion, or other effects associated with agricultural expansion. It would also increase the GHG emissions of the animal feed, as cereal grains would have higher cultivation emissions than sugar beet pulp.

Potato pulp

Although there are no figures of the market size of potato pulp readily available, it can be derived from the size of the potato starch market. Europe is the leading producer of potato starch, representing over 70% of the market share. Globally, the market for potato starch was 3.6 million tonnes in 2017 (imarc, n.d.). This would imply a global potato pulp production of 108 kt in 2017, which in an order of magnitude smaller than sugar beet pulp.[19] Since potato pulp is assumed to have a low economic value and could be considered a residue of the potato starch process, it is a rigid supply. This means that using potato pulp for bioenergy production could have distortive effects on the markets it is currently being used in, both animal feed and beverages.

4.2. 2030/2050 Potential

Sugar beet pulp

Annual white sugar production in the EU in 2016-2017 was 16.8 million tonnes, but October 2017 represented a pivotal point for the European sugar industry. The European sugar market was reshaped due to the removal of a sugar production quota that had been in place for nearly 50 years. It is thus expected that in the medium term, EU sugar production will increase 12% and that lower EU sugar prices will halve imports and double exports. Globally, white sugar production (both sugarcane and beet sugar) is also expected to increase. Following the forecasted increase in sugar consumption, global white sugar is expected to increase to 228 million tonnes in 2030 (European Commission, 2018). This would imply a **potential of 13.7 million tonnes of sugar beet pulp in 2030 globally**.

Potentials of sugar beet pulp in 2050 will depend on diet changes (sugar consumption per capita) and population growth. If sugar consumption were to remain at 26 kg per capita in 2050, and population were to grow to 10 billion (World Bank Blogs, 2019) in 2050, this would result in a global potential of 15.6 million tonnes of sugar beet pulp in 2050. **However, given that almost**

[19] Assuming 3 kg of potato pulp is generated per 100 kg of potato starch (Feedipedia, n.d.).

all of sugar beet pulp is currently used by the animal feed industry, thus there is no available potential for the biofuel market.

Potato pulp

In 2017, the global market for potato starch was 3.6 million tonnes, implying a potato pulp production of 108 kt (imarc, n.d.). Looking forward, some forecasts expect an annual growth of 2.4% per year from 2020-2025, reaching 4.5 million tonnes of potato starch by 2025 (EMR, n.d.). Even with this growth, the potential for potato pulp in 2030 and 2050 remains fairly limited in comparison to other feedstocks in. **Since it already has other uses in the animal feed and beverage markets, there is also limited potential for use as a biofuel feedstock without distorting these existing markets.**

5. ADDITIONAL DEMAND FOR LAND

5.1. Assessment of additional demand for land

As identified in Section 4, sugar beet pulp is currently widely used in multiple non-energy markets, and in particular as animal feed. Section 4.2 also identified that sugar beet pulp as animal feed could be potentially be substituted with cereal grains such as maize or barley, although further research would be needed to explore potential substitution effects. These crops both correspond with a medium risk category for additional demand for land. We thus select the medium risk category for sugar beet pulp.

Similarly, it is also expected that potato pulp use in as animal feed would also be most likely be substituted with cereal grains. We therefore also consider that use of potato pulp for bioenergy would also correspond to a medium risk category for additional demand for land.

6. PROCESSING TECHNOLOGIES

6.1. Evaluation of processing technology (mature vs advanced)

For both potato and beet pulp, the two biofuel pathways to consider are **pulp to ethanol** and **pulp to biogas**. The process technology for pulp to biogas is through anaerobic digestion. Anaerobic digestion is considered a **mature technology** with almost 20,000 biogas plants already operational in the EU (EBA, n.d.). Sugar beet is considered to be a quality substrate for anaerobic digestion (Muzik et al., 2012), with examples of commercial deployment (Zorg Biogas, n.d.). As indicated in Section 1.3, anaerobic digestion can be used to convert potato pulp to biogas, however studies highlight the challenges with regards to inefficient performance.

The fermentation and distillation of sugars from sugar beet for conventional bioethanol production is a mature technology that has been used commercially for decades (Eubia, n.d.). However, bioethanol production from sugar beet pulp needs to first be pretreated and hydrolysed in order to be fermentable for ethanol production. The hydrolysis of sugar beet pulp, which can be done chemically or enzymatically, could be considered an advanced technology as it is less mature (Marzo et al., 2019). No commercial demonstration of using this feedstock for bioethanol production could be identified. Similarly, for potato pulp, experiments have shown that the starch, cellulose and pectin contained in potato pulp can be hydrolysed and used as nitrogen and carbon sources for ethanol fermentation (Gao et al., 2012). This part of the bioethanol production process has only been proven at lab scale and in a limited amount of studies, thus can be considered an advanced rather than mature technology.

Therefore, pulp to biogas is considered as the main processing pathway for potato and beet pulp and is considered **mature** for the purpose of this assessment.

7. CONCLUSIONS

Overall compliance, areas of uncertainty, need for further research, etc.

Nomenclature:

- No concern = the evaluation did not reveal any significant concern about this feedstock.
- Some concern = the evaluation identified limited conditions under which some concerns may exist, i.e. using this feedstock for biofuel production could be in contradiction with this criterion.
- Significant concern = the evaluation reveals that using this feedstock for biofuel production would be in contradiction with this criterion in most circumstances.
- Not applicable = this criterion is not applicable to the feedstock.

Table 66 : Summary of evaluation results.

	Evaluation Result	Rationale
Circular economy	No concern	No commercial uses exist that can extend product life and sequester carbon for longer than energy uses. Diverting these feedstocks to energy uses would reduce waste generation.
Union sustainability criteria	No concern	Under which circumstances could this feedstock be problematic? Expansion of sugar beet has been observed since the abolition of sugar quotas in the EU. How to mitigate this concern? Failure to meet the Union sustainability criteria will be efficiently addressed throughout the certification process by an EU-approved voluntary or national scheme.
Sustainability GHG	No concern	Sugar beet pulp ethanol would likely meet a minimum of 65% GHG emission savings.
Sustainability Others	Some concern (sugar beet pulp) Not applicable (potato pulp)	Under which circumstances could this feedstock be problematic? Sugar beet carries high soil erosion risk (water and wind). Potential compaction risks. Risks due to application of application of herbicides and fungicides and nitrogen fertiliser. Potato pulp is considered to be a residue (from processing) and the requirements do not apply. How to mitigate this concern? Whereas some EU-approved voluntary schemes have additional environmental requirements, which could potentially mitigate the identified concerns, new policy instruments would be required to address these consistently and

		systematically.
Market distortion	Significant concern	Sugar beet pulp and potato pulp are already widely used in non-energy applications, in particular as animal feed. How to mitigate this concern? This feedstock has been assessed as potentially appropriate for inclusion in Annex IXB. The contribution of Annex IXB feedstocks to national RED transport targets is capped at 1.7% of transport energy. Inclusion under this cap would limit the amount of feedstock likely to be used for biofuel/biogas production and thus mitigate against the most market distortive outcomes, but would not fully prevent indirect impacts.
2030/2050 Potential	Sugar beet pulp: 2030 (global): 13.7 million tonnes (i.e. 4.6 million tonnes of ethanol or 3 million tonnes of biogas) 2050 (global): 15.9 million tonnes (i.e. 5.4 million tonnes of ethanol or 2.6 million tonnes of biogas) Potato pulp: 2030 (global): 5 million tonnes (i.e. 1.7 million tonnes of ethanol or 1 million tonnes of biogas) 2050 (global): 5 million tonnes (i.e. 1.7 million tonnes of ethanol or 1 million tonnes of biogas)	The evaluation concluded that there is a potential of approximately 13.7 million tonnes of sugar beet pulp in 2030. This can increase to a potential of 15.9 million tonnes in 2050. An estimated 5 million tonnes of potato pulp may be available in 2030 and 2050. However, given that almost all of available supply is currently used in non-energy applications, particularly by the animal feed industry, **there is no available potential for the bioenergy market.**
Land demand	Some concern	Sugar beet pulp and potato pulp used as animal feed would most likely be substituted with cereal grains such as maize or barley. This would pose a medium risk for additional land demand. The overall risk is considered **medium-high**. How to mitigate this concern? See “Market distortion”.
Processing Technologies	Mature (biogas)	Commercial demonstration of using sugar beet pulp for biogas identified.

	Advanced (bioethanol)	Potato pulp may be less suitable for anaerobic digestion due to inefficient performance. No commercial demonstration of using either sugar beet pulp or potato pulp for bioethanol production could be identified.

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Starchy effluents

1. TECHNICAL DESCRIPTION

1.1. Feedstock description

This category includes various effluents from the milling and processing of starchy crops such as corn and wheat into food/feed or ethanol, namely:

- Starch-containing wastewaters
- Waste starch slurry
- Steep water
- Corn steep liquor

These effluents include a significant concentration of nutrients such as starch and sugars (Annex IX Task 1 report).

S**tarch-containing wastewaters** are generated out of the wet and dry milling of corn/wheat to produce ethanol/starch (Vohra et al., 2013; stakeholder feedback). **Waste starch slurry** is defined by the United Kingdom (RTFO) as a mixture of starch and water arising from the wet milling of wheat or corn with:

- dry matter content not exceeding 20% (as measured at the point of separation in the production process).
- total suspended solid particles larger than 5 microns in diameter not exceeding 10% (as measured by a filter with a standardized perforation of 5 micrometer) (UK DfT, 2021).

We consider waste starch slurry to be a subset of starch containing wastewaters.

Waste starch slurry is included in the ISCC list of materials and is double counted in the UK, Ireland, and the Netherlands (stakeholder feedback, UK DfT, 2021; REV, 2020; NORA, 2019). The UK's RTFO feedstock guidance classifies 'starch slurry regular' separately from 'waste starch slurry', and the former is not double counted (UK DfT, 2021).

Steep water is produced during the steeping stage of the wet milling process used to produce corn and wheat starch (see section 1.2). The light steep water contains between 6-9% solids by weight. The light steep water is then evaporated until it contains 40-60% solids to form **corn steep liquor**, also known as heavy corn steep water. Corn steep liquor contains proteins, amino acids, minerals, vitamins, reducing sugars (such as dextrose), organic acids (in particular lactic acid), enzymes, and elemental nutrients such as nitrogen (Packwood and Kueber, 2014). Details related to the composition of wheat steep water are not available.

1.2. Production process

Starchy effluents are produced during the milling and processing of starchy crops such as corn and wheat into food/feed or ethanol. **Figure 19** shows the production of starch, ethanol and several other products from starchy crops in the EU.

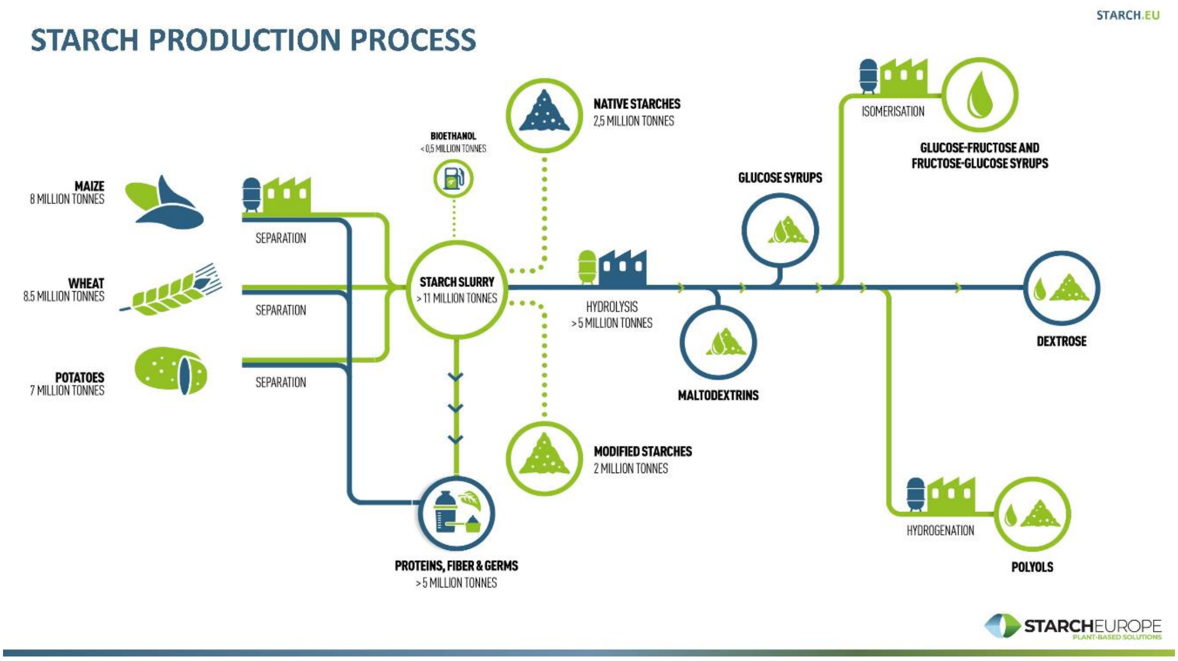

Figure 19: European starch production and use (Source: Starch Europe, 2019)

The following sub-sections focus on different effluent streams that are generated during the production of starch and/or ethanol from corn or wheat milling.

- **Starch containing wastewaters, steep water and corn steep liquor from corn milling:**

    - **Starch containing wastewaters obtained during production of bioethanol via corn dry milling**

        - Corn dry-milling process is carried out in five steps viz: (i) biomass handling (milling), (ii) liquefaction, (iii) hydrolysis (saccharification), (iv) fermentation, and (v) distillation and recovery (Vohra et al., 2013). In dry-grind process, the corn passes through the hammer mills that grind it into fine particles. This process facilitates the entry of water and enzymes in the next steps. In a typical dry mill process, the grains are milled to a powder and heated with water at 85°C. While still hot, powder of alpha amylase enzymes are added and the mixture is heated at 110–150°C for an hour. This causes the liquefaction of starch and reduces the level of bacteria. It is again cooled to 85°C, and held at this temperature for one hour after adding more alpha-amylase enzymes (Vohra et al., 2013). It is cooled to room temperature and gluco-amylase enzymes are added to ensure the conversion of corn starch to dextrose (Vohra et al., 2013). In most of the dry-grind milling plants, the gluco-amylase enzymes are directly added into the fermenter using the process known as 'simultaneous saccharification and fermentation' (SSF). This process reduces the costs associated with the requirement of saccharification vessels and minimizes the risk of contamination (Vohra et al., 2013). In the fermentation process, yeasts convert glucose into ethanol and carbon dioxide. Fermentation process can be operated in batch held until the process is completed within 48 hours or can be operated continuously with ongoing addition of sugar and taking out of fermented broth know as beer. Usually, it takes about 40–50 hours for the completion of fermentation process. During fermentation, the mash is agitated continuously to distribute yeast uniformly and to keep it highly active. After fermentation, the resulting beer is transferred to distillation columns where ethanol is separated from the remaining stillage (Vohra et al., 2013). The stillage containing the remaining protein, oil, and fibre are dried to a 27% protein product known as distillers dried grains with solubles (DDGS) or just distillers dried grains (DDG), depending on whether process syrup is combined with the solids or not (Vohra et al., 2013). As per stakeholder feedback, **what is left in the wastewater is the wastes of starch slurry from milling of corn and this is used in the AD plant**.

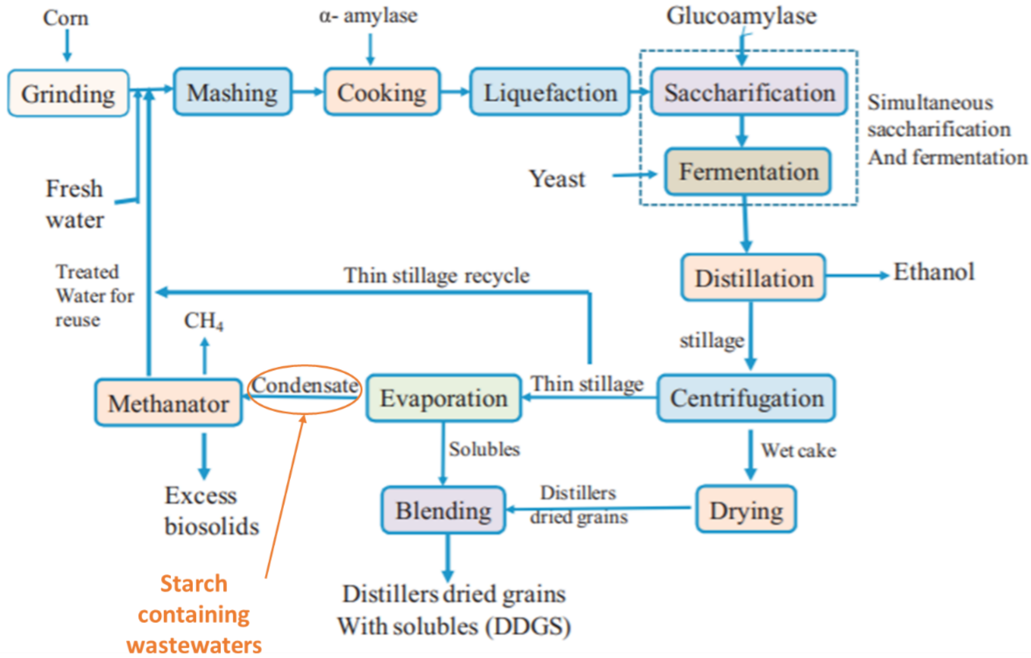

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Figure 20: Corn dry milling process flow diagram (Source: Vohra et al., 2013)

Specific details regarding the production of waste starch slurry, as defined by the RTFO, are not available.

- **Corn steep liquor obtained during production of corn starch and other derivatives via wet milling**

Wet milling is the most common process used to produce corn starch with high quality and yield. This process involves chemical, biochemical, and mechanical operations to separate the principal components of the corn grain: starch, protein, germ and fibre (Haros et al., 2006). Kernel steeping is the first and the most important step in the milling process, and is also a capital-intensive and time-consuming step because it involves grain soaking in weak solution of sulphurous acid at sub-gelatinisation temperatures (50–55°C) for 30–55 hours (Haros et al., 2006). The steeping objective is to degrade the kernel structure to enhance milling by the absorption of water and SO_2 (Haros et al., 2006). Sulphurous acid and warm temperatures control growth of putrefactive microorganisms and help starch release by cleaving disulphide bonds of protein matrix from the endosperm where the starch is encapsulated (Haros et al., 2006). During steeping, solubles leach out from the corn and end up in the **light steep water** (Alfa Laval, 2004). To recover this, the steep water is processed in an evaporator, where these soluble solids are concentrated by evaporating part of the water resulting in the production of **corn steep liquor** (Alfa Laval., n.d.; Packwood and Kueber, 2014). **In most plants, corn steep liquor are subsequently mixed with the fibre fraction before the mixture (fibres + corn steep liquor) is dried (Alfa Laval, 2004). This dried product is often called gluten feed** (Alfa Laval, 2004; Trenkle and Ribeiro, 1999).

Starch and protein (gluten) are then separated in two steps. First, the main protein fraction is separated using nozzle centrifuges, in a process known as primary separation. This is followed by washing with fresh water in hydrocyclones to separate out the remaining proteins and other impurities (Alfa Laval, 2004).

The protein separated in the nozzle centrifuge is then pre-dewatered in another nozzle centrifuge, followed by final dewatering using vacuum filters. Water recovered from the protein is used as process water for washing the fibres and germ and in the steeping process (Alfa Laval, 2004).

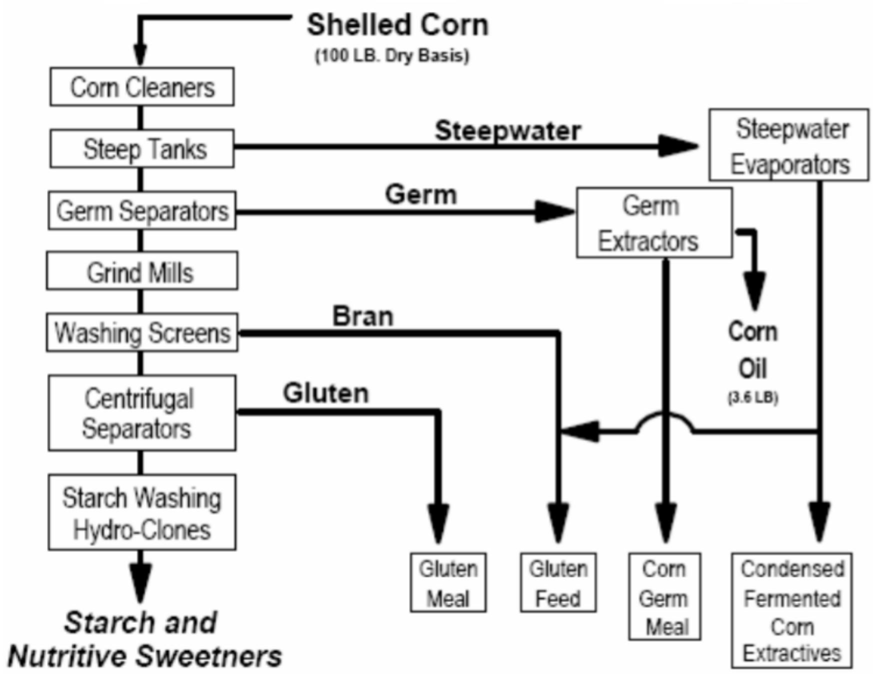

Figure 21: Overview of corn wet milling process, including production of steep water

- **Starch slurry and corn steep liquor obtained during starch production via corn wet milling**

  In wet milling process, the corn kernel is separated into three parts in an aqueous medium prior to fermentation: (1) the hull, (2) the germ, and (3) the endosperm. The primary products of wet milling include starch and starch-derived products (e.g. high fructose corn syrup and ethanol), corn oil, and corn gluten (Vohra et al., 2013). A wet mill generally receives shelled corn, which pass through mechanical cleaners designed to remove unwanted material, such as pieces of cobs, sticks, husk, and stones. The cleaned corn is next fed into steep tanks, where these are soaked in dilute sulphuric acid for 24 to 48 hours at a temperature of 52°C (Vohra et al., 2013). Steeping softens the kernel, helps to break down the protein holding the starch particles, and removes various soluble constituents. A number of tanks are used in series. Corn that has steeped for the requisite duration is discharged from the tank for further processing, and the tank is filled with fresh corn (Vohra et al., 2013). Generally, water drained from the steep tank, called **light steep water**, contains about 6% of the original dry weight of the grains and is discharged to evaporators,. The solids from steep water are rich in protein and are concentrated to 30–55% solids in multiple-effect evaporators[20].

[20] A multiple-effect evaporator uses the water vapor from one effect as the heating medium for the next effect, which operates at a lower boiling point. The latent heat in water vapor can also be reused by thermally or mechanically compressing the vapor to a higher pressure and temperature (AIChE, 2018).

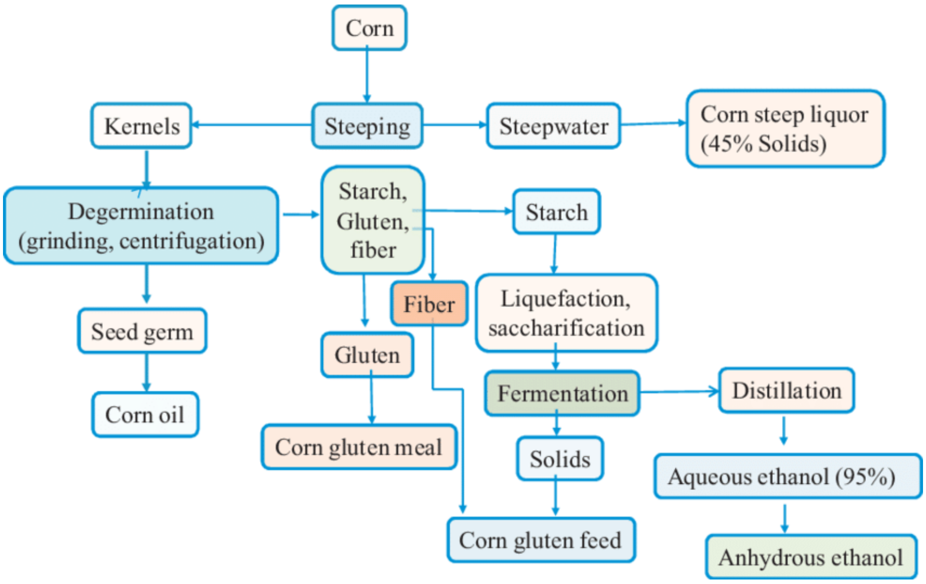

Figure 22: Corn wet milling process flow diagram (Vohra et al., 2013)

The germ is removed from the steeped corn in a process that breaks the kernel apart to free both the germ and about half of the starch and gluten (Vohra et al., 2013). The germ is separated in liquid cyclones from the mixture of fibre, starch, and gluten. It is subsequently washed, dewatered, and dried, and further processed to extract corn oil. The starch and gluten from the product slurry are removed from the rest of the fibrous material by further washing, grinding, and screening operations. The starch is separated from the gluten by centrifugation. When the purified starch slurry is obtained, the wet-mill process is very similar to that of dry milling (Vohra et al., 2013). First, the pH of the starch slurry is adjusted to 5.8–6.2 with lime, after which alpha amylase is added to convert the starch polymer into soluble short chain dextrins (liquefaction). Calcium is often added (20–100 ppm) to enhance enzyme stability. As the starch stream is relatively free of fibre or other components, it is well suited to the high temperature and short time of jet cooking and subsequent enzyme liquefaction (Vohra et al., 2013). Hence, solid slurries of 30–40% starch are common. **The starch slurry from the liquefaction stage is mixed with heat sterilized steep water and sent for saccharification** (Vohra et al., 2013). The steep water provides both the fermentation nutrients and pH adjustment for saccharification, in which the added glucoamylase converts the dextrins to glucose at a pH of 4.5 and a temperature of 65 °C. After saccharification, *S. cerevisiae* is added to ferment the sugars to ethanol and CO_2. The total fermentation time varies from 20 to 60 h, depending mainly on the degree of saccharification prior to fermentation. Most wet mills practice continuous-cascade fermentation. Very few insoluble solids are found in these fermentation systems, which facilitate yeast recycling and improves the overall fermentation rates. The final product from a continuous process will have an ethanol content of 8–10% by volume (Vohra et al., 2013).

It should be noted that the stakeholder consultation suggests that recent improvement in wet milling processes have significantly reduced the volume of starch slurry being wasted, either by eliminating slurries or by almost removing all starch from the slurry. **Therefore, the volumes of starch-containing wastewaters available for biofuel/biogas production can be expected to decrease in the coming decades.**

- **Starch-containing wastewaters and steep water generated during starch and ethanol production from wheat**
    - **Starch-containing wastewaters obtained during wet wheat milling**
      The first step of the wheat starch process is a milling step where bran and flour are separated. The flour is mixed with water in a dough mixer, pH is adjusted and enzymes to reduce viscosity are added (stakeholder feedback; Alfa Laval, 2004). More water is then added, forming a slurry that is subsequently separated into the following fractions using a three phase decanter centrifuge: 1) A Starch 2) B Starch + Gluten 3)

Wheat solubles. **Wheat solubles** refers to a brown liquor that contains, in suspension some fine granules of starch called C Starch and most of the impurities contained in wheat, like pentosanes, solubles proteins or minerals (stakeholder feedback; Velicogna and Miller, 2016). Stakeholder feedback indicate the generation of **residual starch slurry** and **liquid starch residues (LSR)** during the production of starch. Residual starch slurry refers to dilute residual process streams that are also called process water (or solubles) and pentosans (stakeholder feedback). On the other hand, LSR are generated during the gluten and high-quality (A) starch extraction process, and have a water content of about 90% (stakeholder feedback). **Based on the definitions available, it appears that residual starch slurry and LSR are both referring to wheat solubles**.

After gluten and B Starch separation, B Starch is blended with A Starch to feed the upstream process (stakeholder feedback)/ for conversion into glucose (Alfa Laval, 2004). After the hydrolysis step other impurities are released. These impurities, also called retentates, are separated by a tangential filtration step on ceramics membranes. All these impurities, wheat solubles, retentates, that are caught in two steps, not suitable for food applications, can be blended and this mixture is called **Waste Wheat Starch Slurry (WWSS)** (stakeholder feedback).

- **Wheat steep water generated during wet wheat milling**
  Wheat ethanol production is considered to be similar to that of corn and wheat steep water is generated following the steeping process (Patni et al., 2013; KHN, 2019).

1.3. Possible uses

Starchy effluents are generally used onsite for additional ethanol production due to fact they tend to degrade rapidly, which would make their storage and shipping difficult practically (Annex IX Task 1 report).

- Potential uses of **starch-containing wastewaters**:
  - Anaerobic digestion of **starch-containing wastewaters** to produce **biogas** is a possible use (Concernergy, n.d.; stakeholder feedback). The digestate can be further used as fertiliser (Concernergy, n.d.).
  - Due to the high water content of residual starch slurry, the high content of impurities and the limited storage stability there is no commercial case other than disposal or production of biofuel or bioenergy (stakeholder feedback).
  - Waste starch slurry from milling of corn or wheat (as defined by the RTFO) is being used for producing **bioethanol** in the UK as well as EU Member States such as the Netherlands and Poland (Bureau Veritas, 2020; UK DfT, 2021; REV, 2020; stakeholder feedback)
  - Stakeholder feedback suggests that starch-containing wastewaters are **unsuitable for food/feed applications**. However, there is a patent application for a **chicken feed** formulation that includes waste starch slurry (from corn starch preparation facilities) as an ingredient, albeit the amount can vary from 0 to 3 portions (Patent, 2009).
  - **Wheat gluten feed** pellets are produced during the manufacture of wheat starch and gluten (KW Alternative Feeds, 2016). **They consist of bran, from which the germ may have been partially removed, wheat solubles (stillage which contains yeast fragments), broken wheat and other products derived from the refining or fermentation of starch** (KW Alternative Feeds, 2016). 'Wheat solubles' was mentioned as a constituent of waste wheat starch slurry by a stakeholder (see section 1.2).
  - In case of wheat starch slurry, Starch A (which is a component of the slurry) can be sold as premium wheat starch, or it can remain in the slurry along with Starch B to produce alcohol products (ICCT, 2020). Starch A is mostly sold to the paper industry, where it is used as a wet-end adhesive, in surface coating, and as an adhesive for the

manufacture of corrugated board (ICCT, 2020). However, we are unable to find any references regarding potential use of **'waste'** wheat starch slurry in food/feed applications.

- Potential uses of **corn steep water and corn steep liquor:**
    - Corn steep water can also be used as the starting substrate for **biofuel production**, such as **biogas** (Yasri et al., 2015; US EPA, 2010).
    - Potential use of corn steep water as a base of compositions for **de-icing and anti-icing materials** (Yang and Montgomery, 2003).
    - The primary use of corn steep liquor is as a **nutrient for ruminant animals and swine** (Packwood and Kueber, 2014; Shur-Gain, 2011; Vohra et al., 2013; Persistence Market Research, 2019). The majority of corn steep liquor produced is immediately added to corn gluten and fibrous materials for use as animal feed (Packwood and Kueber, 2014).
    - Corn Steep Powder (CSP) is a water-soluble powder made by spray drying corn steep liquor (Grower's Secret, n.d.). Both corn steep liquor and corn steep powder are used as **fertiliser** (Grower's Secret, n.d.).
    - Corn steep liquor can also be used in the **production of antibiotics** (Packwood and Kueber, 2014; ECHA, n.d.). It is a good additive for microbial growth media and hence plays a vital part in the production of penicillin (Grower's Secret, n.d.).

Possible uses of starchy effluents are summarised in **Table 67**.

Table 67 : Summary of possible uses of starchy effluents

	Food use	Feed use	Other uses
Starch-containing wastewaters (from corn and wheat milling)	No documented evidence of commercial implementation.	Documented evidence in the form of a patent application.	Biogas: Documented evidence of commercial implementation. Fertiliser: Documented evidence of use of biogas digestate as fertiliser. Bioethanol: Documented evidence of commercial implementation.
Corn steep water and corn steep liquor	No documented evidence of commercial implementation	Documented evidence of commercial implementation	Antibiotics: Documented evidence in the form of patents, research articles and ECHA registration dossier. De-icing / anti-icing material: Research article published, however, no documented evidence of commercial implementation. Biogas production: Mentioned in research article, however, no documented evidence of commercial implementation. Fertiliser: Documented evidence of use of corn steep liquor and corn steep powder

			as fertiliser

2. CIRCULAR ECONOMY AND WASTE HIERARCHY

2.1. Classification of the feedstock as a co-product, residue or waste

On the basis of the feedstock description provided in sub-section 0, their possible uses in sub-section 0, stakeholder feedback and additional references, starch-containing wastewaters, waste starch slurry, steep water and corn steep liquor can be classified as residues or wastes as described below.

Table 68 : Classification of starchy effluents

<table>
<tr><th>Evaluation question</th><th>Answer</th><th>Rationale</th></tr>
<tr><td>Is the feedstock the primary aim of the production process?</td><td>No</td><td>The primary aims of starchy crop processing are food-grade starch, ethanol and gluten feed. Starch-containing wastewaters, steep water and corn steep liquor are generated during starchy crop processing.</td></tr>
<tr><td>Does the feedstock have any economic value, but is not the primary aim of the process, and therefore a residue?</td><td>Variable</td><td rowspan="2">Starch-containing wastewaters are used for generating energy such as biogas or bioethanol, and can be used for feed production. Corn steep water can be used for biogas production and as base of compositions for de-icing and anti-icing materials. Corn steep liquor serves as a nutrient in feed for ruminants and swine, and can also be used in the production of antibiotics and fertilisers (see section 0 for possible uses). All three materials are therefore considered to have economic value and can be classified as residues.

When value-added uses for corn steep water is not economically viable, it is disposed in rivers and streams (Yasri et al., 2015). Such volumes of corn steep water can be classified as waste.</td></tr>
<tr><td>Is the feedstock normally discarded, and therefore a waste?</td><td>Variable</td></tr>
</table>

2.2. Is the use of feedstock to produce biofuel/biogas in line with circular economy principles?

- **Does the feedstock have non-energy (re)uses, which could extend its life or sequester carbon for longer?**

  Answer: Variable.

  Rationale: **Starch-containing wastewaters, corn steep water and corn steep liquor** can be used for the production of fertilisers; **corn steep water** can be used for production of bio-based chemicals such as de-icing materials, while **corn steep liquor** is used in antibiotics production (see section 0). These uses would sequester carbon over a longer period than if these are used to produce biofuel or biogas.

  Evidence of the use of **starch-containing wastewaters** and **corn steep liquor** in the production of animal feed are documented but would not constitute a significant extension of the life-time. It would only temporarily extend the life-time of the material, which eventually exits the circular chain by being released into the environment (air, soil and water) through animal metabolism, even when manure is collected for biogas production.

The economic viability of non-energy uses may change in different geographic and economic contexts.

- **Does its use as biofuel/biogas feedstock contribute to nutrient recovery?**

  Answer: Variable.

  Rationale: Anaerobic digestion of **starch-containing wastewaters** and **corn steep water** generates a digestate, which retains C, N, P and other important nutrients and can be used as fertiliser, thus contributing to decreasing the need for industrial fertiliser production (IEA Bioenergy, 2015; European Commission, 2019). There is no evidence of the use of **corn steep liquor** for biogas production.

  Bioethanol derived from **starch-containing wastewaters** has no documented contribution to nutrient recovery.

- **Does its use as biofuel/biogas feedstock contribute to a more efficient use of resources by avoiding primary material extraction?**

  Answer: Variable.

  Rationale: As with all other biomass feedstocks, biofuels and biogas derived from starchy effluents displaces fossil fuels and natural gas, thus reducing the need for primary material extraction. When economically feasible, using **starch-containing wastewaters** and **corn steep liquor** in feed chains and other non-energy related applications (mentioned above in this section) would, however, reduce the need for primary production (e.g. nutrients in feed) as well. Similarly, when economically feasible and commercially viable, using corn steep water for bio-based chemicals production would reduce the need for primary production (e.g. fossil-based de-icing materials) as well.

  Finally, comparative benefits of using starchy effluents for energy rather than in feed chains through avoided primary material extraction should be further explored to assess which use should be prioritised at policy level.

- **Does its use as biofuel/biogas feedstock contribute to reducing waste generation, especially food waste?**

  Answer: Variable.

  Rationale: Transforming starchy effluents into energy, which eventually displaces fossil fuels, has higher environmental benefits than if these residues/wastes were discarded as effluent. Industry stakeholders reported that **starch-containing wastewaters** and **corn steep water** were being converted into biogas or bioethanol, thus generating additional revenues, which could constitute an incentive against trying to improve corn/ wheat mill efficiency to reduce the share of residues or waste. It is, however, unclear whether such extra revenues would be higher than if those were used in feed chains instead. Whenever selling residues or waste for energy recovery is the only alternative to discarding starchy effluents, using it as biofuel/biogas feedstock does indeed contribute to reducing waste generation.

2.3. Is the use of this feedstock for biofuel/biogas production in line with the waste hierarchy?

- **Contribution to increasing waste?**

  Answer: Variable.

  Rationale. No evidence exists that using starchy effluents such as **starch-containing wastewaters** and **corn steep water** for biogas or biofuel production would generate more waste. One stakeholder did comment that there should not be high volumes of starch slurry available due to advancement in process operations. However, there could be a broader risk to create an incentive against reducing existing volumes of waste by offering an extra source of income to operators.

- **Can this feedstock be potentially reused?**

  Answer: No/ not applicable.

  Rationale: Starchy effluents are generated during the milling of cereals such as corn or wheat, and has not been used at that stage. The documentation received during the stakeholder consultation and additional references indicate that **starch-containing wastewaters** and **corn steep liquor** can be used as feed. This cannot, however, be considered as "reuse".

- **Can this feedstock be potentially recycled?**

  Answer: Variable.

  Rationale: The main documented use of starch-containing wastewaters and corn steep water is for production of biogas and bioethanol, while the main use of corn steep liquor is in animal feed production, fertilisers and antibiotics production (see section 0). As per the Waste Framework Directive, use of feedstock for energy production does not qualify as recycling. However, there is potential for using **corn steep liquor** and **corn steep water** in the production of antibiotics and de-icers respectively (see section 0), which would qualify as recycling[21].

2.4. Conclusion

Contribution to circular economy

There is no demonstrated commercial use of **starch-containing wastewaters** and **corn steep water** for material/chemical purposes, which could ensure a significantly longer life time and/or carbon sequestration than energy uses (biogas and bioethanol), which can therefore be considered in line with circular economy principles. However, it should be noted that corn steep water is concentrated by evaporation into **corn steep liquor**, and the latter is used in antibiotics production which can ensure a significantly longer life time and/or carbon sequestration than energy uses, which can therefore be considered not in line with circular economy principles. In summary, only the use of starch-containing wastewaters for biofuel/biogas is considered to be in line with circular economy principles.

With regards to contributing to waste reduction, it can be expected that further encouraging the use of starchy effluents for biogas or biofuel risks incentivising producers against improving processes and reducing the amount of cereal mill waste being generated, should these be economically and technically feasible.

Alignment with the waste hierarchy

Using starchy effluents for biogas/biofuel is in line with the waste hierarchy under the following conditions:

- Waste do not meet food or feed quality standards.
- Waste, for which a food or feed use is not economically viable for the economic operator or the logistical chains to collect and/or process residues and waste into food or feed chains are not in place, and could not be readily put in place.

Whenever using starchy effluents, such as **starch-containing wastewaters** and **corn steep liquor**, as feed ingredient is both logistically and economically possible, using these feedstocks for energy purposes (biogas and bioethanol) is not in line with the waste hierarchy.

[21] As per the Waste Framework Directive, 'recycling' means any recovery operation by which waste materials are reprocessed into products, materials or substances whether for the original or other purposes. It includes the reprocessing of organic material but does not include energy recovery and the reprocessing into materials that are to be used as fuels or for backfilling operations (EC, 2008)

3. Sustainability and Greenhouse gases

3.1. Union sustainability criteria

The Union sustainability criteria relate to agricultural field residues (Article 29(2)), agricultural biomass (Articles 29 (3) to (5)) and forestry biomass (Articles 29 (6) and (7)), and therefore do not apply to starchy effluents which are classified as a process residue/ waste.

3.2. GHG Savings Criteria

The first conversion process considered is fermentation and distillation to produce **bioethanol**. Starchy effluents do not have a default GHG intensity value provided in the RED II. As it is likely to be considered a process residue and therefore according to REDII considered to have zero life cycle emissions until the point of collection.

Default values of corn (maize) ethanol or other cereals excluding maize ethanol from REDII are used as a proxy since the starting material for the starchy effluents to ethanol pathway are corn and wheat. The emissions associated with cultivation were excluded from the calculation as these feedstocks are process residues.

The default value for the emissions associated with processing (e_p) was between 2.2-42.5 gCO2e/MJ, dependent on the process fuel used.

Biofuel and bioliquid production pathway	Greenhouse gas emissions – typical value (g CO_2eq/MJ)	Greenhouse gas emissions – default value (g CO_2eq/MJ)
corn (maize) ethanol (natural gas as process fuel in conventional boiler)	20,8	29,1
corn (maize) ethanol, (natural gas as process fuel in CHP plant (*))	14,8	20,8
corn (maize) ethanol (lignite as process fuel in CHP plant (*))	28,6	40,1
corn (maize) ethanol (forest residues as process fuel in CHP plant (*))	1,8	2,6
other cereals excluding maize ethanol (natural gas as process fuel in conventional boiler)	21,0	29,3
other cereals excluding maize ethanol (natural gas as process fuel in CHP plant (*))	15,1	21,1
other cereals excluding maize ethanol (lignite as process fuel in CHP plant (*))	30,3	42,5
other cereals excluding maize ethanol (forest residues as process fuel in CHP plant (*))	1,5	2,2

Figure 23: Default GHG emissions savings associated with processing of corn ethanol and other cereals ethanol (RED II)

The default value for the emissions associated with transport and distribution (e_{td}) was 2.2 gCO2e/MJ for all process fuel types.

Biofuel and bioliquid production pathway	Greenhouse gas emissions – typical value (g CO_2eq/MJ)	Greenhouse gas emissions – default value (g CO_2eq/MJ)
corn (maize) ethanol (natural gas as process fuel in CHP plant (*))	2,2	2,2
corn (maize) ethanol (natural gas as process fuel in conventional boiler)	2,2	2,2
corn (maize) ethanol (lignite as process fuel in CHP plant (*))	2,2	2,2
corn (maize) ethanol (forest residues as process fuel in CHP plant (*))	2,2	2,2
other cereals excluding maize ethanol (natural gas as process fuel in conventional boiler)	2,2	2,2
other cereals excluding maize ethanol (natural gas as process fuel in CHP plant (*))	2,2	2,2
other cereals excluding maize ethanol (lignite as process fuel in CHP plant (*))	2,2	2,2
other cereals excluding maize ethanol (forest residues as process fuel in CHP plant (*))	2,2	2,2

Figure 24: Default GHG emissions savings associated with transport and distribution of corn ethanol and other cereals ethanol (RED II)

The emissions of the fuel in use is taken to be 0 gCO_2e/MJ for biofuels. The fossil fuel comparator for biofuels as per RED II is 94 gCO_2e/MJ. The total emissions from the disaggregated default values for corn ethanol and other cereals ethanol, excluding cultivation emissions, is therefore between 4.4-44.7 gCO_2e/MJ depending on the process fuel used. This implies there could be GHG savings ranging from 52-95% from using starchy effluents for bioethanol production. The process fuel used in the bioethanol production plant will determine whether the feedstock pathway is compliant with the GHG savings criteria. This is substantiated by stakeholder feedback which suggests that **over 80% GHG savings** compared to the fossil fuel comparator can be achieved by producing bioethanol from waste starch slurry. The stakeholder claims that the GHG emission calculation has been audited under ISCC EU.

The second conversion process considered is biogas production which provides **biomethane** for transport. According to the approach outlined for assessing this criterion, the first consideration is to look for a proxy in existing default values in REDII. Default values are provided for biomethane production in REDII Annex VI Part C for wet manure, maize and biowaste[22]. No default value for biomethane from starchy effluents is available. As an initial estimate, default values provided in the RED II for biowaste are considered which show based on the technological option a large variation in GHG emission savings is observed (20 – 80 %) depending on whether digestate is stored in an open or a closed tank and whether the off-gas is vented or combusted (see **Figure 25**). The GHG savings criteria for new installations require at least 65% GHG savings. This shows that to be eligible, the technology option of close digestate, off-gas combustion should be applied. Otherwise there is a high risk of non-compliance with GHG saving criteria.

[22] As per Directive 2008/98/EC, 'biowaste' means biodegradable garden and park waste, food and kitchen waste from households, restaurants, caterers and retail premises and comparable waste from food processing plants.

BIOMETHANE FOR TRANSPORT (*)			
Biomethane production system	Technological options	Greenhouse gas emissions savings – typical value	Greenhouse gas emissions savings – default value
Biowaste	Open digestate, no off-gas combustion	43 %	20 %
	Open digestate, off-gas combustion	59 %	42 %
	Close digestate, no off-gas combustion	70 %	58 %
	Close digestate, off-gas combustion	86 %	80 %

(*) The greenhouse gas emissions savings for biomethane only refer to compressed biomethane relative to the fossil fuel comparator for transport of 94 g CO_2eq/MJ.

Figure 25. Default GHG emissions savings values provided in REDII for biomethane for transport from biowaste

3.3. Other environmental impacts

Starchy effluents are process residues/ wastes and therefore have no land management impact. The evaluation of risks of adverse effects on soil, water, air and biodiversity is not applicable.

4. MARKET EFFECTS AND 2030/2050 POTENTIAL

4.1. Market effects

The market analysis for starchy effluents takes into account the production of wheat and corn starch as well as the production of corn and wheat bioethanol. We assume that corn wet milling bioethanol will not contribute much to the overall volumes as steep water is mixed with slurry and sent for saccharification followed by fermentation to ethanol (Vohra et al., 2013). We are unable to confirm the same for wheat wet milling bioethanol due to absence of references.

Corn is the main crop that supplies more than 80% of global starch markets, the largest industry of which is situated in the US. A much smaller starch production (>8%) comes from wheat (Bergthaller and Hollmann, 2007).

From 75 starch production facilities in 19 EU Member States, the European Starch Industry today produces 10.7 million tonnes of starch and starch-derivatives, and more than 5 million tonnes of proteins and fibres each year (Starch Europe, 2019). This is primarily extracted from 24 million tonnes of EU grown wheat, maize/corn and potatoes, but also from barley, rice and peas (Starch Europe, 2019). 45% of starch and starch derivatives (around 4.8 million tonnes) are corn-based while 41% of starch and starch derivatives (around 4.4 million tonnes) are wheat-based (Starch Europe, 2019). In the EU, 48.6% of the ethanol produced in 2019 was from corn (2.72 billion litres of ethanol), followed by wheat (21.1% or 1.18 billion litres) and sugar (19.3% or 1.08 billion litres) (ePURE, 2020).

The US is the world's largest producer of ethanol, most of which is corn-based (AFDC, 2020). With over 200 corn ethanol plants, the US can produce an estimated 59.8 billion litres of ethanol per year (U.S. Grains Council, 2021). Nearly 90% of ethanol plants are dry mills due to lower capital costs (AFDC, n.d.).

Starch-containing wastewaters

11 million tonnes of starch slurry is obtained per annum from the processing of corn, wheat and potatoes in Europe of which some is used in the production of 0.5 million tonnes of bioethanol (see **Figure 19**). The bulk of the slurry is used for the production of native and modified starches, proteins, fibres and germs, maltodextrins, dextrose, syrups and polyols (see **Figure 19**). It is not clear how much of the 0.5 million tonnes of bioethanol is produced using waste starch slurry, but

we assume this is a very small percentage given few players producing ethanol using this feedstock. We do know that nearly **0.8 million tonnes of waste starch slurry was certified by ISCC in 2019** (ISCC, 2020; ISCC, 2021). Waste corn starch slurry can also be used in animal feed, although level of commercial scale production of such feed is not clear (see section 0). Taking the case of waste wheat starch slurry specifically, although there is no reference for its use as feed, there is evidence of the use of one of its constituents (wheat solubles) in the production of **wheat gluten feed** (KW Alternative Feeds, 2016). Wheat gluten feed pellets are produced during the manufacture of wheat starch and gluten (KW Alternative Feeds, 2016). They consist of bran, from which the germ may have been partially removed, wheat solubles (stillage which contains yeast fragments), broken wheat and other products derived from the refining or fermentation of starch (KW Alternative Feeds, 2016). Wheat gluten feed is a fibre-rich ingredient, containing nutritious protein and starch, used in ruminant, swine, poultry feed and petfood (Nordfeed, 2016).

As per stakeholder feedback, 0.18 tonnes of waste corn starch slurry are generated per tonne of starch produced. The global corn starch market reached a volume of nearly 78 million tonnes in 2020 (EMR, 2020). Therefore, we estimate around 14 million tonnes of waste corn starch slurry may have been generated globally in 2020. However, we have not come across references that state the volumes of waste corn starch slurry used in different applications.

Therefore, incentivising starch-containing wastewaters such as waste corn starch slurry for transport fuel production could **pose some risk** by diverting the feedstock from its use by feed industries. However, the level of risk is **uncertain** as although we are able to estimate the volume of waste corn starch slurry produced, we are not aware of how much of it is currently used for feed versus biofuel production. **It should be noted that in locations where feed demand is low, market distortion due to use of this feedstock for biofuel production will be limited as this feedstock degrades rapidly and has to be used locally.**

Corn steep water and corn steep liquor

As per stakeholder feedback, 0.012 tonnes of corn steep water are generated per tonne of starch produced. The global corn starch market reached a volume of nearly 78 million tonnes in 2020 (EMR, 2020). Therefore, we estimate nearly 1 million tonnes of corn steep water may have been generated globally in 2020 as a result of corn starch production. Corn steep water is also generated during corn ethanol production. As per stakeholder feedback, 0.41 tonnes of corn steep water are generated per tonne of ethanol produced. In 2019, US corn ethanol production was around 46 million tonnes (AFDC, 2020). US is considered to be the major producer of corn ethanol globally. Therefore, we estimate around 19 million tonnes of corn steep water may have been generated in the US in 2019 as a result of corn ethanol production. Stakeholder feedback does not specify volumes of corn steep liquor generated per tonne of starch or ethanol produced.

As mentioned in section 1.2, in most corn starch plants, corn steep liquor that is derived by the concentration of corn steep water is mixed with the fibre fraction before the fibres are dried (Alfa Laval, 2004). This dried product is often called **gluten feed** and is widely used as a raw material in animal feed (Alfa Laval, 2004; Trenkle and Ribeiro, 1999). Similarly, in corn ethanol plants, the corn steep liquor is sold as animal feed. Corn steep liquor and corn steep powder are used as fertilisers. **Therefore, incentivising corn steep water and corn steep liquor for transport fuel production could pose a risk by diverting the feedstock from its use in animal feed production and as fertiliser.**

If corn steep liquor were to be diverted from corn gluten feed (CGF) production, then potential substitutes for this animal feed would need to be considered. The nutritional composition of CGF needs to be understood to find suitable substitutes. CGF is relatively high in crude protein (CP) since the starch and oil have been removed (Myer and Hersom, 2017). Crude protein averages 23.5% (dry matter (DM) basis) but can range from 16% to 30% (Myer and Hersom, 2017). However, quality of amino acid content is lower for corn gluten feed compared to soybean meal (Boyles, 1999). The energy value of CGF is almost as high as that of corn. The total digestible nutrients (TDN) value of CGF is about 75% to 83%, compared to whole corn grain, which has a TDN value of 88% (Myer and Hersom, 2017). In CGF the energy comes from digestible fibre (bran fraction). Corn gluten feed is considered to be a good compliment to forage-based diets because it is a low starch, high fibre energy source, and also contains some fat (Myer and Hersom, 2017). Since CGF is a good source of both protein and energy, the relative economic value of this feed depends upon the relative price of corn and of a protein supplement such as soybean meal (Myer and Hersom, 2017). The protein and energy provided by 100 lb of CGF (90% DM) is roughly equal to 75 lb of corn and 25 lb of soybean meal (48% CP) (Myer and Hersom, 2017). Therefore, if CGF availability reduced due to diversion of corn steep liquor to the biofuel market, then **alternate feed mix containing cereals like corn and soybean meal** would be needed to fulfil the animal feed demand. The same can be said for wheat gluten feed given that it needs to be replaced with a feed that is a source of energy, proteins and other nutrients.

4.2. 2030/2050 Potential

Since starchy effluents are residues/ wastes of bioethanol and starch production from grain, the potential supply is largely driven by ethanol and starch demand. The International Energy Agency (2019) forecasts that global ethanol production will increase from 110 to 130 billion litres from 2019 to 2024, and if this growth is extrapolated to 2030, ethanol production would be approximately 154 billion litres. This also roughly aligns with the OECD Agricultural Outlook (2019) which projects 143 billion litres in 2028.

Global corn starch market is expected to reach 95 million tonnes by 2025 (EMR, 2017). Applying the same CAGR of 4% that was assumed in the EMR report, global corn starch market could reach 116 million tonnes by 2030 and 253 million tonnes by 2050. Similar market data is not available for wheat starch. However, we know that corn supplies more than 80% of global starch markets and a much smaller starch production (>8%) comes from wheat (Bergthaller and Hollmann, 2007). We can therefore estimate that the global wheat starch market could reach 12 million tonnes by 2030 and 25 million tonnes by 2050.

Starch-containing wastewaters

As per stakeholder feedback, 0.18 tonnes of **waste corn starch slurry** are generated per tonne of starch produced. Therefore, we estimate over 20 million tonnes of waste corn starch slurry could be generated globally in 2030 and over 45 million tonnes by 2050. This feedstock could yield 7.1 million tonnes of ethanol or 4 million tonnes of biogas in 2030 and 15.5 million tonnes of ethanol or 8.7 million tonnes of biogas in 2050. However, we have not come across references that state the volumes of waste corn starch slurry that will be used in different applications. We are not aware of the volume of slurry generated per tonne of corn ethanol produced. In case of corn ethanol production, the slurry from the liquefaction stage is mixed with heat sterilized steep water and sent for saccharification (see section 1.2). Therefore, in this case it is highly likely that there would be limited volumes of slurry available for biofuel production in 2030/ 2050.

We are unable to estimate waste wheat starch slurry volumes as we have not come across similar conversion units. However, wheat solubles, which is a component of waste wheat starch slurry, is currently used for producing wheat gluten feed. This could potentially limit the availability of waste wheat starch slurry with required levels of wheat solubles for biofuel production in 2030/ 2050.

Furthermore, stakeholder consultation suggests that recent improvement in wet milling processes have significantly reduced the volume of starch slurry being wasted, either by eliminating slurries or by almost removing all starch from the slurry.

Corn steep water and corn steep liquor

Given that corn steep liquor have existing uses, especially in animal feed, availability of this feedstock for biofuel production, without distortive market effects, would be extremely limited in both 2030 and 2050. As mentioned above, in case of corn ethanol production, the slurry from the liquefaction stage is mixed with heat sterilized steep water and sent for saccharification (see section 1.2). Therefore, in this case also it is highly likely that there could be limited volumes of corn steep water and corn steep liquor available for biofuel production in 2030/ 2050.

5. ADDITIONAL DEMAND FOR LAND

5.1. Assessment of additional demand for land

As discussed in section 4.1, starch-containing wastewaters and corn steep liquor are used in animal feed production. Therefore, the increased use of these feedstocks in biofuel could lead to higher consumption of substitute materials for preparing animal feed. Section 4.1 identified a mix of cereals such as corn and soybean meal as the most likely substitute for waste starch slurry and corn steep liquor diverted from these industries.

We now assess the additional demand for land due to the increased demand for soybean meal and cereals like corn. Soybean meal and corn both correspond with the medium risk category for additional demand for land. We thus select the **medium risk category** for starchy effluents overall.

6. Processing technologies

6.1. Evaluation of processing technology (mature vs advanced)

One of the common conversion process for starchy effluents such as waste starch slurry is **bioethanol production via fermentation and distillation** (stakeholder feedback). This is a mature technology (TRL 9, CRL 5) which would mean that this feedstock is suitable to be added to Part B of Annex IX. However, as per stakeholder feedback, multiple processing steps are required to convert starch containing wastewaters such as residual starch slurry into an ethanol product of biofuel quality. The challenge is to deal with streams that are dilute, have a high content of non-fermentable impurities and have a composition that is variable depending on the composition of the raw material (i.e. wheat or corn) and the wet mill process performance. Advanced technical know-how and skills are required to execute this in a safe and cost efficient way (stakeholder feedback). Therefore, we consider the overall processing pathway to be at a lower TRL level.

The second common conversion process is the **anaerobic digestion of starchy effluents to biogas**. This is a mature technology (TRL 9, CRL 5) which would mean that this feedstock is suitable to be added to Part B of Annex IX.

Of the two conversion pathways, the AD to biogas pathway appears to be more prevalent in the industry. Therefore, we would suggest that starchy effluents are suitable to be added to Part B of Annex IX.

7. Conclusions

Nomenclature:

- No concern = the evaluation did not reveal any significant concern about this feedstock.
- Some concern = the evaluation identified limited conditions under which some concerns may exist, i.e. using this feedstock for biofuel production could be in contradiction with this criterion.
- Problematic = the evaluation reveals that using this feedstock for biofuel production would be in contradiction with this criterion in most circumstances.
- Not applicable = this criterion is not applicable to the feedstock.

Table 69: Summary of evaluation results

	Evaluation Result	Rationale
Circular economy and waste hierarchy	No concern (starch-containing wastewaters)	Using **starch-containing wastewaters** for biogas/biofuel does neither contribute to, nor contravene circular economy principles or contravene the waste hierarchy.

	Some concern (corn steep water and corn steep liquor)	Under which circumstances could this feedstock be problematic? Using feedstocks which could be used for feed purposes would not contravene circular economy principles, but would not be aligned with the waste hierarchy. Using **corn steep water** and **corn steep liquor** for biogas/biofuel is not considered to be in line with circular economy principles as the latter can be used in antibiotics production which can ensure a significantly longer life time and/or carbon sequestration than energy uses. Furthermore, using these feedstocks for biogas/biofuel would not be aligned with the waste hierarchy when their re-use as feed is technically/ economically possible. **Note**: Corn steep water is processed in an evaporator where soluble solids are concentrated by evaporating part of the water resulting in the production of corn steep liquor. How to mitigate this concern? See "Market distortion"
Union sustainability criteria	Not applicable	These criteria are **not applicable** to starchy effluents as this feedstock is neither primary agricultural biomass or agricultural field residue or forest biomass. Starchy effluents are process residues/ waste.
Sustainability GHG	No concern	GHG savings range between 52 and 95% from using starchy effluents for **bioethanol** production. Under which circumstances could this feedstock be problematic? The process fuel used in the bioethanol production plant will determine whether the feedstock pathway is compliant with the GHG savings criteria. To be eligible with the 65% minimum GHG saving threshold, operators producing **biomethane** from starchy effluents should ensure that the resulting digestate is maintained in a closed infrastructure and off-gas combustion is applied. How to mitigate this concern? Failure to meet the minimum GHG savings will be efficiently addressed throughout the certification process by an EU-approved voluntary or national

		scheme.
Sustainability Others	Not applicable	Starchy effluents are process residues/ waste. These criteria are **not applicable** as this feedstock has no land impact.
Market distortion	Some concern	<u>Under which circumstances could this feedstock be problematic?</u> Given existing use of **starch-containing wastewaters** and **corn steep liquor** in the production of animal feed, adding this feedstock to Annex IX could have a distortive effect on the animal feed market. However, we are unable to ascertain the level of risk as we are not able to determine how much of these materials are currently used for feed versus biofuel production. <u>How to mitigate this concern?</u> Inclusion in Annex IXB (See below) would limit the amount of feedstock being used for biofuel/biogas production. Auditors should check that facilities are producing an expected ratio of main product (food-grade starch, ethanol and gluten feed) to other materials. The auditor should have access to historical data to be able to determine that the ratio of process streams has not materially changed over time. New policy developments would also be required to evaluate local markets and demonstrate that no local demand exists from the food/feed sector and/or that available supply largely exceeds the demand from the food/feed sector. Furthermore, market distortion associated with the use of **starch-containing wastewaters** for biogas/biofuel production may be limited in areas where feed demand is low. This is because this feedstock degrades rapidly and has to be used locally.
2030/2050 Potential	2030: Waste corn starch slurry: 20 million tonnes (global) (i.e. 7.1 million tonnes of ethanol or 4 million tonnes of biogas) Corn steep water:	No specific data could be found for the production levels of starchy effluents in 2030 or 2050. The **waste corn starch slurry** *(a subset of starch-containing wastewaters)* estimates are based on volumes of the feedstock generated per tonne of corn starch produced and projections for corn starch production in 2030

	Unknown Corn steep liquor: Unknown 2050: Waste corn starch slurry: 45 million tonnes (global) (i.e. 15.5 million tonnes of ethanol or 8.7 million tonnes of biogas) Corn steep water: Unknown Corn steep liquor: Unknown	and 2050. Volumes of **corn steep water** and **corn steep liquor** produced are anticipated to increase in 2030 and 2050 as these are linked with starch and bioethanol production which are expected to rise.
Land demand	Some concern	The use of **starch-containing wastewaters** and **corn steep liquor** for biogas/biofuel may divert this feedstock from animal feed, and farmers may then seek alternate feed mix containing **cereals like corn and soybean meal**. How to mitigate this concern? See "Market distortion"
Processing Technologies	Mature (biogas)	Biogas production via anaerobic digestion of starchy effluents is at high TRL (9) and CRL (5).

8. References

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Dry starch from corn fractionation

1. TECHNICAL DESCRIPTION

1.1. Feedstock description

This assessment is limited to dry starch generated through the dry fractionation of corn, which is an alternative to conventional dry milling and wet milling (See further description in the Section 1.2). Starch generated in conventional dry corn or wet milling is not covered in this assessment.

The content of corn is typically made up of 72% starch, 4% oil, 10% protein and 10% fibre and 4% other unfermentable components, all with various uses (Kurambhatti et al., 2019) and which can be extracted in various proportions, depending on the type milling process (See Section 1.2). Starch is a polymer composed of repeated glucose units, which is commonly found in vegetable and animals. Corn dry starch is a white, odourless and tasteless powder used as a staple ingredient worldwide (Cision, 2021).

1.2. Production process

When it is not used directly as a livestock feed, corn is generally processed via conventional dry or wet milling, which can be distinguished in terms of the amounts and grades of generated co-products and residues. Conventional dry milling is less capital-intensive and is generally preferred to maximise bioethanol yields, with dried distillers' grains and solubles (DDGS) and feed-grade corn oil (also known as technical corn oil) as co-products. Wet milling aims to maximise the production of food-grade starch (which can be transformed into ethanol but at lower yields than in conventional dry milling), high-protein feed and food-grade corn oil.

Dry fractionation of corn is comparable to conventional dry milling, but instead of grinding the entire corn grains in a hammer mill and then soaking corn grits in water before hydrolysis and fermentation, an earlier stage of fractionation is used to remove corn germs. The remnant of the corn kernel (endosperm and pericarp) is then milled to extract starch, which is further broken down into glucose via a mashing process. This starch may then be fermented into ethanol or isobutanol, or supplied to other markets. Corn germs may be transformed into food-grade corn oil, fibre gums and/or lignocellulosic ethanol. A comparison of a conventional dry milling process and dry fractionation is provided in **Figure 26**.

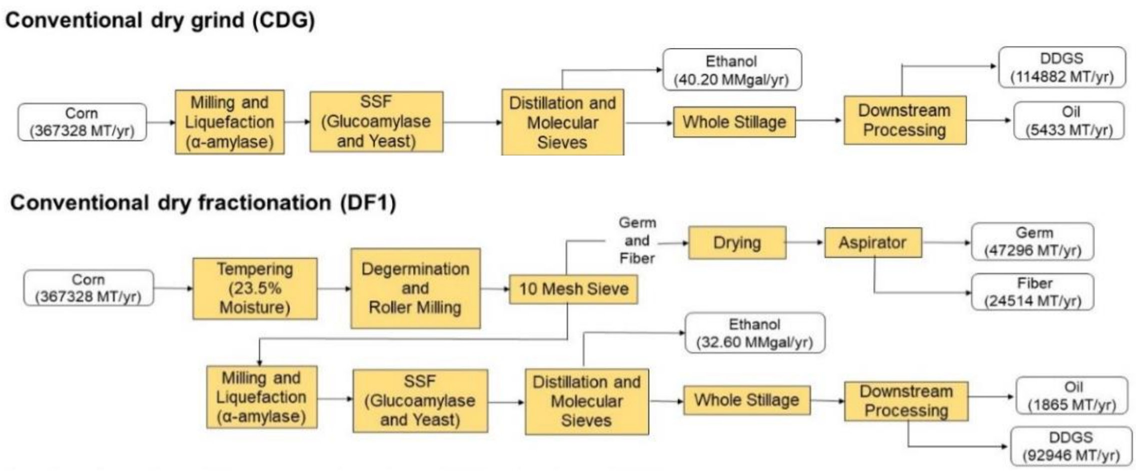

Figure 26 : Comparison of conventional dry milling (CDG) and dry fractionation (DF1) (Source: Kurambhatti, 2019)

According to Kurambhatti (2019) and Gustafson & Fewell (2010), dry fractionation allows improvements over traditional dry milling, including:

- Early separation of germ and pericarp allows extracting fibres, which can be further valorised as fibre gums, fibre oil and germ oil. Fibres may also be turned into ligno-cellulosic ethanol;

- DDGS are produced in lower amounts, but with higher protein content, which improves their nutritional value;

- The percentage of starch left in degermed defibered corn for ethanol production or for conversion into food products is higher, this may allow greater overall throughput (in terms of total corn processed and total ethanol output) than is possible in a conventional dry mill facility with the same fermentation capacity.

- The high fibre and low protein content in DDGS from traditional dry milling makes it only suitable for feed uses. Dry fractionation.

Dry fractionation does, however, result in lower ethanol yields per tonne of corn processed, as some starch remains in the separated corn germ rather than being sent for fermentation. Renewable Fuels Association (2016) states that about 10% of U.S. corn ethanol production comes from wet mills and the rest from dry mills. It is not known how many dry mills have added a dry fractionation process.

1.3. Possible uses

Globally, the main market for corn is **animal feed** (US Department of Agriculture, 2018). Corn used directly for animal feed applications is normally fed without separation of starch from protein and oil. In the United States, 40% of corn is used in animal feed, about 50% used for ethanol production and about 10% used for food seed and industrial uses (USDA ERS, 2021).

Conventional **corn ethanol** is based on starch, which is separated from the protein and other constituents, either as a result of fermentation (in the conventional dry mill process) or prior to fermentation (in the wet mill or dry fractionation processes. See Section 1.2 for details).

In addition to ethanol production, extracted corn starch is also widely used in the **food** industry to increase shelf-life, add texture, increase nutritional value and act as stabilisers and emulsifiers (Persistence Market Research, n.d.). Dry starch also has potential application in **cosmetics, packaging material and drug delivery systems** for the pharmaceutical, **paper and textile** industries (Silva Timm et al., 2020; Fernando, 2021). Corn starch from the relatively novel dry fractionation process has potential applications in the same markets as corn starch from wet milling.

Starch is also used in the paper industry as a flocculant and retention aid, as a bonding agent, as a binder for coatings, and as an **adhesive** in corrugated board, laminated grades, and other products (Maurer, 2009). Starch can also be converted to **isobutanol**, alongside ethanol, which can be used in transport fuels, including jet fuels (Gevo, 2019a).

Documented examples exist (e.g. Cargill[23], Roquette[24], or Novamont[25]) of corn starch being used as platform chemical in a commercial biorefinery setup producing simultaneously chemicals, starches, polymers, food, feed and ethanol.

Possible uses of the dry starch from corn processing are summarised in **Table 70**.

Table 70 : Summary of possible uses of dry starch from corn processing

	Food use	Feed use	Other uses
Dry starch from corn processing	Widely used in food to improve shelf-life,	Non-processed corn (and therefore starch)	Bioethanol and isobutanol production

[23] Cargill, Krefel biorefinery, https://www.cargill.de/en/krefeld-location
[24] Roquette, https://www.roquette.com/
[25] Novamont, MATER-BI, https://novamont.it/eng/mater-bi

	texture, nutritional value and act as stablisers and emulsifiers.	is widely used as a livestock feed..	at commercial scale. Other industries: applications in pharmaceutical, paper and textile industries. Platform chemical in biorefineries.

2. CIRCULAR ECONOMY AND WASTE HIERARCHY

2.1. Classification of the feedstock as a co-product, residue or waste

On the basis of the feedstock description provided in sub-section 0, its possible uses in sub-section 0, stakeholder feedback and additional references, the dry starch from corn processing can be classified as a co-product as described below.

Table 71 : Classification of dry starch from corn processing

Evaluation question	Answer	Rationale
Is the feedstock the primary aim of the production process?	Yes	Dry starch can be considered to be a primary product in the dry fractionation process, alongside protein meal and food-grade corn oil.
Does the feedstock have any economic value, but is not the primary aim of the process, and therefore a residue?	No	Dry starch is one of the primary aims of the process.
Is the feedstock normally discarded, and therefore a waste?	No	

2.2. Is the use of feedstock to produce biofuel/biogas in line with circular economy principles?

- **Does the feedstock have non-energy (re)uses, which could extend its life or sequester carbon for longer?**

  Answer: Yes

  Rationale: Applications in the paper and textile industries would extend its life and sequester carbon for longer than energy uses. Starch can also be used as platform chemical in a biorefinery setup to produce chemicals, along side food, feed and ethanol.

- **Does its use as biofuel/biogas feedstock contribute to nutrient recovery?**

  Answer: Variable

  Rationale: No documented evidence of nutrient recovery associated with biofuel production.

- **Does its use as biofuel/biogas feedstock contribute to a more efficient use of resources by avoiding primary material extraction?**

  Answer: Variable.

Rationale: Diverting dry starch to biofuel production would reduce the requirement for extraction of fossil fuels and natural gas. However, extraction of primary materials would be required by industries that otherwise would have utilised the dry starch. Processing of alternative inputs for these industries (food, pharmaceutical, paper and textiles) may result in negative impacts.

- **Does its use as biofuel/biogas feedstock contribute to reducing waste generation, especially food waste?**

  Answer: No

  Rationale: Dry starch is already fully utilised in existing markets. Compared to wet fractionation, dry fractionation reduces the amount of water used and wastewater generated.

2.3. Is the use of this feedstock for biofuel/biogas production in line with the waste hierarchy?

The waste hierarchy is not applicable to corn dry starch, since this is a co-product.

2.4. Conclusion

Contribution to circular economy

Utilising dry starch for biofuel production is not in line with circular economy principles if it competes with uses that extend product life and sequester carbon for longer than energy uses; there may be negative impacts from diverting dry starch away from food/pharmaceutical/paper applications that may then require more raw material production. Using starch in a biorefinery setup to produce energy, alongside chemicals and other products could mitigate this risk.

Finally, there is no evidence that using dry starch for biofuel production contributes to reducing waste generation, although dry fractionation reduces water consumption and wastewater generated, compared to wet milling.

Alignment with the waste hierarchy

Not relevant as dry starch is a co-product.

3. Sustainability and Greenhouse gases

3.1. Union sustainability criteria

Table 72: Assessment of dry starch from corn processing

Criterion (all land status assessed in 2008)	Assessment
(2) for wastes and residues derived from agricultural land operators or national authorities have monitoring or management plans in place in order to address the impacts on soil quality and soil carbon	Dry starch is a co-product. Therefore, this criterion is not applicable.
(3) bioenergy from agricultural biomass shall not be made from raw material obtained from land with a high biodiversity value	In the US and in the EU, corn is generally cultivated on land that has been in agricultural production since before 2008 and agricultural land is not highly biodiverse. A high risk of non-compliance is not foreseen for this criterion.
(4) bioenergy from agricultural biomass shall not be made from raw material obtained from land with high-carbon stock in January 2008 if the status of the land has changed	European Commission (2019) reports that there is a low rate of expansion of the maize crop into high carbon stock land in temperate countries such as the EU and

	U.S., which are considered the most likely regions of origin for dry corn starch as a feedstock for EU biofuels. A high risk of non-compliance is not foreseen for this criterion.
(5) bioenergy from agricultural biomass shall not be made from raw material obtained from land that was peatland in January 2008, unless evidence is provided that the cultivation and harvesting of that raw material does not involve drainage of previously undrained soil.	Corn is generally not cultivated in land that was peatland. A high risk of non-compliance is not foreseen for this criterion.

Criterion (6) and (7) lay down criteria for bioenergy from forest biomass which are not applicable.

3.2. GHG Savings Criteria

RED II default values for corn ethanol are used to evaluate potential GHG savings for biofuels derived from dry starch from corn processing (**Table 73**).

Table 73 : Default values for corn ethanol (Source: RED II)

	GHG savings – Default values
Corn (maize) ethanol (natural gas as process fuel in conventional boiler)	40%
Corn (maize) ethanol, (natural gas as process fuel in CHP plant	48%
Corn (maize) ethanol (lignite as process fuel in CHP plant	28%
Corn (maize) ethanol (forest residues as process fuel in CHP plant	68%

Default GHG emissions savings for corn ethanol range between 28% and 68%, depending on the type of process energy. On this basis, only ethanol plants using forest residues as process fuel would comply with minimum savings criteria (50-65% depending on the year when operations started).

Therefore, the risk for bioethanol/isobutanol derived from dry corn starch of not complying with the GHG savings requirement in REDII is considered to be medium-high.

3.3. Other environmental impacts

Dry starch is derived from corn so an overview of the potential negative environmental impacts from corn production are highlighted in **Table 74**.

Table 74: Overview of evaluation of risks for adverse effects on soil, water, air and biodiversity for corn dry starch

Type of risk to be reviewed	Risk indicator	Risk level	Rationale and sources
Adverse	2.1 Soil Organic Matter:	Medium	Soil erosion is high risk for wide

Type of risk to be reviewed	Risk indicator	Risk level	Rationale and sources
impacts on soil quality	decline should be avoided		row crops such as corn due to the high demands for direct sunlight exposure, and from late sowing, resulting in the soil being left bare for long periods of time (Ecofys, 2013). Erosion contributes to soil organic matter depletion. Fertilizer use in corn cultivation is traditionally high (Cao et al., 2018), in addition to the soil being left bare for long time periods, resulting in considerable loss of nutrients through leaching. There is a medium compaction risk during corn cultivation from the use of agricultural machinery (Ecofys, 2013).
	2.2 Nutrient and phosphate balance: a disturbance of the balance leading to strong leaching of nutrients should be avoided	Medium	
	2.3 Soil erosion: should be minimised	High	
	2.4: Soil structure: soil compaction and waterlogging should be avoided	Medium	
	2.5: Soil biodiversity: contamination of soils with metals and other toxic component, disturbance of soil structure and decline in soil organic carbon may all lead to a decline in biodiversity and this should be avoided	Medium	
Adverse impacts on water quality	3.1 Water quality: ground and surface water quality should not decline through increased leaching and run off of N, P from fertilization and of other contaminants from fertilization and weed and pest control.	Medium	Water pollution from nitrogen and sediment run-off in corn cultivation is recognised as a key risk. Pesticide use is required for corn cultivation and harvesting (Ecofys, 2013).
Adverse impacts on water quantity	4.1 Water quantity: excessive water consumption in agriculture should not lead to depletion of sweet water resources and salinization.	High	High intensity water requirements are common practice for corn cultivation in the EU. 80% of corn croplands are under irrigated systems in the Mediterranean region. 40% of corn croplands are under irrigated systems in the Atlantic regions (Ecofys, 2013).
Adverse effects on air quality	5.1 GHG emissions: GHG emissions from cropping should be minimized	Medium	During processing of corn into biofuels, there are potential emissions of VOCs, SOx, CO and NOx (Ecofys, 2013). Pesticide use is required for corn cultivation and harvesting.
	5.2 Ammonia and NOx emissions: should be minimized	Medium	
	5.3 Air pollution through spreading of herbicides and pesticides should be	Medium	

Type of risk to be reviewed	Risk indicator	Risk level	Rationale and sources
	minimized		
Adverse effects on biodiversity	6.1 Crop diversity: large scale monocultures decreasing crop diversity strongly in a region should be avoided	High	Significant crop areas of maize in the EU are under monoculture (30% or more) (Ecofys, 2013). Expansion of corn cultivation in the US leads to lower biodiversity (Joley et al., 2015).
	6.2 Biodiversity: Direct adverse impacts on flora and fauna should be avoided	Low	
	6.3 Pollination: Direct adverse impacts on pollinators and their habitats should be avoided	Low	
	6.4 Invasive species: use of biomass crops that are invasive should be banned	Low	

4. Market effects and 2030/2050 potential

4.1. Market effects

According to FAOSTAT, total world corn production in 2018 was 1.12 billion tonnes, out of which the following ingredients were produced, primarily for food/pharmaceutical/paper purposes:

- 161.6 million tonnes of corn flour (14.4% of total corn production by weight)

- 34.9 million tonnes of corn starch (3.1% of total corn production by weight)

- 10.2 million tonnes of corn fructose and syrup (0.9%)

In 2017-2018, the US Department of Agriculture estimates a total world production of 1.08 billion tonnes (US Department of Agriculture, 2018). Out of this total, 670 million tonnes were used as cattle feed (i.e. approx. 62%). According to Bartes-Marquez (2018), the annual use of corn for ethanol in the world was 5.6 billion bushels, i.e. approx. 142 million tonnes, thus representing 12.7% of total corn production by weight.

The different uses of corn in the world for the 2017-2018 period can therefore be summarised in **Table 75**. Important geographic variations exist: in the United States, Ethanol production currently represents approx. 30% of the production according to the National Corn Growers Association (2021a). This share is expected to grow by up to 5 billion gallons annually if blending/octane limits are raised with the Next Generation Fuels Act.

Table 75: Estimated uses of corn in the world in 2017-2018 (Source: US Department of Agriculture, 2018; Bartes-Marquez, 2018)

Corn uses	Percentage of total production
Cattle feed	62%

Flour (food)	14.4%
Ethanol	12.7%
Starch (food, pharmaceutical, paper)	**3.1%**
Fructose/syrup (food)	0.9%
Others	6.9%

As of 2018, about 41% of the demand for corn starch came from the food sector and about 30% from the paper and board sectors, according to Fortune Business Insights (2019). Other uses include pharmaceuticals and feed.

Food uses of corn starch are mostly driven by nutritional benefits, taste (sweetener) and material property (thickener). Uses in the paper and board sectors are primarily driven by material properties. Feed use is reportedly smaller, compared to other industries, due to the need to remove starch in some cases to leave high protein feeds and reduce acidosis as described in Section 0.

Based on the above, corn grains are currently being entirely used for feed, food, ethanol and other uses, corn starch representing 3.1% of the total. The size of the corn starch market is anticipated to grow due to changes in consumer behaviour (Cision, 2021).

Corn starch supply is not rigid, as corn production may increase in reaction to an increase in the demand for corn starch.

Global corn imports represented approx. 12.7% of total world production in 2017-2018 (US Department of Agriculture, 2018) and may provide additional corn supplies to countries willing to increase corn starch production. However, exports from Asia have been reported to decline due to the high price of corn starch. In addition to the price of starch, transport costs and disruptions have also impacted the EU imports from Asia. In the EU, the price of corn starch in the paper industry is expected to decline to its lowest value in the past ten years. There is also competition from modified starches for which the industrial market is projected to remain relatively stable (Packaging Europe, 2021). On the other hand, the inclusion of dry starch from corn dry fractionation in Annex IX may trigger a large adoption of the dry fractionation technology by existing dry milling facilities in the US, followed by important exports to the European Union. Therefore, the potential extra supply from imports cannot be assessed with certainty.

Given the large proportion of corn grains being used for ethanol production, especially in the US, it can be anticipated that an increase in the use of corn to produce dry starch through the dry fractionation process could be at the expense of conventional ethanol production. Should the amount of corn used by conventional ethanol plants remain unchanged or increase, additional supply of corn to produce isobutanol/ethanol via the dry fractionation process could negatively impact other uses, especially direct use of corn as feed and food. **Considering the current use of corn starch, there is medium to high risk of distortion of the food or animal feed market if this feedstock were to be added to Annex IX.**

4.2. 2030/2050 Potential

The main driver for corn demand through 2030 will remain livestock feed (OECD-FAO, 2020). The production of corn is projected to increase by 193 million tonnes between 2019 and 2029, which represents a growth rate of 17% over that period. The EU domestic corn production is projected to reach 68.0 million tonnes by 2030 (European Commission, 2020) while global production is expected to reach 1.3 billion tonnes (OECD-FAO, 2020). On the basis of current corn starch production share (3.1% of total production) and projected growth in corn production (17%), we estimate that approx. 2.1 million tonnes and 40.3 million tonnes of corn starch will be produced in the EU and the world respectively. The exact fraction of corn starch produced via dry fractionation cannot be estimated, given uncertainties over the technology adoption by existing dry milling facilities, should corn starch from dry fractionation be double counted in the European Union (See Section 4.1). It should, however, be noted that corn is made up of 72% starch (Kurambhatti et al. 2019); therefore, the theoretical maximum corn starch potential in 2030 can be estimated at 49 million tonnes and 936 million tonnes in the EU and the world. As mentioned above, an increase of the share of dry starch use for isobutanol/ethanol production beyond an overall increase in corn production poses a medium to high risk of market distortions.

Applying a similar growth rate through 2050, approx. 55.2 million tonnes of corn starch could be available worldwide (2.9 million tonnes for the EU), with a maximum theoretical potential of approx. 1.28 billion tonnes.

5. Additional demand for land

5.1. Assessment of additional demand for land

Corn starch is considered an elastic resource, and therefore additional demand is likely to be met with additional corn production. Corn is considered as medium risk for global land use change.

6. Processing technologies

6.1. Evaluation of processing technology (mature vs advanced)

Dry fractionation technology used to extract dry starch to convert into transport fuel is claimed to be at commercial scale since 2014 (Gevo, 2019b). It can therefore be considered a mature technology, alongside any fermentation process converting dry corn starch into ethanol. If this feedstock were added to Annex IX, it would be most appropriate in Part B.

7. Conclusions

Nomenclature:

- No concern = the evaluation did not reveal any significant concern about this feedstock.
- Some concern = the evaluation identified limited conditions under which some concerns may exist, i.e. using this feedstock for biofuel production could be in contradiction with this criterion.
- Problematic = the evaluation reveals that using this feedstock for biofuel production would be in contradiction with this criterion in most circumstances.
- Not applicable = this criterion is not applicable to the feedstock.

Table 76: Summary of evaluation results

	Evaluation Result	Rationale
Circular economy	Some concern	Corn starch can be used as platform chemical in a biorefinery setup, thus producing simultaneously chemicals and energy products. <u>Under which circumstances could this feedstock be problematic?</u> Utilising dry starch for biofuel production is not in line with circular economy principles if it competes with uses that extend product life and sequester carbon for longer than

		energy uses.
Union sustainability criteria	No concern	Corn cultivation is generally on land that has been in agricultural use prior to 2008.
Sustainability GHG	Some concern	Under which circumstances could this feedstock be problematic? On the basis of EU RED II default values for corn ethanol, only plants using forestry residues for process energy would pass the minimum GHG saving thresholds. Producers using actual values may demonstrate higher GHG savings (up to 80%).
Sustainability Others	Significant concern	Potential high risk for water resources, soil erosion, air quality and crop diversity concerning corn cultivation.
Market distortion	Some concern	All available corn and corn starch is currently being used. Corn and corn dry starch supplies are elastic. Under which circumstances could this feedstock be problematic? An increased use of dry corn starch for isobutanol/ethanol (via dry fractionation) at the expense of other food/pharmaceutical/paper, feed or corn ethanol from dry milling without additional corn production would lead to market distortions.
2030/2050 Potential	2030: 2.1 million tonnes (EU); 40.3 million tonnes (world) 2050: 2.9 million tonnes (EU) 55.2 million tonnes (world)	Corn production globally is projected to reach 1.3 billion tonnes in 2030 with EU production accounting for 68.0 million tonnes. Applying the same increase projected from 2020 to 2030, the starch production was calculated to reach 40.3 million tonnes globally in 2030 and, 55.2 million tonnes globally in 2050.
Land demand	Some concern	Diverting dry starch away from other uses would likely require substitute materials. Under which circumstances could this feedstock be problematic? In case market distortions are observed, substitute materials such as corn and cereals are evaluated to have a **medium risk** on additional

		demand for land. In cases where corn starch is supplied through expanded corn production, this would directly cause additional demand for land, also with a **medium** risk. <u>How to mitigate this concern?</u> Feedstock would fall under the food/feed crop cap, which would limit the amount of feedstock being used for biofuel production.
Processing Technologies	Mature (biofuel)	Fermentation of dry starch to produce biofuel has been used for the development of dry fractionation technology. This technology is claimed to be used at commercial scale. Therefore, it is considered to be a **mature processing technology**.

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Dextrose ultrafiltration retentate, hydrol and raffinate from sugar refining (formerly "Sugars (fructose, dextrose) refining residues")

Important note: Publicly available literature and sources of information on sugar refining residues are very limited. This assessment is primarily based on direct inputs from industries participating in the stakeholder consultation organised in Task 1 of this project. The validity of some of the technical descriptions and data provided by these stakeholders and used in this assessment could not be cross-checked with other sources.

1. TECHNICAL DESCRIPTION

1.1. Feedstock description

This feedstock includes materials extracted through the processing of cereals (e.g. corn and wheat) to produce sugars such as glucose, fructose or dextrose and derivatives (e.g. sweeteners). In addition to sugars, this process generates **retentates** from ultrafiltration and retention steps, **hydrol** and **raffinate**. Wheat and corn are the main feedstocks for starch production globally, and therefore this assessment focuses on the processing of corn and wheat and the different materials extracted during the refining process.

Dextrose ultrafiltration retentate is composed of sugars, proteins, fats and impurities (Global food processing company, Personal communication)

Hydrol, also known as corn sugar molasses, contains a minimum of 43% reducing sugars[26] expressed as dextrose (Iowa State University, 2013; Barnard Health Care, 2020). Hydrol is also considered to have about the same composition as that of blackstrap molasses[27]. Blackstrap molasses contains 83.2% total soluble solids, 17.8% reducing sugars, 32.1% sucrose, 49.9% total sugars, 10.25% ash, 0.54% calcium, 0.28% sodium, 2.89% potassium (Abubaker et al., 2012).

Raffinate is a product containing more than 85% of dextrose and less than 10% of fructose (Global food processing company, Personal communication). It is the side stream of a HFCS-55 fractionation column, that is an equipment enriching a feed stream containing 42% fructose to a food grade extract containing more than 80% of fructose (Global food processing company, Personal communication).

1.2. Production process

Dextrose ultrafiltration retentate, hydrol and raffinate are generated during the milling and processing of starchy crops such as corn and wheat into sweeteners. **Figure 27** shows the production of starch, glucose syrups, dextrose and several other products from starchy crops in the EU.

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[26] According to Wikipedia, A reducing sugar is any sugar that is capable of acting as a reducing agent because it has a free aldehyde group or a free ketone group.[1] All monosaccharides are reducing sugars, along with some disaccharides, some oligosaccharides, and some polysaccharides.

[27] Molasses remaining after the third crystallisation (sometimes referred to as blackstrap molasses, final molasses or 'C molasses') are considered to have a lower quality and have market roles including animal feed and vinegar manufacture.

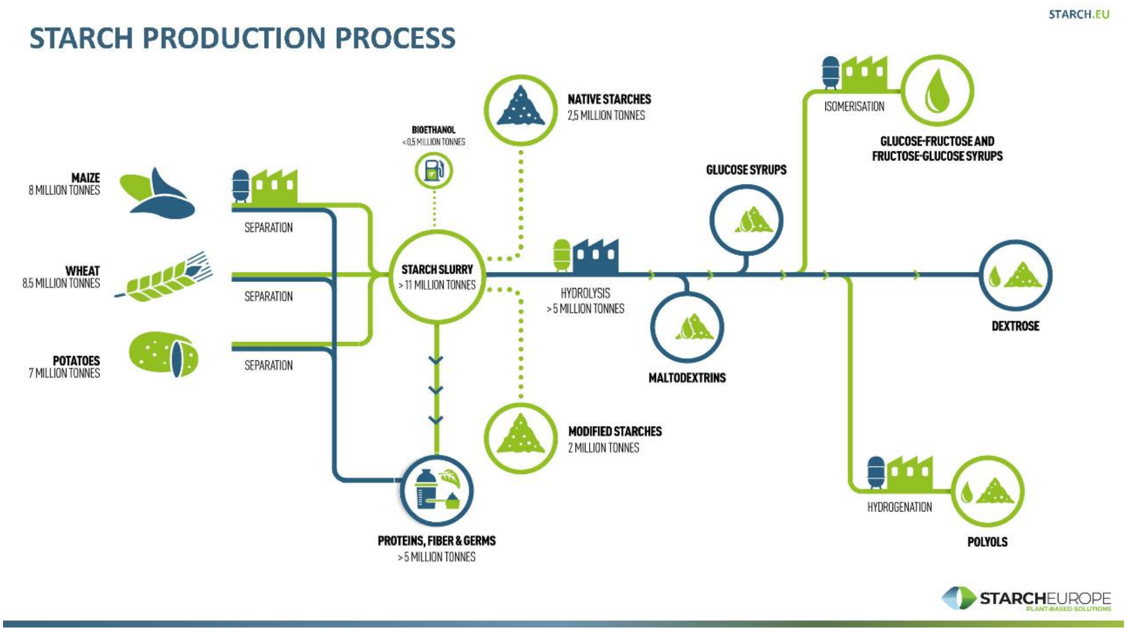

Figure 27: European starch production and use (Source: Starch Europe, 2019)

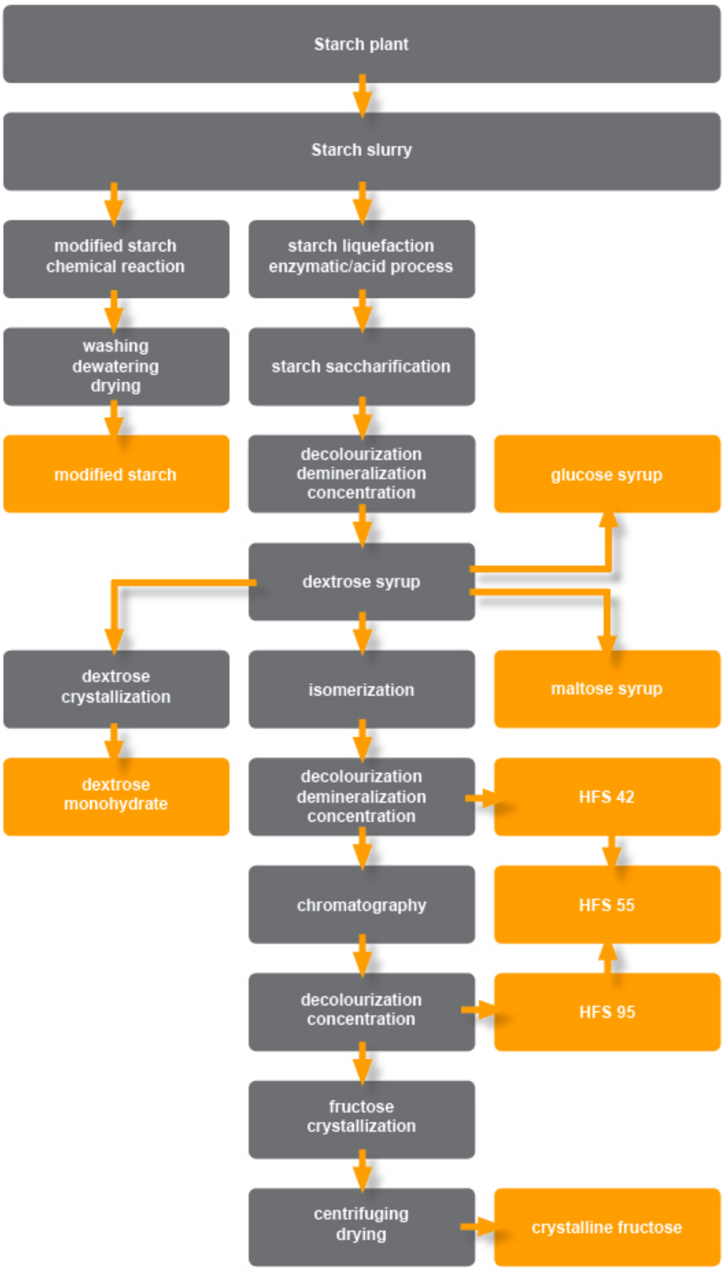

Figure 28: Production process of starch-based sweeteners (HFS = High Fructose Syrup) (Source: SST, 2012)

In the wet milling process, starch is recovered from the slurry (steeped cereals) via a physical separation processes. The starch slurry contains impurities like proteins, fats and other materials which need to be removed at a certain point of the process to produce marketable food grade high fructose syrup (HFS or HFCS in the case of high fructose corn syrup).

The starch slurry is first cooked at 108 °C with alfa-amylase enzyme, then the liquefied starch is sent to saccharification to obtain a dextrose solution with more than 95% of glucose concentration. After saccharification and in order to remove the impurities, the raw dextrose solution is treated with an ultrafiltration process. During this process:

- The part concentrating impurities, namely the **ultrafiltration retentate** cannot be used for sugar syrup production. All the impurities are concentrated in the retentate part.

- The clean part, namely the filtrate or permeate is used for DMH (dextrose monohydrate) production (see **Figure 28**). Dextrose syrup is passed through cleaning and concentrating steps, after which it enters the crystallisation process step (Global food processing company, Personal communication). Dextrose monohydrate is produced by crystallization of high dextrose equivalent (DE) syrup (Markande et al., 2012; Pinto, 2009). Crystals are separated in a centrifuge and dried for producing the DMH. During centrifugation, liquid phase is separated and forms the **hydrol** (see Figure 29) (Pinto, 2009), which is later recycled for HFCS production or is evaporated and sold as a concentrated liquid dextrose (Global food processing company, Personal communication).

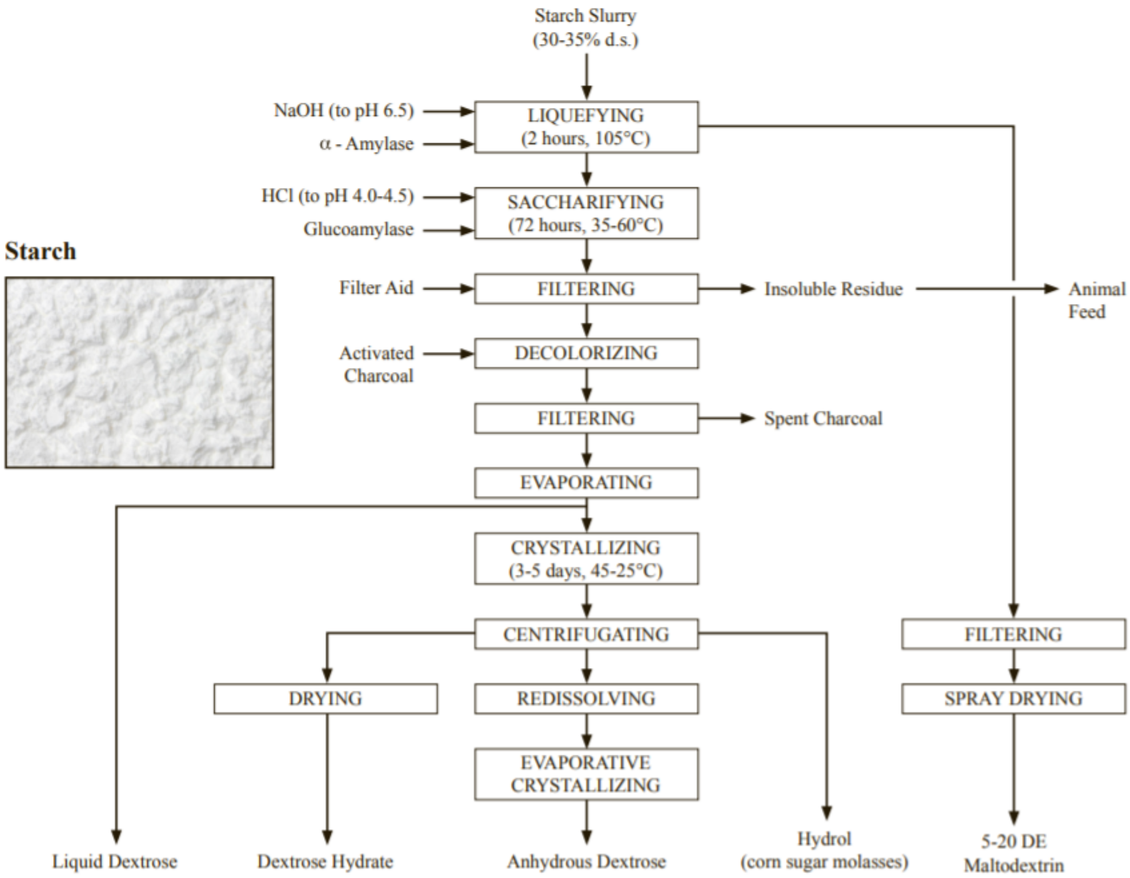

Figure 29: Hydrol production (Source: Iowa State University, 2013; Anderson & Watson, 1982)

- In the next step, the dextrose syrup is passed through an isomerisation process converting it into fructose syrup having 42% fructose concentration. Finally, the fructose syrup is enriched in the fructose fractionation columns. The fructose fractionation process generates two streams: a fructose enriched stream (with 85% fructose content) and a residual stream (**raffinate** with 8-10 % fructose content).

  Another process employs chromatographic fractionation using organic resins. Fructose is selectively held in fractionating columns but dextrose is not. Deionized and deoxygenated water is used for the elution[28] of fructose from the column. Usually a column packed with low crosslinked fine-mesh polystyrene sulfonate-Ca cation exchange resin is used for enrichment purpose. The enriched syrup contains nearly 90% fructose and is called very enriched fructose com syrup (VEFCS), when using corn starch as feedstock. The VEFCS is

[28] Process of extracting one material from another by washing with a solvent

blended with 42%-fructose syrup to obtain the desired fructose content, such as 55%. The effluent from the isomerization step may be recycled back to the feed solution to obtain 42%-fructose syrup in the effluent of the isomerization column. According to stakeholders consulted for this study, the raffinate stream rich in oligosaccharides is generally recycled back to the saccharification step.

1.3. Possible uses

- Potential uses of **dextrose ultrafiltration retentate:**

  Using **dextrose ultrafiltration retentate** for **feed** purposes is theoretically possible. However, stakeholders consulted during this study report that the low dry substance (30-38%) makes the microbiological stability of ultrafiltration retentate challenging to ensure over transport and storage. Due to presence of both sugars and proteins, at such low dry substance concentration, ultrafiltration retentate can ferment both aerobically and anaerobically, thus rapidly making it unfit for food or feed uses. **Energy uses** therefore appear as a more convenient use from a logistic and economic point of view.

- Potential uses of **hydrol:**

  - Hydrol can be used for **HFCS** production or is evaporated and sold as a concentrated **liquid dextrose** (Global food processing company, Personal communication). It can also be converted into **powdered dextrose** (Dae-Hyun et al., 2001).

  - Due to a high oligosaccharide content, only part of the hydrol produced by wet mills can be recycled in the HFCS production. In order to save energy and investments, it appears as common practice that wet mills use the hydrol portion that cannot be used in the HFCS stream for producing **ethanol**.

  - As an alternative, hydrol could also go through a secondary treatment, and can be sold as a feedstock for the **animal feed** industry, fermentation industries, including **yeast production** (Global food processing company, Personal communication). There is a patent for **liquid animal feed** comprised of corn steep water (protein source) and hydrol (carbohydrate source) (Packwood and Kueber, 2014).

- Potential uses of **raffinate:**

  - Depending on the type of HFCS line (in case of corn starch-based sweeteners production), raffinate stream can be directly recycled within the **fructose production** process or need to be treated prior to being recycled. Plants equipped with large HFCS-42 lines are able to recycle back the raffinate to the saccharification step in **fructose** production (Vogelbusch, n.d.). Plants without large HFCS-42 lines need to upgrade/treat the raffinate and reuse it in the HFCS-55 line (Global food processing company, Personal communication).

  - As with ultrafiltration retentate and hydrol, a high content in oligosaccharides combined with high moisture content prevents raffinate to be transported over long distance or long storage, due to rapid microbiological contamination and production of toxins (Global food processing company, Personal communication). Therefore, raffinate is commonly used onsite to produce **ethanol**.

Possible uses of dextrose ultrafiltration retentate, hydrol and raffinate generated during sugar refining are summarised in **Table 77**.

Table 77 : Summary of possible uses of dextrose ultrafiltration retentate, hydrol and raffinate generated during sugar refining

	Food use	Feed use	Other uses
Dextrose ultrafiltration retentate	No documented evidence of commercial	No documented evidence of commercial	Ethanol: Documented evidence of commercial

	implementation.	implementation.	implementation
Hydrol	Documented evidence of commercial implementation	Documented evidence of commercial implementation	Ethanol: Documented evidence of commercial implementation
Raffinate	Documented evidence of commercial implementation	No documented evidence of commercial implementation.	Ethanol: Documented evidence of commercial implementation

2. CIRCULAR ECONOMY AND WASTE HIERARCHY

2.1. Classification of the feedstock as a co-product, residue or waste

On the basis of the feedstock description provided in sub-section 0, its possible uses in sub-section 0, stakeholder feedback and additional references, dextrose ultrafiltration retentate, hydrol and raffinate generated during sugar refining can be classified as residues or wastes as described below.

Table 78 : Classification of dextrose ultrafiltration retentate, hydrol and raffinate generated during sugar refining

Evaluation question	Answer	Rationale
Is the feedstock the primary aim of the production process?	Dextrose ultrafiltration retentate: No Hydrol: No Raffinate: No	The aim of process that yields **dextrose ultrafiltration retentate** is to produce HFS from cereal starch slurry. Similarly, the aim of the process that yields **hydrol** is to produce dextrose monohydrate. Finally, **raffinate** is a side stream of the HFCS (high fructose corn syrup) production process (see section 1.2). Therefore, dextrose ultrafiltration retentate, hydrol, and raffinate are not the primary aim of the processes that lead to their production.
Does the feedstock have any economic value, but is not the primary aim of the process, and therefore a residue?	Dextrose ultrafiltration retentate: Variable Hydrol: Variable Raffinate: Variable	**Dextrose ultrafiltration retentate** is currently used for bioethanol production. It could theoretically be used in feed but isn't due to rapid degradation of the material. **Hydrol** is suitable for food/feed and is currently used for bioethanol production. **Raffinate** is suitable for food and is currently used for bioethanol production. Given their current and potential uses (see section 1.3), these three materials are considered to have economic value. Such feedstock can be defined as **residue**. On the basis of uses of hydrol described in section 1.3 and the lack of references stating that this feedstock is disposed as effluent, we conclude that hydrol is <u>not</u> considered as **waste**. On the other hand, dextrose ultrafiltration retentate is an unstable material and can lead to contamination of final product such as feed (Global food
Is the feedstock normally discarded, and therefore a waste?	Dextrose ultrafiltration retentate: Variable Hydrol: No Raffinate: Variable	

		processing company, Personal communication). An alternative to its use in ethanol production is separating its components such as sugars, proteins and fats. However, this would require additional energy and may not be economically viable (Global food processing company, Personal communication). The only remaining alternative would be to dispose the material which would make it a **waste**. If raffinate is not recycled in the starch mill and/or not used for bioethanol production, then it would need to be disposed of which would make it a **waste**.

2.2. Is the use of feedstock to produce biofuel/biogas in line with circular economy principles?

- **Does the feedstock have non-energy (re)uses, which could extend its life or sequester carbon for longer?**

  Answer: No

  Rationale:

  Dextrose ultrafiltration retentate can be used as feed, but this use appears limited for logistic reasons. Feed uses would, however, not constitute a significant extension of the life-time. It would only temporarily extend the life-time of the residue/ waste, which eventually exits the circular chain by being released into the environment (air, soil and water) through metabolism.

  Hydrol has food/feed applications, including yeast production. Food/feed uses would, however, not constitute a significant extension of the life-time.

  Raffinate can be recycled into the fructose production. Such use would, however, not constitute a significant extension of the life-time.

- **Does its use as biofuel/biogas feedstock contribute to nutrient recovery?**

  Answer: No.

  Rationale: Bioethanol derived from dextrose ultrafiltration retentate, hydrol and raffinate generated during sugar refining has no documented contribution to nutrient recovery.

- **Does its use as biofuel/biogas feedstock contribute to a more efficient use of resources by avoiding primary material extraction?**

  Answer: Variable.

  Rationale: As with all other biomass feedstocks, bioethanol derived from dextrose ultrafiltration retentate, hydrol and raffinate generated during sugar refining displaces fossil fuels and natural gas, thus reducing the need for primary material extraction. When economically feasible, using dextrose ultrafiltration retentate, hydrol and raffinate generated during sugar refining in food/feed chains and other non-energy related applications would, however, reduce the need for primary production (e.g. dextrose) as well.

  Finally, comparative benefits of using these residues/ wastes for energy rather than in food/feed chains through avoided primary material extraction should be further explored to assess which use should be prioritised at policy level.

- **Does its use as biofuel/biogas feedstock contribute to reducing waste generation, especially food waste?**

  Answer: Variable.

Rationale: Wherever the alternative fate of dextrose ultrafiltration retentate, hydrol and raffinate generated during sugar refining into energy is to be discarded, using these residues and waste for energy production has a positive impact on waste reduction. Additional incomes from ethanol production would be further increased if these feedstocks were to be added to Annex IX, thus preventing potential improvements in corn/ wheat mill efficiency to reduce the share of these substances.

2.3. Is the use of this feedstock for biofuel/biogas production in line with the waste hierarchy?

- **Contribution to increasing waste?**

  Answer: Variable.

  Rationale. No evidence exists that using dextrose ultrafiltration retentate, hydrol and raffinate generated during sugar refining for bioethanol production would generate more waste. However, there could be a broader risk to create an incentive against reducing existing volumes of these residues/ wastes by offering an extra source of income to operators.

- **Can this feedstock be potentially reused?**

  Answer: No/ not applicable.

  Rationale: Dextrose ultrafiltration retentate, hydrol and raffinate are generated during the milling of cereals such as corn or wheat, and have not been used at that stage. The documentation received during the stakeholder consultation and additional references indicate that some of these residues/ wastes can be used as food/feed. This cannot, however, be considered as "reuse".

- **Can this feedstock be potentially recycled?**

  Answer: Variable.

  Rationale: The main documented use of dextrose ultrafiltration retentate, hydrol and raffinate generated during sugar refining is for production of bioethanol (see section 1.3). As per the Waste Framework Directive, these do not qualify as recycling of residues. However, hydrol can be used for HFCS (high fructose corn syrup) production or can be evaporated and sold as a concentrated liquid dextrose or converted into powdered dextrose. This could qualify as recycling[29].

2.4. Conclusion

Contribution to circular economy

There is no demonstrated commercial use of dextrose ultrafiltration retentate, hydrol and raffinate from sugar refining for material/chemical purposes, which could ensure a significantly longer life time and/or carbon sequestration than energy uses (bioethanol), which can therefore be considered in line with circular economy principles.

With regards to contributing to waste reduction, it can be expected that further encouraging the use of dextrose ultrafiltration retentate, hydrol and raffinate generated during sugar refining for bioethanol risks incentivising producers against improving processes and reducing the amount of these residues/ wastes being generated, should these be economically and technically feasible.

Alignment with the waste hierarchy

[29] As per the Waste Framework Directive, 'recycling' means any recovery operation by which waste materials are reprocessed into products, materials or substances whether for the original or other purposes. It includes the reprocessing of organic material but does not include energy recovery and the reprocessing into materials that are to be used as fuels or for backfilling operations (EC, 2008)

Using dextrose ultrafiltration retentate, hydrol and raffinate generated during sugar refining for biofuel is in line with the waste hierarchy under the following conditions:

- Waste do not meet food or feed quality standards.
- Waste, for which a food or feed use is not economically viable for the economic operator or the logistical chains to collect and/or process residues and waste into food or feed chains are not in place, and could not be readily put in place.

Whenever using dextrose ultrafiltration retentate, hydrol and raffinate generated during sugar refining as food or feed ingredient is both logistically and economically possible, using these feedstocks for energy purposes (bioethanol) is not in line with the waste hierarchy.

3. SUSTAINABILITY AND GREENHOUSE GASES

3.1. Union sustainability criteria

The Union sustainability criteria relate to agricultural field residues (Article 29(2)), agricultural biomass (Articles 29 (3) to (5)) and forestry biomass (Articles 29 (6) and (7)), and therefore do not apply to dextrose ultrafiltration retentate, hydrol and raffinate generated during sugar refining which are classified as process residues/ wastes.

3.2. GHG Savings Criteria

The conversion process considered is fermentation and distillation to produce **bioethanol**.

No default value exists in REDII for **bioethanol derived from dextrose ultrafiltration retentate, hydrol and raffinate generated during sugar refining**, but it can be estimated as follows:

$$E = e_{ec} + e_l + e_p + e_{td} + e_u - e_{sca} - e_{ccs} - e_{ccr}$$

Where

E = total emissions from the use of the fuel;
e_{ec} = emissions from the extraction or cultivation of raw materials;
e_l = annualised emissions from carbon stock changes caused by land-use change;
e_p = emissions from processing;
e_{td} = emissions from transport and distribution;
e_u = emissions from the fuel in use;
e_{sca} = emission savings from soil carbon accumulation via improved agricultural management;
e_{ccs} = emission savings from CO_2 capture and geological storage; and
e_{ccr} = emission savings from CO_2 capture and replacement.

In line with Annex V in RED II, dextrose ultrafiltration retentate, hydrol and raffinate generated during sugar refining are considered "to have zero life-cycle greenhouse gas emissions up to the process of collection of those materials irrespectively of whether they are processed to interim products before being transformed into the final product." For the purpose of this calculation, it is assumed that no CO2 capture and storage/replacement (CCS/CCR) is implemented. Finally, emissions in use are assumed to be zero for any biofuel and bioliquid.

Therefore the above formula can be simplified as:

$$E = e_p + e_{td}$$

No disaggregated default value could be found for processing ethanol from dextrose ultrafiltration retentate, hydrol and raffinate generated during sugar refining (e_p), either in RED II, JEC's Well-to-Tank report (Prussi et al., 2020), GREET or academic literature. Disaggregated default values for processing in RED II for corn ethanol range from 2.2 g CO_2eq/MJ (sugarcane ethanol) to 42.5 g CO_2eq/MJ (other cereals with lignite as process fuel in CHP Plant).

Biofuel and bioliquid production pathway	Greenhouse gas emissions – typical value (g CO_2eq/MJ)	Greenhouse gas emissions – default value (g CO_2eq/MJ)
corn (maize) ethanol (natural gas as process fuel in conventional boiler)	20,8	29,1
corn (maize) ethanol, (natural gas as process fuel in CHP plant (*))	14,8	20,8
corn (maize) ethanol (lignite as process fuel in CHP plant (*))	28,6	40,1
corn (maize) ethanol (forest residues as process fuel in CHP plant (*))	1,8	2,6
other cereals excluding maize ethanol (natural gas as process fuel in conventional boiler)	21,0	29,3
other cereals excluding maize ethanol (natural gas as process fuel in CHP plant (*))	15,1	21,1
other cereals excluding maize ethanol (lignite as process fuel in CHP plant (*))	30,3	42,5
other cereals excluding maize ethanol (forest residues as process fuel in CHP plant (*))	1,5	2,2

Figure 30: Default GHG emissions savings associated with processing of corn ethanol and other cereals ethanol (RED II)

The disaggregated default value for transport and distribution (e_{td}) in RED II Annex V ranges between 2.2 and 2.3 g CO_2eq/MJ.

Biofuel and bioliquid production pathway	Greenhouse gas emissions – typical value (g CO_2eq/MJ)	Greenhouse gas emissions – default value (g CO_2eq/MJ)
corn (maize) ethanol (natural gas as process fuel in CHP plant (*))	2,2	2,2
corn (maize) ethanol (natural gas as process fuel in conventional boiler)	2,2	2,2
corn (maize) ethanol (lignite as process fuel in CHP plant (*))	2,2	2,2
corn (maize) ethanol (forest residues as process fuel in CHP plant (*))	2,2	2,2
other cereals excluding maize ethanol (natural gas as process fuel in conventional boiler)	2,2	2,2
other cereals excluding maize ethanol (natural gas as process fuel in CHP plant (*))	2,2	2,2
other cereals excluding maize ethanol (lignite as process fuel in CHP plant (*))	2,2	2,2
other cereals excluding maize ethanol (forest residues as process fuel in CHP plant (*))	2,2	2,2

Figure 31: Default GHG emissions savings associated with transport and distribution of corn ethanol and other cereals ethanol (RED II)

Total GHG emissions of bioethanol derived from dextrose ultrafiltration retentate, hydrol and raffinate generated during sugar refining would therefore range between 4 g CO_2eq/MJ and 44.8 g CO_2eq/MJ, which would represent between 52% and 96% GHG savings (using RED II fossil comparator of 94 g CO_2eq/MJ). When using any e_p value (processing) without lignite as processing fuel, the maximum GHG emissions obtained are 31.5 g CO2eq/MJ (using "other cereals excluding maize ethanol (natural gas as process fuel in conventional boiler" as proxy), i.e. minimum 66% savings, which is above the required 65% savings for biofuels, biogas (biomethane) consumed in the transport sector, and bioliquids produced in installations starting operation from 1 January 2021. Therefore, the risk of bioethanol derived from dextrose ultrafiltration retentate, hydrol and raffinate generated during sugar refining of not complying with the GHG savings requirement in REDII is considered to be low.

3.3. Other environmental impacts

Dextrose ultrafiltration retentate, hydrol and raffinate generated during sugar refining are process residue/ waste and therefore have no land management impact. The evaluation of risks of adverse effects on soil, water, air and biodiversity is not applicable.

4. MARKET EFFECTS AND 2030/2050 POTENTIAL

4.1. Market effects

We have not come across any references that indicate current or future potential supply of sugar refining residues/ wastes. We therefore focus on the current and future markets for corn and wheat starch as they form the basis for production of starch-based sugars or sweeteners.

From 75 starch production facilities in 19 EU Member States, the European Starch Industry today produces 10.7 million tonnes of starch and starch-derivatives, and more than 5 million tonnes of proteins and fibres each year (Starch Europe, 2019). 11 million tonnes of starch slurry is obtained per annum from the processing of corn, wheat and potatoes in Europe (see Figure 27). The bulk of the slurry is used for the production of native and modified starches, maltodextrins, dextrose, glucose syrups, glucose-fructose syrups, proteins, fibres and germs, polyols, and ethanol (see Figure 27). The EU consumes 9.2 million tonnes of starch and derivatives, 4.7 million tonnes of which are starch sweeteners, including maltodextrins, dextrose and syrups (Starch Europe, 2019).

It is unclear how much dextrose ultrafiltration retentate, hydrol or raffinate is generated during the EU production of 4.7 million tonnes of starch sweeteners. However, the following estimates have been provided by stakeholders during the consultation process, but could not be verified through external sources.

Table 79: Residue/ waste produced per tonne of sweetener produced (dry basis)

Residue/ waste	Name of sweetener	Tonnes generated per tonne of sweetener produced (dry basis)
Dextrose ultrafiltration retentate	High Fructose Corn Syrup 55 or Dextrose Monohydrate	0.2
Hydrol	Dextrose Monohydrate	0.16
Raffinate	High Fructose Corn Syrup 55	0.35

Production of HFCS, known as isoglucose in the EU, was estimated at over 0.5 million tonnes in the EU and around 15 million tonnes globally in 2020 (European Commission, 2021; OECD/FAO, 2018). The references do not provide further breakdown of the data into HFCS 55 and HFCS 42. Dextrose monohydrate production data is not available and therefore we are unable to estimate the volume of hydrol that could be generated in the EU. Combining the HFCS production data with the data provided in **Table 79**, we have estimated the volumes of dextrose ultrafiltration retentate and raffinate that may have been generated in the EU and globally in 2020 (see **Table 80**).

Table 80: Estimated production of dextrose ultrafiltration retentate and raffinate in the EU and globally in 2020

Material	Estimated EU production (million tonnes)	Estimated global production (million tonnes)
Dextrose ultrafiltration retentate	0.1	3
Raffinate	0.2	5.2
Hydrol	Unknown	Unknown

Dextrose ultrafiltration retentate has been reportedly used by the HFCS production industry as feedstock for commercial onsite bioethanol production since the 1990s. This appears to be the only existing use of this material and therefore we estimate **low risk** of market distortion if this material were to be used as feedstock for biofuel production.

Hydrol can be recycled in the mill for generation of HFCS. The portion of hydrol that cannot be used in the HFCS stream is used for producing ethanol. Alongside these uses, there is a patent for animal feed that contains hydrol, although commercial scale use cannot be confirmed due to lack of references. **While stakeholder feedback focuses on the use of excess hydrol for ethanol production, if this feedstock were to be incentivised under the REDII, it could lead to the diversion of all hydrol produced in the mill towards ethanol generation. This in turn could increase the input of primary raw material (corn and wheat starch).**

Raffinate can be recycled in the mill for generation of fructose. Reportedly, some starch mills are using raffinate as ethanol feedstock. However, **if this feedstock were to be incentivised under the REDII, it could lead to the diversion of all raffinate produced in the mill towards ethanol generation. This in turn could increase the input of primary raw material (corn and wheat starch).**

Note: We have not come across any publicly available references that indicate the volumes of ethanol generated using dextrose ultrafiltration retentate, hydrol or raffinate.

4.2. 2030/2050 Potential

Since dextrose ultrafiltration retentate, hydrol and raffinate are residues/ wastes of starch production from grain, the potential supply is largely driven by starch demand. Therefore, the supply of these residues/ wastes is rigid. Global corn starch market is expected to reach 95 million tonnes by 2025 (EMR, 2017). Applying the same CAGR of 4% that was assumed in the EMR report, global corn starch market could reach 116 million tonnes by 2030 and 253 million tonnes by 2050. Similar market data is not available for wheat starch. However, we know that corn supplies more than 80% of global starch markets and a much smaller starch production (>8%) comes from wheat (Bergthaller and Hollmann, 2007). We can therefore estimate that the global wheat starch market could reach 12 million tonnes by 2030 and 25 million tonnes by 2050.

We are aware that the global starch sweetener market is projected to grow at a CAGR of 4.55% during the forecast period 2020-2025 (Businesswire, 2020). Global HCFS production was estimated at 15 million tonnes in 2020 (OECD/FAO, 2018). Global HCFS production has been predicted to grow at a CAGR of approximately 1% to 2021 (OECD/FAO, 2018). Using this CAGR value and the data provided in **Table 79** and **Table 80**, we have estimated the volumes of dextrose ultrafiltration retentate and raffinate that could be generated in 2030 and 2050 (see **Table 81**).

Table 81: Estimated global production of dextrose ultrafiltration retentate and raffinate in 2030 and 2050

Feedstock	Estimated global production in 2030 (million tonnes)	Estimated global production in 2050 (million tonnes)
Dextrose ultrafiltration retentate	3.3	4
Raffinate	5.8	7.1
Hydrol	Unknown	Unknown

The estimated volumes of dextrose ultrafiltration retentate could yield 1.5 million tonnes of ethanol in 2030 and 1.8 million tonnes of ethanol in 2050. Similarly, we estimate that 2.6 million tonnes of ethanol could be generated using raffinate in 2030 and 3.2 million tonnes of ethanol in 2050.

As discussed in section 4.1 we are unable to estimate the volumes of hydrol that can be generated on the basis of the quantity of starch sweeteners produced or on the basis of starch consumed for producing starch sweeteners.

Given no other existing use for **dextrose ultrafiltration retentate**, this feedstock should be available in both 2030 and 2050 without causing any distortive market effects**. Therefore this feedstock poses low risk in terms of market distortion.**

However, given that **hydrol** and **raffinate** have existing uses in HFCS and fructose production, availability of this feedstock for biofuel production without distortive market effects **may be limited in both 2030 and 2050.** While stakeholder feedback focuses on the use of excess hydrol, it might be difficult to assess whether only the excess hydrol is being diverted for ethanol production. It should be noted that we are not aware of volumes of hydrol and raffinate that are recycled versus volumes that are generated in excess. Given the uncertainty of volumes consumed**, we consider the use of hydrol and raffinate to pose low to medium risk in terms of market distortion.**

5. Additional demand for land

5.1. Assessment of additional demand for land

As discussed in section 4.1, **hydrol** and **raffinate** are recycled in the starch mills for production of HFCS and fructose respectively. Therefore, the increased use of these feedstocks in biofuel could lead to higher consumption of substitute materials for preparing HFCS and fructose. Section 4.1 identified corn and wheat starch as the most likely substitute for hydrol and raffinate diverted from the production of HFCS and fructose.

We now assess the additional demand for land due to the increased demand for corn and wheat starch. Corn and wheat starch correspond with the **medium risk category** for additional demand for land. Even though **hydrol** and **raffinate** require high iLUC substitutes, they are considered to represent a **medium risk** of additional land demand overall given low to medium market distortion risk.

Dextrose ultrafiltration retentate does not have any other existing uses and so it's unlikely that it will have an impact on any other resource. No market distortion is anticipated if dextrose ultrafiltration retentate is used for fuel production, and therefore, this fits the **low risk category** for additional demand for land.

6. PROCESSING TECHNOLOGIES

6.1. Evaluation of processing technology (mature vs advanced)

The documented process for sugar refining residues/ wastes is **bioethanol** production via **standard fermentation and distillation process**. This is a mature technology (TRL 9, CRL 5).

7. CONCLUSIONS

Nomenclature:

- No concern = the evaluation did not reveal any significant concern about this feedstock.
- Some concern = the evaluation identified limited conditions under which some concerns may exist, i.e. using this feedstock for biofuel production could be in contradiction with this criterion.
- Problematic = the evaluation reveals that using this feedstock for biofuel production would be in contradiction with this criterion in most circumstances.
- Not applicable = this criterion is not applicable to the feedstock.

Table 82: Summary of evaluation results

	Evaluation Result	Rationale
Circular economy and waste hierarchy	No concern	Using **dextrose ultrafiltration retentate, hydrol** and **raffinate** generated during sugar refining for biofuel does neither contribute to, nor contravene circular economy principles or contravene the waste hierarchy when their re-use as food/feed, including as yeast, is not technically/ economically possible. <u>Under which circumstances could this feedstock be problematic?</u> Using feedstocks which could be used for food/feed purposes would not contravene circular economy principles, but would not be aligned with the waste hierarchy.
Union sustainability criteria	Not applicable	These criteria are **not applicable** to dextrose ultrafiltration retentate, hydrol and raffinate generated during sugar refining as this feedstock is neither primary agricultural biomass or agricultural field residue or forest biomass. They are process residues/ wastes.
Sustainability GHG	No concern	GHG savings range from 52-95% from using dextrose ultrafiltration retentate, hydrol and raffinate generated during sugar refining for **bioethanol** production. <u>Under which circumstances could this feedstock be problematic?</u> The GHG threshold is not met if we

		consider lignite as process fuel in CHP plant in the bioethanol production plant. <u>How to mitigate this concern?</u> Whereas some EU-approved Voluntary Schemes have additional environmental requirements, which could potentially mitigate the identified concerns, new policy instruments would be required to address these consistently and systematically.
Sustainability Others	Not applicable	Dextrose ultrafiltration retentate, hydrol and raffinate generated during sugar refining are process residues/ wastes. These criteria are **not applicable** as this feedstock has no land impact.
Market distortion	No concern (dextrose ultrafiltration retentate) Some concern (hydrol and raffinate)	Adding **dextrose ultrafiltration retentate** to Annex IX should not have a distortive effect on any market given the lack of evidence of existing non-energy uses of this feedstock. <u>Under which circumstances could this feedstock be problematic?</u> Given existing use of **hydrol** and **raffinate** in the production of HFCS and dextrose, adding this feedstock to Annex IX could have a low to medium distortive effect on the HFCS and dextrose market. <u>How to mitigate this concern?</u> Inclusion in Annex IXB (See below) would limit the amount of feedstock being used for biofuel/biogas production. Auditors should check that facilities are producing an expected ratio of main product (e.g. glucose, fructose, dextrose) to other materials. The auditor should have access to historical data to be able to determine that the ratio of process streams has not materially changed over time. New policy developments would also be required to demonstrate that available supply largely exceeds the demand from the starch-based sugar refining sector.
2030/2050 Potential	2030: Dextrose ultrafiltration retentate: 3.3 million tonnes (global) (i.e.	Production is anticipated to increase as starch production is expected to rise.

	1.5 million tonnes of ethanol) Raffinate: 5.8 million tonnes (i.e. 2.6 million tonnes of ethanol) Hydrol: Unknown 2050: Dextrose ultrafiltration retentate: 4 million tonnes (i.e. 1.8 million tonnes of ethanol) Raffinate: 7.1 million tonnes (i.e. 3.2 million tonnes of ethanol) Hydrol: Unknown	
Land demand	No concern (dextrose ultrafiltration retentate)	**Dextrose ultrafiltration retentate** does not have any other existing uses and so it's unlikely that it will have an impact on any other resource. The risk of additional demand for land is therefore in the **low risk category**.
	Some concern (hydrol and raffinate)	The use of **hydrol** and **raffinate** for biofuel may divert this feedstock from HFCS and dextrose production, which will need to be substituted with wheat and corn starch. The risk of additional demand for land for these substitutes would fall in the **medium risk category**. How to mitigate this concern? See "Market distortion"
Processing Technologies	Mature (bioethanol)	Standard fermentation and distillation process (TRL 9, CRL 5) is required for conversion of this feedstock into bioethanol.

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Final molasses (formerly "molasses")

1. TECHNICAL DESCRIPTION

1.1. Feedstock description

Final molasses is a sugary material remaining after sugar is crystallised out of sugarcane or sugarbeet juice. The sugar production process generally involves several rounds of boiling and crystallisation, resulting in different 'grades' of molasses as more sugar is extracted from the liquid. Molasses from sugar cane may be used for human consumption, for example as a sweetener or to make rum. With additional rounds of sugar removal the molasses become more bitter in flavour. Sugar beet molasses are generally not used for human consumption. Molasses remaining after the third crystallisation (sometimes referred to as blackstrap molasses, final molasses or 'C molasses') are considered to have a lower quality and have market roles including animal feed and vinegar manufacture. Final molasses can be expected to contain 30-50% sucrose and around 25% other sugars (Delgado & Casanova, 2001; El Takriti et al., 2017; Perez, 1995) along with a range of trace minerals concentrated from the original juice. This section considers specifically final molasses from which sugar has been extracted with at least three crystallisation steps.

1.2. Production process

In sugar production, juice from the cane or beet is boiled several times to promote crystallisation of sugar, which is then removed. After the first crystallisation the juice may already be referred to as molasses. These molasses from first crystallisation may be specified as light molasses or 'A molasses'. It is normal practice to use three crystallisation stages. Additional sugar crystallised out from the molasses two further times after the initial stage, producing first 'B molasses' and then 'C molasses'/final molasses. For sugar production from cane, molasses may be exported from the process after only one or two crystallisations, generally for sale for human consumption. Ethanol can be produced either by fermentation of the juice or of the molasses produced at any of the three stages (or of mixtures of molasses and juice, Basso et al., 2011).

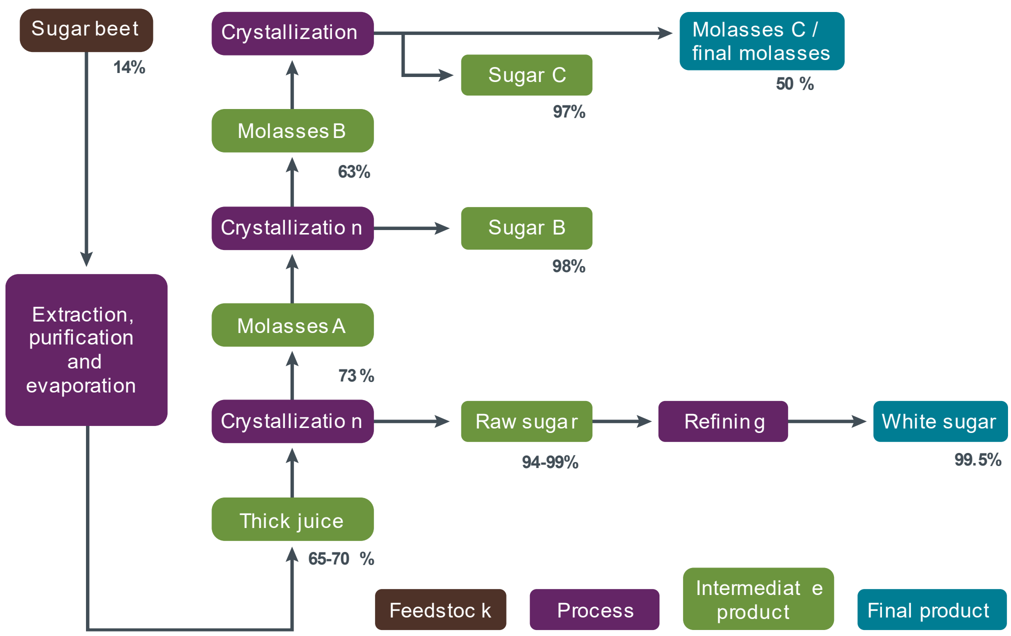

Figure 32: Schematic of sugar beet processing (El Takriti et al. 2017)

Sugarcane processing results in about 35 kg of final molasses per tonne, equivalent to 310 kg of final molasses per tonne sugar (Castañeda-Ayarza & Cortez, 2017). Sugarbeet processing results in about 38 kg of final molasses per tonne, equivalent to 320 kg per tonne sugar (Food and Agriculture Organisation, 2009).

1.3. Possible uses

The uses of final molasses differ between the product from sugarcane and from sugar beet. Final molasses from cane sugar may be sold directly for human consumption (for instance in the UK as a constituent of 'black treacle', in the U.S. as blackstrap molasses or in France as *mélasse verte*), but these uses are believed to be modest in terms of quantity. Sugarcane final molasses may also be used in rum or vinegar production for human consumption. Rum may be produced from any of the three grades of molasses or directly from sugarcane juice (Delgado & Casanova, 2001), but final molasses is identified by Mangwanda et al. (2021) as the most commonly used rum feedstock. About 1.6 billion litres of rum are produced a year (Euromonitor, 2017). Human consumption accounts for only a modest fraction of the total sugarcane molasses resource, however.

The largest utilisations of final molasses from both sugarcane and sugarbeet processing are in animal feed applications (where final molasses have several useful properties as a feed additive) as a substrate for the growth of yeast, and as a fuel ethanol feedstock. In the feed market, molasses have a relatively high metabolisable energy density and mineral content, can enhance palatability when mixed with other feed ingredients and can play a role as a binding agent for pelletised feeds (El Takriti et al., 2017). The stakeholder consultation noted that there are also applications in the fermentation chemicals industry (European Fermentation Group, 2020). Final molasses are understood to be fully utilised.

Table 83 : Summary of possible uses of final molasses

	Food use	Feed use	Other uses
Final molasses	From cane: treacle/blackstrap molasses/etc.; rum; vinegar From beet: none	Both types: Widespread use as a feed ingredient, especially for ruminant animals	Both types: yeast, chemicals applications, ethanol production.

2. CIRCULAR ECONOMY AND WASTE HIERARCHY

2.1. Classification of the product as a co-product, residue or waste

There was some disagreement among consultation respondents about whether final molasses should be characterised as a residue or as a co-product, though almost all agreed it is not a waste. The sugar production process is optimised for sugar extraction, and there is generally no modification to the process to increase production of final molasses. Molasses does have considerable value however, and the majority of consultees considered that molasses is a co-product that is too valuable to be considered a residue in the context of RED (i.e. that molasses could be considered one of the primary aims of the sugar milling process). For example, COFALEC stated in its consultation response that, "Molasses prices, expressed in sugar equivalent, are very close to those of EU sugar prices. Hence, from a price standpoint, molasses should be considered as sugar coproducts". This argument was substantiated by reference to OECD price data.

To inform the classification we considered the value of final molasses compared to the value of produced sugar. Based on world prices reported by OECD-FAO (2019), the price of molasses per unit mass is generally between a third and a half of the price of raw sugar. On that basis, and assuming molasses yields as documented by International Sugar Organization (2020), final molasses are estimated to account for about 10-15% of the value of sugar cane and 15-20% of the value of sugar beet.

Based on this value calculation and consideration of the role of molasses in the sugar value chain, the consortium tends to agree that final molasses can be considered a primary aim of production. Final molasses are therefore assessed as a co-product for the purposes of this evaluation. If further clarifying guidance relating to classification of co-products and residues should be made available by the Commission it would be appropriate to review this classification.

Table 84 : Classification of final molasses

Evaluation question	Answer	Rationale
Is the feedstock the primary aim of the production process?	Yes	Molasses represent a significant fraction of the sugar crop by both physical quantity and value, and should be understood as a co-product alongside sugar.
Does the feedstock have any economic value, but is not the primary aim of the process, and therefore a residue?	No	Not applicable as molasses has been identified as a primary aim of production.
Is the feedstock normally discarded, and therefore a waste?	No	Molasses are not normally discarded.

2.2. Is the use of feedstock to produce biofuel/biogas in line with circular economy principles?

- **Does the feedstock have other material (re)uses, which could further extend its life?**

  Answer: Limited for either type of molasses.

  Rationale: There are a range of other uses for final molasses but most of them are 'destructive', i.e. the final molasses would generally be consumed as food or feed or to produce a single use product. While there are some potential materials/chemicals applications these currently use only a small fraction of the available material.

- **Does its use as biofuel/biogas feedstock contribute to nutrient recovery?**

  Answer: No for either type of molasses, though equally biofuel/biogas use does not prevent nutrient cycling.

  Rationale: Following fermentation trace nutrients from final molasses remain in vinasse. Vinasse may be used in animal feed (in which case the nutrients are cycled in a similar way to if final molasses were used directly as animal feed) or may be used for fertirrigation. Fertirrigation allows nutrients to be returned to plantations, but has various problematic aspects (as detailed in the assessment of vinasse) and is therefore not considered a preferred nutrient cycling approach compared to nutrient cycling via manure after feed use.

- **Does its use as biofuel/biogas feedstock contribute to a more efficient use of resources by avoiding primary material extraction?**

  Answer: No for either type of molasses.

  Rationale: Final molasses will be utilised in other markets if not used for biofuels, and therefore primary material extraction is shifted rather than reduced by the use of final molasses for biofuels.

- **Does its use as biofuel/biogas feedstock contribute to reducing waste generation, especially food waste?**

  Answer: No for either type of molasses.

Rationale: Use of final molasses for biofuel/biogas production is not expected to significantly affect overall waste generation.

2.3. Is the use of this feedstock for biofuel/biogas production in line with the waste hierarchy?

Final molasses is considered a co-product for the purpose of this assessment and therefore assessment against the waste hierarchy is not necessary.

2.4. Conclusion

Using final molasses as biofuel/biogas feedstock does not actively contribute to a circular economy as this is a material that is already utilised in other markets including some limited food use (sugarcane molasses) and in animal feed. Use of final molasses for biofuel/biogas production nevertheless would be considered acceptable under circular economy principles.

3. Sustainability and Greenhouse gases

3.1. Union sustainability criteria

Table 85: Assessment of final molasses

Criterion (all land status assessed in 2008)	Assessment
(2) for wastes and residues derived from agricultural land operators or national authorities have monitoring or management plans in place in order to address the impacts on soil quality and soil carbon	As a co-product this requirement does not apply.
(3) bioenergy from agricultural biomass shall not be made from raw material obtained from land with a high biodiversity value	For both sugarcane and sugarbeet molasses there is some risk of expansion into land with high biodiversity value. Hamelinck et al. (2013) notes that there is a history of sugarcane expansion into natural grasslands in Brazil (Cerrado).
(4) bioenergy from agricultural biomass shall not be made from raw material obtained from land with high-carbon stock in January 2008 if the status of the land has changed	European Commission (2019) estimates that 5% of sugarcane expansion globally is at the expense of high carbon stock landscapes. This may be considered a medium risk for sugarcane molasses (below the threshold for high ILUC-risk feedstocks but a greater risk than most other crops considered by the Commission). This report identifies very little sugarbeet expansion into high carbon stock areas, so this may be considered a low risk for sugarbeet molasses.
(5) bioenergy from agricultural biomass shall not be made from raw material obtained from land that was peatland in January 2008, unless evidence is provided that the cultivation and harvesting of that raw material does not involve drainage of previously undrained soil.	For both sugarcane and sugarbeet molasses there is expected to be limited risk of expansion onto peatland. As for other agricultural feedstocks, this should be assessed through certification of the production system against the requirements.

3.2. GHG savings criteria

There is no default GHG intensity value for molasses ethanol in the REDII. El Takriti et al. (2017) provide a review of estimates from the wider literature. For studies that treat molasses as a co-product of sugar production a range in GHG emission values is reported from 15 to 29 g CO_2eq/MJ. This range would correspond to a reportable GHG saving of 69% or more[30]. It is therefore expected that biofuels produced from molasses ethanol would be likely to be able to meet the minimum GHG saving requirements set by the REDII.

3.3. Other environmental impacts

Table 86: Evaluation of risks for adverse effects on soil, water, air and biodiversity for final molasses

Type of risk to be reviewed	Risk indicator	Risk level	Rationale and sources
Adverse impacts on soil quality	2.1 Soil Organic Matter: decline should be avoided	Medium	Hamelinck et al. (2013) identifies sugar beet cultivation as requiring extensive soil disturbance as a root crop. Autumn sugarbeet harvesting requires heavy machinery on wet soils and can lead to soil compaction. Sugarcane, in contrast, is a perennial crop and therefore requires less tillage and represent less risk to soil structure. Sugarcane expansion on sandy soils may present an elevated risk of nutrient leaching (Hamelinck et al., 2013). Excess application of vinasse in fertirrigation systems can be associated with soil degradation.
	2.2 Nutrient and phosphate balance: a disturbance of the balance leading to strong leaching of nutrients should be avoided	Medium	
	2.3 Soil erosion: should be minimised	Medium	
	2.4: Soil structure: soil compaction and waterlogging should be avoided	High	
	2.5: Soil biodiversity: contamination of soils with metals and other toxic component, disturbance of soil structure and decline in soil organic carbon may all lead to a decline in biodiversity and this should be avoided	Medium	
Adverse impacts on water quality	3.1 Water quality: ground and surface water quality should not decline through increased leaching and run off of N, P from fertilization and of other contaminants from fertilization and weed and pest control.	High	Sugar beet and sugarcane are both identified by Hamelinck et al. (2013) as requiring relatively high use of inputs including fertilisers and pesticides. Growth of sugar crops therefore presents risk of nitrogen leaching. Hamelinck et al. (2013) states that "Brazilian sugarcane has the highest green, blue, and grey water impacts and may be considered high risk for

[30] Although there may be some methodological differences between these studies and the REDII.

Type of risk to be reviewed	Risk indicator	Risk level	Rationale and sources
			water availability and water quality".
Adverse impacts on water quantity	4.1 Water quantity: excessive water consumption in agriculture should not lead to depletion of sweet water resources and salinization.	High	Sugarcane agriculture has high demand for both green and blue water (Hamelinck et al., 2013). Hamelinck et al. (2013) noted however that there was evidence that the regulatory regime in high-sugarcane regions was developing to manage the risks to water availability. Gerbens-Leenes & Hoekstra (2009) report that ethanol from sugarcane has a higher average green and blue water footprint than ethanol from maize, but that the average blue and green water footprints for sugarbeet are lower than either.
Adverse effects on air quality	5.1 GHG emissions: GHG emissions from cropping should be minimized	High	Pre-harvest burning of sugarcane was standard practice in the industry up until relatively recently, and is associated with both GHG emissions and air pollution including NOx. While the practice has been significantly reduced in Brazil, it still remains in place in some regions (Mugica-Álvarez et al., 2018). Hamelinck et al. (2013) associates sugarbeet with high air pollution risk associated with herbicide and fungicide application. Biograce default values suggest that rates of pesticide application per hectare are lower for sugar crops than for cereals.
	5.2 Ammonia and NOx emissions: should be minimized	High	
	5.3 Air pollution through spreading of herbicides and pesticides should be minimized	High	
Adverse effects on biodiversity	6.1 Crop diversity: large scale monocultures decreasing crop diversity strongly in a region should be avoided	High	Sugarcane cropping is associated with large monocultures. Sugarbeet cropping is generally rotational and therefore of less concern in this regard, although even rotational sugarbeet systems may demonstrate low overall regional crop diversity. Sugarcane and sugarbeet fields support only limited biodiversity, though this may be improved through the implementation of good practices and alternative pest management (Global Nature Fund, 2018). Neonicotinoids may be applied to
	6.2 Biodiversity: Direct adverse impacts on flora and fauna should be avoided	Medium	
	6.3 Pollination: Direct adverse impacts on pollinators and their habitats should be avoided	Medium	
	6.4 Invasive species: use	Low	

Type of risk to be reviewed	Risk indicator	Risk level	Rationale and sources
	of biomass crops that are invasive should be banned		beet seed, presenting a potential risk to pollinators, but as beets are not generally attractive to bees it has been suggested that application to beet seed may be a limited direct risk (Institut Technique de la Betterave, 2017).

4. Market effects and 2030/2050 potential

4.1. Market effects

Molasses is a fully utilised resource, and therefore increased use of molasses as biofuel/biogas feedstock will result in displacement from other uses. **Figure 33** and **Figure 34** show OECD-FAO statistics for disposition of molasses. This data does not distinguish between grades of molasses, but the reported rates of molasses production are broadly consistent with the expected final molasses yields for sugarcane and sugarbeet processing that are given above[31]. We therefore consider it reasonable to treat this data as representative of final molasses disposition. **Figure 33** shows that at the global level total consumption of molasses has increased since 2003, with most of that increase accounted for by the biofuel market (ethanol production).

[31] In fact reported global molasses production in this data is persistently about 10% lower than expected based on the stated final molasses yields.

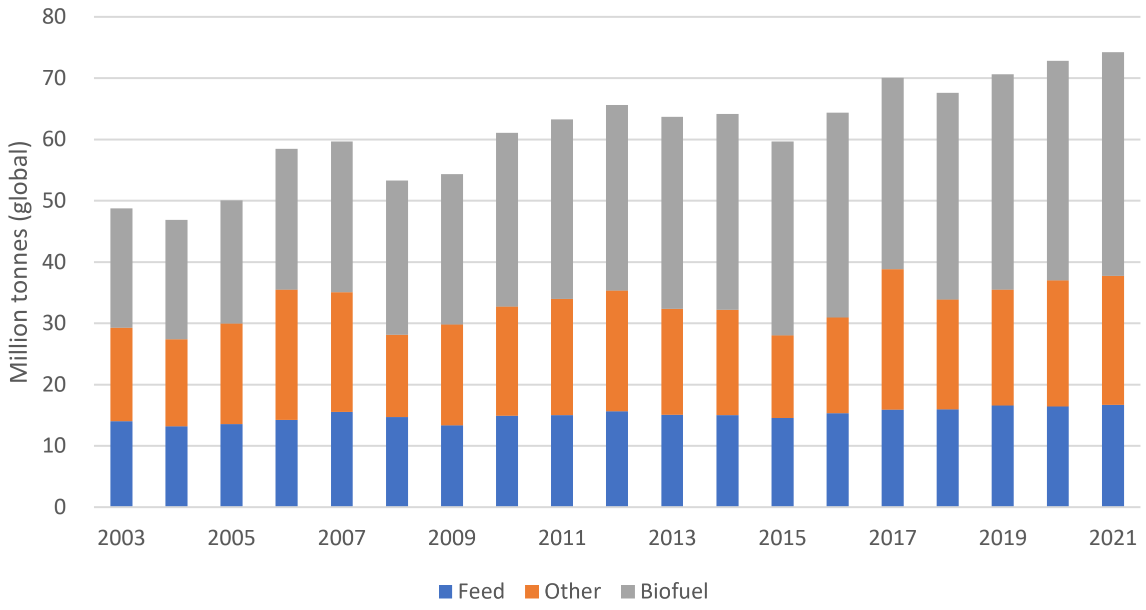

Figure 33: Global utilisation of molasses

Source: (OECD-FAO, 2019); includes projected values for 2019-21

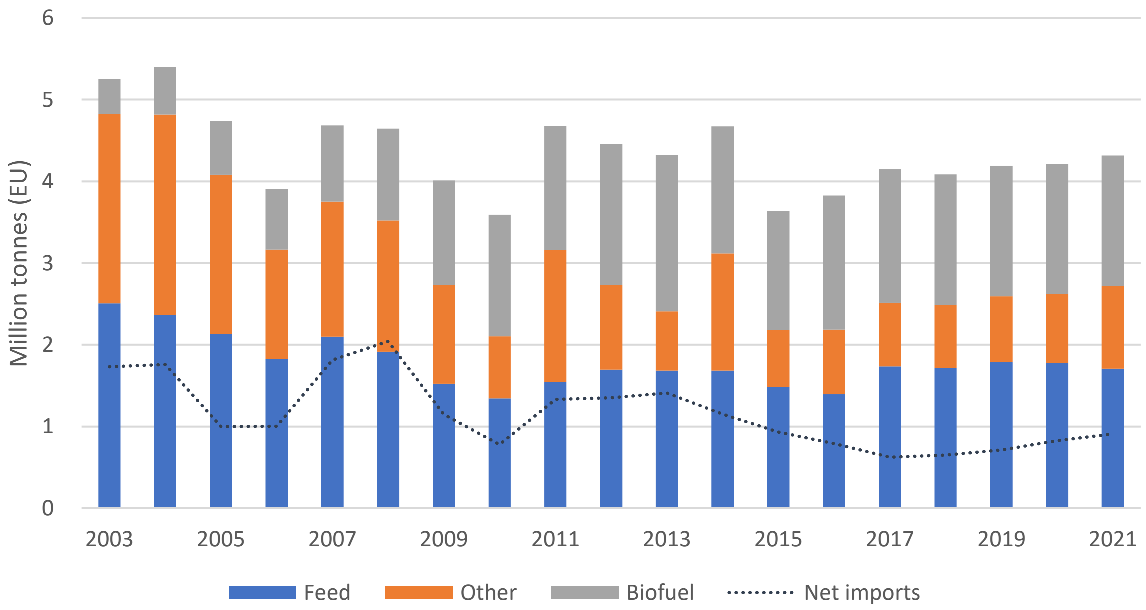

Figure 34: EU-27 utilisation of molasses and net imports of molasses

Source: (OECD-FAO, 2019); includes projected values for 2019-21

The increase in molasses production appear to partly reflect an increase in global sugar production and partly a slight increase in the amount of molasses produced per unit of sugar. The absolute availability of molasses for other uses does not appear to have been reduced by this growth in biofuel production. For the EU, **Figure 34** shows a slightly different picture. Biofuel use has increased since 2003 with an accompanying reduction in feed and other uses to a minimum in 2015, and some recovery in consumption for other uses since then.

The OECD-FAO data does not identify the use of molasses for food applications, but such applications are believed to represent only a fraction of total molasses volume, and to be likely to be relatively robust against competition from the fuel sector (uses such as retail sales and rum distilling are likely to be less sensitive to prices than uses such as animal feed).

El Takriti et al. (2017) assess potential displacement effects from increased consumption of molasses by the biofuel/biogas market in the EU. It is assumed by that analysis that each additional tonne of consumption of molasses will result in 0.5 tonnes being displaced from yeast production and 0.5 tonnes being displaced from animal feed applications. In the yeast market, sugarbeet juice is identified as a likely substitute. In the animal feed market, El Takriti et al. (2017) assume that the non-sugar content remnant in vinasse after ethanol production would still be available to the feed market and would therefore not result in any displacement of other materials, but that the sugars that constitute 63% of molasses by dry weight would be replaced by alternative low cost energy feeds, which are identified as maize and barley. Additional ethanol for the EU market could also be produced by diverting non-EU molasses from existing uses. While the precise break down of uses and alternatives is likely to vary by region the displacement implications would be expected to be somewhat similar – increased demand for energy feed for livestock and increased demand for sugar substrates for yeast production (Baldino et al., 2020).

Another possible market response to a strengthened value proposition for molasses-based ethanol in the EU would be for existing supplies of molasses ethanol to be redirected to the EU market. Globally, about 36 million tonnes of molasses are reported as used for ethanol production, implying a global molasses ethanol production of about 8 billion litres given a yield of 227 litres ethanol per tonne molasses (El Takriti et al., 2017). That represents about 1.5% of expected 2030 EU transport energy demand, close to the 1.7% cap on the contribution to renewable energy targets for feedstocks in Part B of Annex IX. It is not clear what fraction of this is derived from final molasses. This suggests that if molasses was added to Annex IX then the resulting demand in the EU could in principle be met by importing existing molasses ethanol supplies from outside the EU. That ethanol may be replaced in domestic markets by additional production of sugarcane ethanol, or by reduced local biofuel/biogas consumption and hence higher gasoline consumption.

4.2. 2030/2050 potential

Based on OECD-FAO (2019) estimates, by 2030 global molasses production is expected to increase to about 76 million tonnes, of which about 7 million tonnes will be produced in Europe. Assuming sugarcane and sugarbeet production continue to grow linearly to 2050 (Alexandratos & Bruinsma, 2012), global molasses production could reach around 98 million tonnes, of which about 8 million tonnes would be produced in Europe. If entirely converted to ethanol, this implies a maximum production potential of 22 million tonnes in 2030 (2.0 million tonnes from European molasses) and 28 million tonnes in 2050 (2.3 million tonnes from European molasses).

5. Additional demand for land

5.1. Assessment of additional demand for land

The potential replacement materials identified for molasses are primary sugar crops and grains that are medium or medium-low risk substitutes. This is expected to be true for both EU produced and other sources of molasses. The risk of market distortion is high. Overall, the risk of creating additional land demand through the use of molasses for biofuel/biogas feedstock is considered medium-high.

6. Processing technologies

6.1. Evaluation of processing technology (mature vs advanced)

Processing of molasses into ethanol is well established and mature technology and therefore if added to Annex IX it would be appropriate to include molasses in Part B.

7. Conclusions

Table 87: Summary of evaluation results

	Evaluation Result	Rationale

Circular economy	No concern	There are some chemical/materials applications for final molasses but these use relatively small volumes. No largescale commercial uses were identified that would extend product life and sequester carbon for longer than energy uses. Increased production of biofuels from final molasses could reduce availability for other uses, but does not directly contradict circular economy principles.
Sustainability Union criteria	No concern	For sugarcane final molasses there is some risk of sugarcane expansion into highly biodiverse or high carbon stock areas if demand increases. For sugarbeet final molasses the risk is considered low. <u>How to mitigate this concern?</u> Failure to meet the Union sustainability criteria will be efficiently addressed throughout the certification process by an EU-approved voluntary or national scheme.
Sustainability GHG	No concern	Lifecycle analyses of ethanol from final molasses suggest that GHG emissions are likely to be below the REDII threshold.
Sustainability Others	Significant concern	As a co-product of sugar production, final molasses is associated with several potential negative environmental impacts from land management. For example, both sugarcane and sugarbeet culture are identified in previous work for the Commission as requiring high fertiliser and pesticide inputs. <u>How to mitigate this concern?</u> Whereas some EU-approved Voluntary Schemes have additional environmental requirements, which could potentially mitigate the identified concerns, new policy instruments would be required to address these consistently and systematically.
Market distortion	Significant concern	As final molasses is a fully utilised resource, increased use for bioenergy would result in displacement from other applications leading to market distortions. If displaced from the animal feed market final molasses would need to be replaced by other energy feeds. <u>How to mitigate this concern?</u>

		By considering molasses as covered under the definition of food/feed crop, they would fall under the corresponding food/feed crop cap, which would limit the amount of final molasses being used for biofuel production.
Land demand	Some concern	Under which circumstances could this feedstock be problematic? The materials that are identified as likely to replace final molasses in existing applications (additional production of wheat, barley and sugarbeet) are identified as medium or medium-low risk substitutes. The overall risk of additional demand for land is medium-high. How to mitigate this concern? Land demand risk could in principle be mitigated by requiring low ILUC-risk certification for the sugar crop from which final molasses is produced.
Processing Technologies	Mature	Ethanol production from final molasses is a well-established technology.
2030/2050 Potential	2030: 7 million tonnes [2.0 million tonnes ethanol] (EU); 76 million tonnes [22 million tonnes ethanol] (global) 2050 : 8 million tonnes [2.3 million tonnes ethanol] (EU) ; 96 million tonnes [28 million tonnes ethanol] (global)	Final molasses production can be expected to scale with total sugar production, which is forecast to increase approximately linearly to 2050.

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Vinasse and thin stillage

1. TECHNICAL DESCRIPTION

1.1. Feedstock description

Vinasse and **thin stillage** are dilute fractions remaining after the production of ethanol from sugar crops or starch crops respectively (although the terms are somewhat interchangeable and references to **thin stillage** from sugar crops or **vinasse** from grains may be found in the literature). **Vinasse** is produced in the process of ethanol production from sugarbeet or sugarcane juice or from molasses. Sugarcane **vinasse** generally contains more than 90% water (Carrilho et al., 2016; Christofoletti et al., 2013), whereas characterisations of sugarbeet **vinasse** suggest a lower water content (40-50% according to Cárdenas-Fernández et al., 2017, and NNFCC, 2019). **Thin stillage** is produced in the process of ethanol production from grains such as corn and wheat and contains more than 90% water (Kim et al., 2008).

The main constituents of dry matter in **vinasse** (both sugarcane and sugarbeet) include protein, fibre, glycerol, monosaccharides and sugar alcohols (Cárdenas-Fernández et al., 2017; Rodrigues Reis & Hu, 2017). It has a low pH value. Precise composition varies depending on feedstock (Christofoletti et al., 2013), with **vinasse** from fermentation of molasses having a higher solids content than **vinasse** from fermentation of sugar juice (Cortez & Perez, 1997).

Thin stillage contains the soluble constituents of the fermentate ('solubles'). The main constituents of dry matter in **thin stillage** include glycerol, lactic acid, proteins, crude fats, and carbohydrates (Kim et al., 2008; Ratanapariyanuch, 2016). Like **vinasse** it has a low pH (Wilkins et al., 2006). The precise constituents of this stillage can be expected to vary according to process details and feedstock (Ratanapariyanuch, 2016). Example chemical composition results for **thin stillage** from wheat, barley and corn are given in **Table 88**. The dry matter in **thin stillage** has a lower fraction of carbohydrates than distillers' but a higher concentration of protein and fats. The fatty content of **thin stillage** may be extracted as technical corn oil.

Table 88 : Chemical composition of grains, thin stillage and wet distillers' grains from wheat, barley and corn (Mustafa et al., 2000)

	Wheat			Barley			Corn		
	Grain	Thin stillage	Distillers' grains	Grain	Thin stillage	Distillers' grains	Grain	Thin stillage	Distillers' grains
Ash	2	8	4	3	10	4	1-2	7	5
Crude fat	2	14	4	2	13	6	3-5	9	10
Neutral detergent fibre	16	34	74	24	32	80	11-12	13	45
Acid detergent fibre	3	4	22	7	8	31	NA	NA	NA
Crude protein	16	46	26	12	37	15	9-10	19	30
Starch	63	2	2	53	1	1	70	25	8
Total carbohydrates	80	32	64	82	40	75	84	65	55
Non-structural carbohydrates	65	28	7	64	38	4	77	NA	29

1.2. Production process

Following fermentation of sugarbeet, sugarcane or molasses the resulting fermentate is distilled to separate the ethanol content from water and other substances, which are referred to as **vinasse (see Figure 35)**. Rodrigues Reis & Hu (2017) state that up to 20 litres of **vinasse** may be produced per litre of sugarcane ethanol produced, although other sources suggest slightly different values, for example Martinelli et al. (2013) suggest a production rate of at least 10 litres per litre of ethanol. For sugarbeet ethanol production, Bowen et al. (2010) reports about 9 litres of **vinasse** output per litre of ethanol while Wilkie et al. (2000) reports **vinasse** yield from 11 to 16 litres per litre ethanol depending on configuration. 'Raw' **vinasse** may be dehydrated before onwards supply leaving a consistency similar to molasses; Cárdenas-Fernández et al. (2017) reports a final **vinasse** yield for sugarbeet ethanol of only one tonne for every four tonnes ethanol.

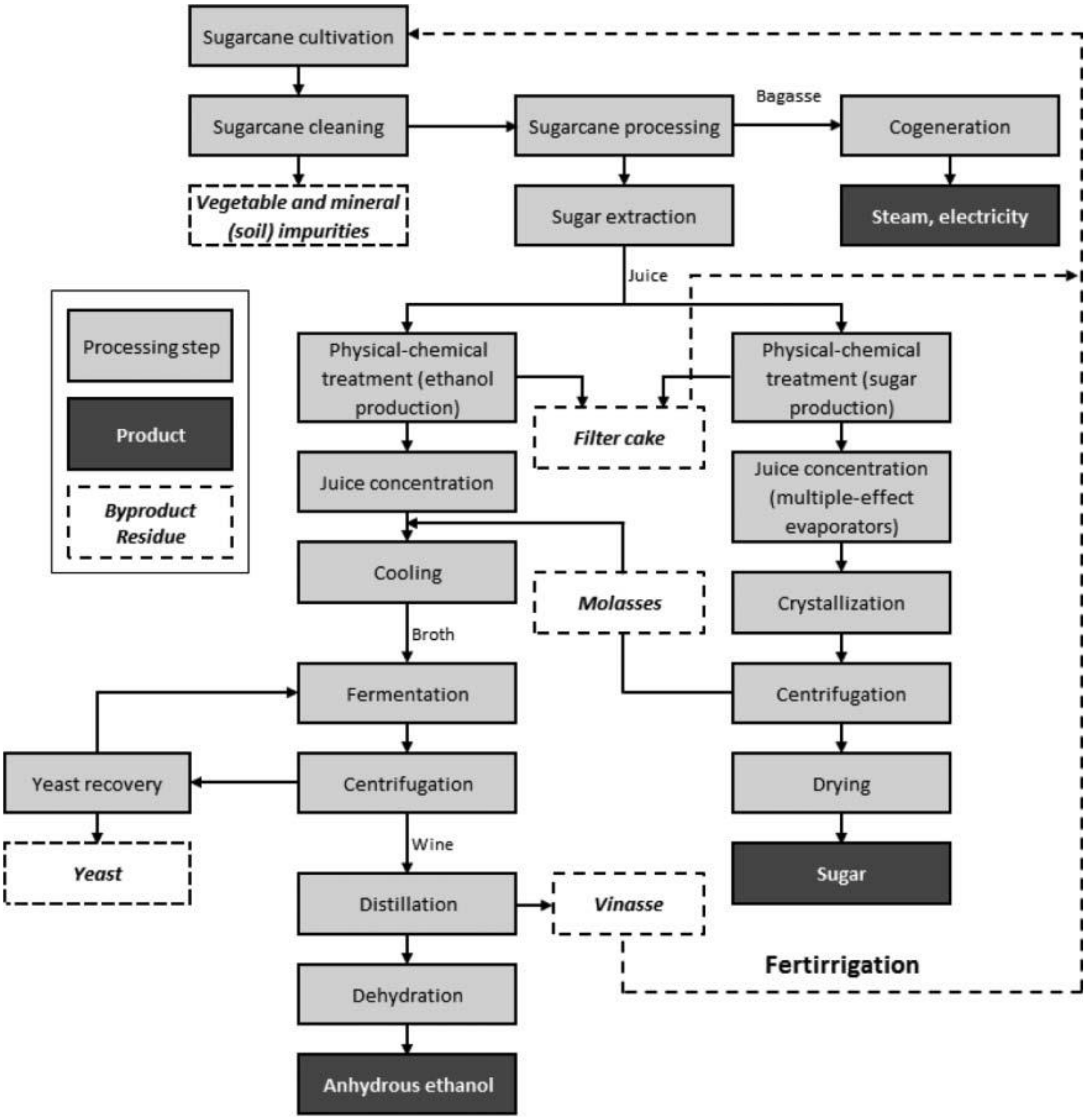

Figure 35: Schematic of the process of ethanol production from sugarcane, showing vinasse use for fertirrigation (Fuess et al., 2017)

In the process of ethanol production from starchy grains such as corn or wheat, the fermentate is distilled to separate out an ethanol fraction, and the remaining material containing water and the unfermented parts of the grain is referred to as whole stillage. The solid fraction of whole stillage is filtered out and referred to as wet distillers grains, while the liquid fraction is **thin stillage** (**Figure 36**). The volume of **thin stillage** produced can be as much as 15 times the volume of ethanol (Reis et al., 2017).

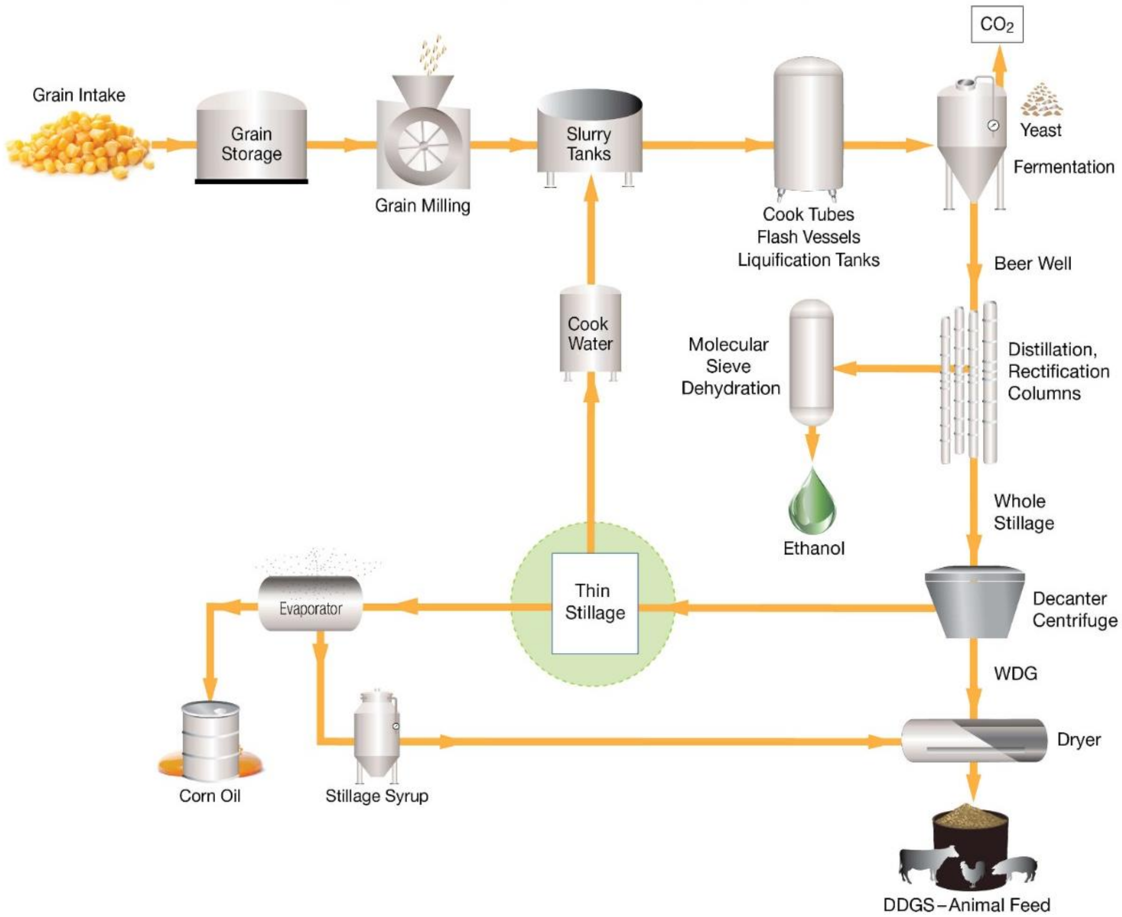

Figure 36: Schematic of the process of ethanol production from corn, showing thin stillage evaporation and addition of recovered solubles to DGS (Pall Corporation, 2021)

1.3. Possible uses

Historically, sugarcane **vinasse** was often disposed of directly into water courses (Christofoletti et al., 2013; Martinelli et al., 2013). This is now illegal in Brazil, but there is some evidence that some discharge without utilisation may continue, for example in Argentina (Muruaga et al., 2017). **Vinasse** from sugarbeet or sugarcane may be productively utilised as a fertiliser, may be anaerobically digested to produce biogas, may be used as an animal feed or may be used as a substrate for biochemical applications such as enzyme production (Cárdenas-Fernández et al., 2017; Carrilho et al., 2016; López-Campos et al., 2011; Marafon et al., 2020) or for cultivation of fungi as aquatic feed (Nitayavardhana et al., 2013).

In the case of sugarcane **vinasse**, Rodrigues Reis & Hu (2017) suggests that the dominant current use is fertirrigation (direct application as liquid fertiliser and water source) but that this practice tends to be associated with longer term negative impacts on soil and groundwater quality. For example, Christofoletti et al. (2013) mentions associated salinisation, metal leaching and alkalinity reduction. More positively, **vinasse** application may however allow for increased soil carbon formation (Zani et al., 2014). For UK sugarbeet **vinasse** Cárdenas-Fernández et al. (2017) identify animal feed as the primary market. **Vinasse** is identified as a useful source of minerals in animal feed and as a probiotic with immunological benefits[32].

In the corn and wheat ethanol industries, it is normal practice for **thin stillage** to be condensed by evaporation to give a product sometimes referred to as condensed distillers' solubles or syrup and then added to distillers grains to produce distillers grains and solubles (DGS), which are sold

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[32] https://www.allaboutfeed.net/animal-feed/feed-additives/vinasse-in-feed-good-for-animal-and-environment/

for animal feed (Bioenergy International, 2015; Urbanchuk, 2010). One European consultee did however report the use of **thin stillage** in a local fertilisation application due to lack of market opportunity for feed use. There are also options to feed **thin stillage** to livestock directly, either in a dilute form as a water substitute (Mustafa et al., 2000) or after evaporation in the form of condensed distillers' solubles (Sasikala-Appukuttan et al., 2008). Other potential applications for **thin stillage** identified by Reis et al. (2017) include extraction of phytate for use ion food, textiles of chemicals industries (after which the remnant of **thin stillage** could be returned to the feed market), extraction of glycerol and other trace chemicals, and use as a substrate for microbial cultivation.

Table 89 : Summary of possible uses of vinasse and thin stillage

	Food use	Feed use	Other uses
Vinasse from sugarcane and sugarbeet	None	Livestock feed supplement	Fertirrigation (generally sugarcane **vinasse**)
			Substrate for enzyme cultivation
			Substrate for microbial cultivation (including fungi)
			Biogas
Thin stillage from grain ethanol	None	Evaporation and integration of condensed distillers' solubles with distillers grains to form distillers grains and solubles as a livestock feed.	Extraction of trace chemicals (e.g. phytate, glycerol)
		Direct use as animal feed of **thin stillage** as-is as a water substitute, or after evaporation as condensed distillers' solubles.	Substrate for microbial cultivation (including fungi)
			Biogas

2. Circular economy and waste hierarchy

2.1. Classification of the product as a co-product, residue or waste

Vinasse and **thin stillage** are low value streams produced as a result of fermentation, and it is clear that they are not primary aims of production. While it is likely that some **vinasse** is still discarded without use, in general **vinasse** and **thin stillage** are materials that have some economic value and have several applications. We therefore class **vinasse** and **thin stillage** as residues.

Table 90: Classification of vinasse

Evaluation question	Answer	Rationale

Is the feedstock the primary aim of the production process?	No	**Vinasse** is a low value product stream that is not targeted by the process design, and therefore is not a primary product.
Does the feedstock have any economic value, but is not the primary aim of the process, and therefore a residue?	Yes	**Vinasse** has value as a replacement for chemical fertiliser (although there are some negative aspects to long-term fertirrigation) or as an animal feed ingredient, and a number of other potential productive applications have been documented.
Is the feedstock normally discarded, and therefore a waste?	No	In some regions some fraction of **vinasse** may still be disposed of without productive use, but this is an exception rather than a norm.

Table 91: Classification of thin stillage

Evaluation question	Answer	Rationale
Is the feedstock the primary aim of the production process?	No	**This stillage** is a low value product stream that is not targeted by the process design, and therefore is not a primary product.
Does the feedstock have any economic value, but is not the primary aim of the process, and therefore a residue?	Yes	**Thin stillage** is generally condensed to recover solubles that are added to distillers grains to form distillers grains and solubles that are sold for livestock feed, and other productive applications for **thin stillage** are available.
Is the feedstock normally discarded, and therefore a waste?	No	**Thin stillage** is not normally discarded.

2.2. Is the use of feedstock to produce biofuel/biogas in line with circular economy principles?

- **Does the feedstock have other material (re)uses, which could further extend its life?**

Answer: To only a limited extent.

Rationale: Trace chemicals in both **vinasse** and **thin stillage** could in principle be extracted and may have materials applications. This may however be compatible with anaerobic digestion of the remaining material. Other identified alternative uses of **vinasse** and **thin stillage** are short-term final uses – use as feed, fertiliser or as a biochemical substrate are all 'destructive' uses. Fertirrigation may allow for some part of the carbon content in **vinasse** to be sequestered in soils (Zani et al., 2014), but given the negative long-term implications of **vinasse** application through fertirrigation this may not be a preferred approach to support soil carbon increase.

- **Does its use as biofuel/biogas feedstock contribute to nutrient recovery?**

Answer: Unclear.

Rationale: Biogas production is the likely energy pathway for **vinasse** or **thin stillage**, and some nutrients from the digested material will remain in the digestate and would still be available for fertilisation applications (O'Shea et al., 2020; Salomon et al., 2011). It is unclear, however, what the relative fertilisation values of the untreated **vinasse/thin stillage** would be as compared to the digestate. Application of digestate for fertilisation may avoid some of the downsides of fertirrigation with **vinasse**.

- **Does its use as biofuel/biogas feedstock contribute to a more efficient use of resources by avoiding primary material extraction?**

  Answer: Yes for sugarcane **vinasse** – less clear for **thin stillage** and for sugarbeet **vinasse**.

  Rationale: Sugarcane **vinasse** is a low value resource that is associated with various agricultural issues when used for fertirrigation on a long-term basis. Producing biogas from **vinasse** would allow recovery of the energy value of the material, which is lost when used for fertilisation. Sugarbeet **vinasse** and **thin stillage** are already more likely to be used for animal feed applications in which the energy is utilised to support livestock growth. Diversion of these materials to bioenergy uses would therefore not be so advantageous in avoiding primary resource demand.

  Condensing **thin stillage** requires considerable energy expenditures (Reis et al., 2017) and therefore moving **thin stillage** resources to anaerobic digestion without condensing may reduce energy use by ethanol mills. Zhang (2018) suggests that the energy saved from changing the **thin stillage** treatment many be as much as double the energy output as biogas from digestion.

- **Does its use as biofuel/biogas feedstock contribute to reducing waste generation, especially food waste?**

  Answer: Yes for sugarcane **vinasse** in some regions. No for sugarbeet **vinasse** and **thin stillage.**

  Rationale: There is evidence that in some regions some fraction of sugarcane **vinasse** is treated as waste and discharged without use. Providing viable uses for **vinasse** could reduce the quantity of material wasted. Sugarbeet **vinasse** and **thin stillage** are not expected to be wasted irrespective of use for bioenergy.

2.3. Is the use of this feedstock for biofuel/biogas production in line with the waste hierarchy?

Vinasse and **thin stillage** are considered residues for the purpose of this assessment and therefore assessment against the waste hierarchy is not necessary.

2.4. Conclusion

The use of sugarcane **vinasse** as a biogas substrate may be considered to contribute to a circular economy as it would constitute a more complete recovery of the potential value of the material than is possible through current fertirrigation practice. It is understood that sugarbeet **vinasse** and **thin stillage** are likely to be in use for animal feed, in which case diverting them into biogas production would not contribute to the circular economy but also would not contradict circular economy principles.

3. Sustainability and Greenhouse gases

3.1. Union sustainability criteria

Vinasse and **thin stillage** are process residues, and therefore these requirements do not apply.

3.2. GHG savings criteria

Biogas from **vinasse** and **thin stillage** do not have default GHG intensity values provided in the RED II, and there are few lifecycle assessments for these materials readily available in the existing literature. Zhang (2018) suggests that the energy required for the operation of AD systems for **thin stillage** may be comparable to the energy output as biogas, in which case low GHG-intensity energy inputs would be needed in order for the process to deliver GHG reductions. Silva Neto & Gallo (2021) reports a GHG emissions value of 3.7 gCO2e/MJ for **vinasse**-based biogas. If this is representative of achievable GHG emissions levels for biogas from **vinasse** and **thin stillage** under the REDII methodology it would suggest that biogas from these feedstocks could meet the 65% GHG saving criterion.

3.3. Other environmental impacts

Vinasse and **thin stillage** are process residues and therefore their use is not considered to have a direct land management impact. In cases where the material is currently being used for fertirrigation, which is primarily relevant for sugarcane **vinasse**, displacing it into energy use would have environmental implications. Increased biogas production from **vinasse** could reduce the quantities of organic matter returned to soils and this may affect soil carbon formation (Zani et al., 2014). The literature suggests, however, that the long-term impacts of fertirrigation are negative overall for soil quality (Christofoletti et al., 2013; Rodrigues Reis & Hu, 2017). Martinelli et al. (2013) reports that the problem of potassium build up became sufficiently acute that in 2005 CETESB (the Environmental Company of São Paulo State) introduced regulatory limits on **vinasse** applications. Reduced fertirrigation is therefore unlikely to cause significant harm to soil quality, and may be associated with soil benefits depending on local context. There is also some suggestion that reduced **vinasse** application in fertirrigation may have potential to be biodiversity positive (ELLA, 2012).

4. MARKET EFFECTS AND 2030/2050 POTENTIAL

4.1. Market effects

As **vinasse** and **thin stillage** are process residues whose production is not targeted in the relevant processes, they are considered to have rigid supply, i.e. the rate of production of **vinasse** and **thin stillage** are determined by production of sugar and grain based ethanol.

Martinelli et al. (2013) assumes that every litre of sugarcane ethanol production is associated with at least 10 litres of unconcentrated **vinasse** production[33], and that this **vinasse** contains on average 375 mg/l nitrogen, 60 mg/l phosphorus and 2,000 mg/l potassium. Marafon et al. (2020) suggest an average of 12 litres **vinasse** per litre ethanol. Brazil produces about 30 billion litres of ethanol per year[34], implying about 360 billion litres of unconcentrated **vinasse** production. (Santos et al., 2011) estimate a methane production potential of 0.004 kg per litre of **vinasse**. At that yield, digestion of 100% of current Brazilian **vinasse** production could deliver around 1.4 million tonnes of methane.

In the Brazilian sugarcane industry, it is understood that the dominant utilisation of **vinasse** is fertirrigation. After anaerobic digestion of **vinasse** the nitrogen, phosphorus and potassium content of the **vinasse** will be concentrated into the digestate which may be used for fertilisation (Christofoletti et al., 2013). Given that volumes of **vinasse** produced in Brazil are so large as to be considered environmentally problematic in some areas and that much of the fertilisation value may be preserved through the anaerobic digestion process, increased biogas production from sugarcane **vinasse** should be expected to lead to major market distortions.

In cases where **vinasse** is used as an animal feed supplement, diversion to energy recovery would result in replacement by alternative feed materials. This is more likely to be the case for sugarbeet

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33 It is noted in this paper that the quality of vinasse can vary considerably by mill – the application volumes and associated quantitative results presented in this section should be treated as indicative rather than precise.

34 http://www.anp.gov.br/publicacoes/anuario-estatistico/anuario-estatistico-2018

vinasse than for sugarcane **vinasse**. López-Campos et al. (2011) identifies **vinasse** as a source of non-protein nitrogen appropriate for ruminant diets as an alternative to protein feeds or urea supplementation. Fernández et al. (2009) and Iranmehr et al. (2010) report that mixing **vinasse** into feed rations delivered improved palatability, dry matter intake and dietary digestibility for sheep. There is limited evidence available regarding which feed ingredients would be most likely to replace **vinasse** if it was displaced from animal diets.

Thin stillage is generally fed to livestock following evaporation/drying, and may be used directly as a feed ingredient. Reis et al. (2017) notes that **thin stillage** is seen as a good source of energy and protein and that it can be used as an energy and protein supplement and may improve feed efficiency in some diets. Sasikala-Appukuttan et al. (2008) compared several diets for lactating dairy cows varying the inclusion of distillers grains and condensed distillers solubles. Diets in which condensed distillers solubles replaced (per kg) approximately 0.2 kg of soybean meal and 0.8 kg of corn feed were shown to deliver comparable performance to a control diet. We would expect that, similar to the case with distils grains, where **thin stillage** is displaced from animal diets the likely replacement feed materials would be a combination of soy meal and cereals.

Given the costs involved in moving high-moisture materials over long distances, and the energy required to reduce the moisture content of these materials, it is unlikely that they would be imported to the EU in raw form. Biogas produced from **vinasse** and or **thin stillage** could potentially be imported to Europe, but international trade in biogas has traditionally been more limited than trade in liquid biofuels. It is therefore unlikely that a large import-based trade in biogas from these resources would emerge in the next ten years.

4.2. 2030/2050 potential

Flach et al. (2020) reports that about 6 million tonnes of sugar beets were used for ethanol production in the EU in 2020, producing about 600 million litres of ethanol. This production rate has approximately halved since 2013 when beet use for ethanol production peaked at 12 million tonnes, under pressure as grain prices have come down gradually from the high levels seen at the start of the decade. This implies a current production of roughly 6 billion litres of sugarbeet **vinasse** per year in Europe (at 10 litres **vinasse** per litre ethanol), and a potential for perhaps 20 thousand tonnes per year of methane production. Given the sensitivity of the EU sugarbeet ethanol markets to policy, to sugar and grain markets and to the competitive position of potential ethanol imports, it is not possible to make any convincing prediction of likely growth/reduction in EU sugarbeet ethanol production to 2030. We therefore take current production as a proxy for 2030 production. Given the European Union's commitment to move past first generation ethanol production, sugarbeet ethanol production may be expected to shrink towards zero by 2050, with a proportional reduction in **vinasse** availability.

In respect of **thin stillage**, Flach et al. (2020) reports current EU consumption for ethanol production of 6-7 million tonnes of corn and 2.5 to 3.5 million tonnes of wheat, for 2.5 to 3 billion litres of corn ethanol production and 1 to 1.4 billion litres of wheat ethanol production. This suggests a production of between 50 and 70 billion litres of **thin stillage** a year (assuming 15 litres per litre of ethanol). The challenges of forecasting grain ethanol production in the EU are similar to those for predicting sugarbeet ethanol production. We take current **thin stillage** production as indicative of potential 2030 production which we therefore estimate at 60 billion litres, and assume that by 2050 production of first-generation ethanol in the EU will have been more or less phased out. Assuming 1.04 MJ of methane production per litre of thin stillage digested (Moestedt et al. 2013; Eskicioglu et al. 2011), this implies the potential for around 1.2 million kg of methane production.

5. ADDITIONAL DEMAND FOR LAND

5.1. Assessment of additional demand for land

Where increased utilisation of **vinasse** for biogas production replaces fertirrigation systems, no significant requirement for substitute materials is anticipated. A comparable fertiliser value should be deliverable by application of digestate after biogas extraction, and therefore this displacement would not be expected to have significant land use implications.

In the case that **vinasse** was displaced from other existing uses such as animal feed (likely for sugarbeet **vinasse** in Europe), it may be substituted by other feed materials. The non-protein nitrogen content in **vinasse** might be substituted by urea as a feed supplement for ruminants. As urea is manufactured from ammonia this would not have land use implications. **Vinasse** also contains some digestible protein and energy which would need to be replaced if removed from existing diets (e.g. Weigand & Kirchgessner, 1980). Additional energy could be provided by cereal feeds, while protein could be supplied through oilseed meals. These substitutes are considered medium risk for land use change. Similarly, **thin stillage** would be likely to be displaced from animal feed applications, and would be expected to be replaced by cereal feeds and protein meals with a medium land demand risk.

Given the barriers mentioned above to developing an import trade in **vinasse**/**thin stillage** or the produced biogas, the most relevant cases under REDII are likely to involve use of domestic resources (sugarbeet **vinasse** and **thin stillage** from corn or wheat ethanol facilities in the EU), in which case displacement from feed applications is considered likely. The overall land demand risk is therefore considered medium for both feedstocks.

6. PROCESSING TECHNOLOGIES

6.1. Evaluation of processing technology (mature vs advanced)

Vinasse and **thin stillage** are considered to be potential feedstocks for anaerobic digestion. Anaerobic digestion and subsequent biogas upgrading are mature technologies (TRL 9, CRL 5). If added to Annex IX **vinasse** and **thin stillage** would therefore most appropriately be placed in Part B.

7. CONCLUSIONS

Table 92: Summary of evaluation results

	Evaluation Result	Additional remarks
Circular economy	No concern	Production of biogas from these resources may compete with feed use, but this does not contradict circular economy principles.
Union sustainability criteria	Not applicable	The feedstocks are process residues and thus the mandatory requirements do not apply.
Sustainability GHG	No concern	It is expected that biogas from **vinasse** or **thin stillage** would be able to meet the minimum GHG saving criteria.
Sustainability Others	No concern	In the sugar cane industry, increased biogas production from **vinasse** could reduce application for fertirrigation. As fertirrigation is currently associated with soil degradation where done on a long-term basis, this may deliver net environmental benefits. Given that imports of **vinasse** or biogas from Brazil are not considered likely to be driven by REDII, these impacts may not be realised in the REDII context.
Market distortion	Some concern	Under which circumstances could this feedstock be problematic? Diversion of **vinasse** and **thin stillage** from animal feed markets is likely in Europe, and these would need to be replaced in diets with alternative feeds. These are likely to include soybean meal and cereals. The overall market distortion risk is considered medium. How to mitigate this concern? This concern could be mitigated if the feedstock definition was narrowed to exclude **thin stillage** and sugarbeet **vinasse**, and include only sugarcane **vinasse.**
Land demand	Some concern	Under which circumstances could this feedstock be problematic? Diversion of vinasse and thin stillage from existing feed markets would be likely to lead to increased demand for meals and cereals for livestock feed which are considered medium land demand risk substitutes. The overall land demand risk for final molasses is considered medium. How to mitigate this concern? As with the market distortion risk, this concern could be mitigated if the

		feedstock definition was narrowed to exclude **thin stillage** and sugarbeet **vinasse**, and include only sugarcane **vinasse.**
Processing Technologies	Mature	Biogas production is considered the likely pathway for bioenergy from these feedstocks, and anaerobic digestion technologies for biogas production are mature.
2030/2050 Potential	2030 (EU): 6 billion litres **vinasse** [20,000 tonnes methane] and 60 billion litres **thin stillage** [1.2 million tonnes methane]. Imports: potential considered limited due to cost of transport.	Production of these feedstocks will be dependent on rates of ethanol production which are quite uncertain. There is also some uncertainty around precise yields of **vinasse** and **thin stillage** per litre of ethanol output.

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Alcoholic distillery residues and wastes

1. TECHNICAL DESCRIPTION

1.1. Feedstock description

Ethanol is obtained from fermentation of various agricultural materials that contain sugar, starch or cellulose. In additional distillation and rectification steps it is refined and concentrated to obtain the required quality. Depending on the end use, ethanol quality grades differ in purity and concentration. Neutral alcohol is highly concentrated and purified ethanol (at least 96% vol. ethanol) which is used for alcoholic beverages or for industrial applications. Therefore for neutral alcohol all impurities must be removed. For fuel grade ethanol water removal is important rather than the removal of impurities and the distillery residues can be reintroduced in the next distillation cycle to separate more ethanol. Accordingly, only the alcoholic distillery residues obtained from the **production of alcoholic beverages or purified ethanol for industrial applications** are considered in this assessment.

Alcoholic distillery residues and wastes includes "**heads and tails"**. The impurities have boiling points that are either higher or lower than ethanol. The impurities with the lower boiling points are known as **heads**. Heads include acetaldehyde, acetone and other volatile trace components (Spaho, 2017). **Tails** on the other hand are less volatile alcohols with higher boiling points. Tails include acetic acid, furfural and a group of alcohols known as **fusel oils** comprising of propanol, butanol and amyl alcohols (Difford, 2021). Fusels are alcohols with more than two carbon atom and an oily consistency therefore popularly termed as fusel oils (Gaia, 2014).

The generation of distillery residues and wastes is unavoidable and according to the stakeholder consultation its further processing into biofuel offers an opportunity to valorise the feedstock and increase the supply of waste/residue-based biofuels (Italian Government, 2020).

1.2. Production process

The alcoholic mash is preheated and fed to the distillation section where the crude ethanol is stripped from the mash, leaving behind an alcohol-free liquid, the stillage. The crude ethanol is purified and concentrated in several process columns. Heavier ethanol is separated from the lighter **heads** and fed to rectification for further refining and concentration of ethanol (Vogelbusch, 2021a). The heads are then condensed and separated. The **tails** are concentrated and separated at the end of the distillation/rectification run. The production process is shown in **Figure 37**.

Most of the ethanol from the fermented mash comes off in the middle cut (86.6%) and the rest remains in the heads and tails (Gaia, 2014). The quality and quantity of heads and tails generated during alcohol production depends on:

- The feedstock used and the method of preparation of mash used for fermentation;
- The conditions and environment under which fermentation occurs;
- The choice of enzymes;
- The method of distillation and removal of heads and tails during distillation.

The heads fraction is collected in about 10% of the volume of the alcoholic mash. Once the desired concentration of ethanol in middle cut has been obtained, the remaining alcohol is collected in the tail fractions. The heads have an ethanol content of about 80-90% ethanol and the tails about 30-40% ethanol content dependent on the distillation conditions and the ethanol concentration desired in the final product (Balcerek et al., 2017). The yields of fusel oil obtained in a commercial plant may vary between 0.1% and 0.6% (vol.) (Mayer et al., 2015).

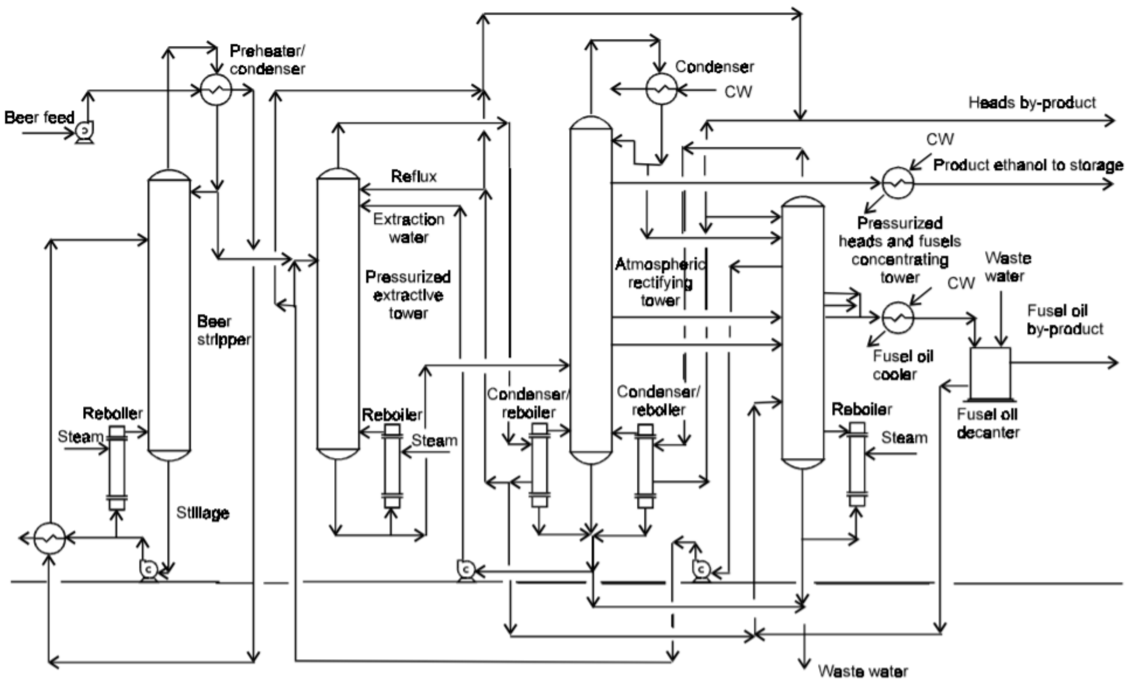

Figure 37. Process scheme of ethanol distillation/rectification (Katzen et al., 1999)

1.3. Possible uses

The generation of heads and tails is unavoidable and they contain the impurities that are separated during the ethanol purification process. Due to these impurities and the strong off-smell, the feedstock is **unsuitable for food/feed** applications.

Heads and tails generated from the production of high quality industrial or beverage grade ethanol, can be used as feedstock to produce **bioethanol** for fuel purpose. There is possibility to have an annex distillery where there is bioethanol production next to neutral ethanol production (Vogelbusch, 2021b). The head and tails from neutral ethanol production can accordingly be utilized as an additional feedstock in bioethanol production to increase the ethanol yield in the process. As there are other chemicals present in the heads and tails, this needs to be done in accordance with the ethanol fuel quality requirements. The specifications for ethanol as a blending component for gasoline in the EU market, according to the standard EN 15376, require a water content of maximum 0.3 % (m/m), higher alcohols (C3-C5) content of maximum 2% (m/m) and acetic acid ($C_2H_4O_2$) content of maximum 0.007% (CEN, 2014). Furthermore the methanol content in ethanol is limited to a maximum 1 % (m/m).

Companies that supply fuels to transport in the Netherlands have obligations under the Energy for Transport legislation and regulations (Dutch Government, 2018). In the list of feedstocks in the Register Energy for Transport (Register Energie voor Vervoer, REV) under liquid biofuels "waste/residues from processing of alcohol" is present. It is categorized as Advanced and suitable for double counting (Nederlandse Emissieautoriteit, 2021).

Under ISCC certification a number of ethanol plants is currently certified to process 'waste/residues from alcohol processing' which includes impurities (heads and tails) from distillation, unsuitable for human or animal consumption (ISCC, 2020). These plants may currently already process the proposed feedstock. In addition, a number of ethanol plants are certified to offer 'waste/residues from alcohol processing' to the market.

Fusel oils can find use as a **blending agent** between the ethanol and gasoline (Katzen et al., 1999). The idea of fusel oil as a renewable fuel for internal combustion engines was generated in the past decade, and its usability studies has been conducted (Arbedili et al., 2020). Despite their low lower heating value, the calorific value of fusel oils is almost the same compared to gasoline and the octane number is comparable to ethanol.

Fusel oils can also be sold to chemical industry for use as **low-grade industrial ethanol** as solvent for paints bases, cleaning liquid and windscreen wash (Ethimex, 2019). They can also be used as raw material for the extraction of other alcohols such as **amyl and isoamyl alcohol**. However, this requires additional processing and energy requirements and is currently not feasible. Ferreira et al. (2013) have proposed an integrated process system to increase ethanol recovery and to purify isoamyl alcohol from fusel oil. In another study, to reduce the energy consumption and costs a dividing wall column was used for separation of isoamyl alcohol from fusel oil (Mendoza-Pedroza et al., 2021). In another approach, fusel oil was used in the generation of organic carbonates via capture and fixation of carbon dioxide (CO_2), also a coproduct generated in the distillery (Pereira et al., 2015).

Possible uses of alcoholic distillery residues and wastes are summarised in **Table 93**.

Table 93 : Summary of possible uses of Alcoholic distillery residues and wastes

Food use	Feed use	Other uses
Not applicable.	Not applicable.	Bioethanol: Documented evidence of commercial implementation. Fusel oil use as a Blending agent with gasoline: Applicability studied, currently limited evidence of commercial implementation. Fusel oil use for Chemicals (low-grade industrial ethanol): Limited commercial implementation after further processing.

2. Circular economy and waste hierarchy

2.1. Classification of the feedstock as a co-product, residue or waste

Alcoholic distillery residues and wastes can be classified as a process residue or waste as described below.

Table 94 : Classification of Alcoholic distillery residues and wastes

Evaluation question	Answer	Rationale
Is the feedstock the primary aim of the production process?	No	The primary aim of the process is to produce alcoholic drinks. Alcoholic distillery residues and wastes is not a product that the produces seeks to produce and the process in not modified to produce it.
Does the feedstock have any economic value, but is not the primary aim of the process, and therefore a residue?	Variable	The feedstock is an unavoidable and undesired process residue of ethanol purification process. If not discarded as a waste then the feedstock can be sold at a significant discount value compared to regular ethanol grades (Ethimex, 2019).
Is the feedstock normally discarded,	Variable	In most cases the feedstock gets discarded due to taste/quality requirement for beverage and purity

and therefore a waste?		requirement of ethanol for industrial applications. This feedstock is present in the list of wastes as "waste from spirits distillation" (02 07 02) (European Union, 2001).

2.2. Is the use of feedstock to produce biofuel/biogas in line with circular economy principles?

- **Does the feedstock have non-energy (re)uses, which could extend its life or sequester carbon for longer?**

  Answer: No

  Rationale: Considered use for alcoholic distillery residues and wastes is liquid fuel. Fusel oils can be used as biobased chemicals but mostly as a solvent or for extracting other chemical compounds which do not result in carbon sequestration.

- **Does its use as biofuel/biogas feedstock contribute to nutrient recovery?**

  Answer: No

  Rationale: Its disposal or use as liquid fuel do not contribute to nutrient recovery.

- **Does its use as biofuel/biogas feedstock contribute to a more efficient use of resources by avoiding primary material extraction?**

  Answer: Yes

  Rationale: As with all other biomass feedstocks, biofuels derived from alcoholic distillery residues and wastes displaces fossil fuels, thus reducing the need for primary material extraction. The processing of this feedstock into biofuel offers an opportunity to increase the supply of waste/residue-based biofuels and will prevent it from going to waste disposal or wastewater treatment.

- **Does its use as biofuel/biogas feedstock contribute to reducing waste generation, especially food waste?**

  Answer: Variable.

  Rationale: In most cases the feedstock gets discarded due to taste/quality requirement for beverage and purity requirement of ethanol for industrial applications. In this case using this feedstock for biofuel contribute to reducing waste.

2.3. Is the use of this feedstock for biofuel/biogas production in line with the waste hierarchy?

- **Contribution to increasing waste?**

  Answer: No.

  Rationale. No evidence exists that using alcoholic distillery residues and wastes for biofuel production would generate more waste.

- **Can this feedstock be potentially reused?**

  Answer: No.

  Rationale: Reuse is not applicable.

- **Can this feedstock be potentially recycled?**

  Answer: No.

  Rationale: Recycling is not applicable.

2.4. Conclusion

Contribution to circular economy

Using alcoholic distillery residues and wastes for energy purposes does neither contribute to, nor contravene circular economy principles. No commercial uses exist that could extend product life and sequester carbon for longer than energy uses. Increasing the use of alcoholic distillery residues and wastes for energy purposes will contribute to a more efficient use of resources and will prevent it from going to waste disposal.

Alignment with the waste hierarchy

Using alcoholic distillery residues and wastes for biofuel is in line with the waste hierarchy. They are inevitably produced from the ethanol purification process. Re-use and recycling are not applicable.

3. SUSTAINABILITY AND GREENHOUSE GASES

3.1. Union sustainability criteria

Alcoholic distillery residues and wastes are secondary process residues and therefore the Union sustainability criteria are not applicable.

3.2. GHG Savings Criteria

Alcoholic distillery residues and wastes, according to REDII, are considered to have zero life cycle emissions until the point of collection. At the point of collection the feedstock already contain ethanol and the higher alcohols that have been produced which can be considered free of burden. Only GHG emissions will arise from further refining and separation/purification requirements for use of this feedstock in bioethanol production or in blending. The GHG savings criteria for new installations require at least 65% GHG savings. There is no readily available data to estimate the processing requirements and associated GHG emissions. The life cycle emissions are not expected to exceed 10 gCO_2eq/MJ, meaning about 89% GHG savings. Therefore, compliance with GHG savings criteria is expected.

3.3. Other environmental impacts

Alcoholic distillery residues and wastes are secondary process residues and therefore have no land management impact. The evaluation of risks of adverse effects on soil, water, air and biodiversity is not applicable.

4. MARKET EFFECTS AND 2030/2050 POTENTIAL

4.1. Market effects

The feedstock (alcoholic distillery residues and wastes) represents a small fraction of the total output from ethanol production, and the feedstock, if not disposed of, is currently used in low value industrial ethanol applications only. This feedstock is considered to have a **rigid supply** since supply is unlikely to increase if demand increases. It is the demand for ethanol that ultimately dictates supply of alcoholic distillery residues and wastes.

The total potential for alcoholic distillery residues and wastes production in the world in 2019 is estimated to be ~550 million litres, with production in EU estimated at ~27 million litres (Arbedili et al., 2020). The share of production of alcoholic beverages or purified ethanol for industrial applications is estimated to be about 55% of the global ethanol market. (Grand View Research, 2020; Mordor Intelligence, 2021). Whereas in the EU, ethanol production amounted to 6.35 billion litres in 2019 with fuel accounting for over 80% of use (ePURE, 2019). Therefore, the alcoholic distillery residues and wastes obtained from the production of alcoholic beverages and purified ethanol for industrial applications can be estimated to be about 300 million litres, with production in EU estimated at about 5.5 million litres.

Since this feedstock can currently find use in the chemical industry such as solvent for paints bases and cleaning liquid, its use for biofuel **could have a distortive effect** on these low grade chemical applications. However, only a small volume is currently utilised for this and its contribution to the total technical ethanol supply is very minor. Therefore, this distortive effect is expected to be **minimal**. The evaluation did not reveal any significant concern for substitution effect from the use of alcoholic distillery residues and wastes for energy. If a diversion occurs from use of alcoholic distillery residues for chemicals to energy, this would potentially cause this supply to be substituted with ethanol produced from sugar and starch crops. This could subsequently lead to **potential negative environmental impacts** as additional cultivation of these crops would be required. This would mean land use, water use, fertilizer use and associated additional GHG emissions.

How to mitigate this concern?

Auditors should check that facilities are producing an expected ratio of main product (alcoholic beverages or neutral alcohol for industrial applications) to distillery residues and wastes. The auditor should have access to historical data to be able to determine that the ratio of process streams has not materially changed over time. New policy developments would also be required to evaluate that available supply largely exceeds the demand from the chemicals sector.

4.2. 2030/2050 Potential

The future potential for alcoholic distillery residues and wastes obtained from the production of alcoholic beverages and purified ethanol for industrial applications, will be dictated by future demand for neutral ethanol in these applications. There is rising consumption of alcoholic beverages which is a major factor supporting market growth (Precedence Research, 2021). Further, in the COVID-19 pandemic, an increased usage of alcohol-based hand sanitizers led to tremendous demand for ethanol in industrial applications.

Neutral alcohol market is projected to register a CAGR of 6.9% from 2020-2030 (Next Move Strategy Consulting, 2020). Long term projections were not found, but the market growth is expected to continue. A more conservative CAGR of 5% is considered for the period of 2030-2050. Considering current world alcoholic distillery residues and wastes potential of ~ 300 million litres from the production of alcoholic beverages and purified ethanol for industrial applications and considering the CAGR of 6.9% of neutral ethanol, the global alcoholic distillery residues and wastes potential is estimated to be about **0.6 billion litres in 2030**. Considering the CAGR of 5% for the period 2030-2050, potential production of alcoholic distillery residues and wastes would be approximately **1.5 billion litres in 2050**.

These volumes provide theoretical alcoholic distillery residues and wastes that may be available in 2030 and 2050 for any application. Given that fusel oils currently find use as solvent in industry and have a rigid supply, its use for biofuel could have **distortive effect** on these low grade chemical applications. However, as it is estimated that much surplus is available than currently utilized this effect is expected to be **minimal**.

5. Additional demand for land

5.1. Assessment of additional demand for land

If a diversion occurs from chemical uses, this would potentially cause this alcoholic distillery residues and wastes to be substituted with ethanol produced from sugar and starch crops. In Table

9, we list a number of possible substitute materials and categorize their risk level for additional demand for land.

Table 95: Categorization of risk of additional demand for land for various materials

Substitute materials	Risk level
Wheat Maize	Medium
Sugarbeet Sugarcane	Medium-low

However, the evaluation did not reveal any significant concern for substitution effect from the use of alcoholic distillery residues and wastes for energy. There is a **low risk** of market distortion and the need for the production of substitute materials.

Final result for alcoholic distillery residues and wastes: low-medium risk for additional demand for land

6. Processing technologies

6.1. Evaluation of processing technology (mature vs advanced)

A simple possibility to use the **heads and tails** derived from the production of alcoholic beverages or purified ethanol for industrial applications for biofuel purpose is to co-feed them to fuel ethanol production plant to recover additional ethanol. Thereby existing mature distillation technology could be utilized.

The usage of **fusel oil** blended with gasoline in internal combustion engines, is investigated by researchers in the last decade (Arbedili et al., 2020). Fusel oil includes several types of alcohols which makes it unsuitable for different operation conditions and therefore separation of some of the components may be required. The water content removal is also seen necessary to improve the performance (Arbedili et al., 2020). Therefore, deployment of combination of chemical reactions, purification and dehydration technologies may be needed to attain the required engine performance. These processing options are yet investigated at research phase.

7. Conclusions

Nomenclature:

- No concern = the evaluation did not reveal any significant concern about this feedstock.
- Some concern = the evaluation identified limited conditions under which some concerns may exist, i.e. using this feedstock for biofuel production could be in contradiction with this criterion.
- Significant concern = the evaluation reveals that using this feedstock for biofuel production would be in contradiction with this criterion in most circumstances.
- Not applicable = this criterion is not applicable to the feedstock.

Table 96: Summary of evaluation results for alcoholic distillery residues and wastes

	Evaluation Result	Rationale

Circular economy and waste hierarchy	No concern	No commercial uses exist that could extend product life and sequester carbon for longer than energy uses. Therefore, using this feedstock for biofuel does neither contribute to, nor contravene circular economy principles or the waste hierarchy.
Union sustainability criteria	Not applicable	This feedstock is a process residue. These criteria are **not applicable** as this feedstock is neither primary agricultural biomass nor agricultural field residue nor forest biomass.
Sustainability GHG	No concern	The evaluation did not reveal any significant concern for this feedstock meeting GHG savings criteria
Sustainability Others	Not applicable	This feedstock is a process residue. These criteria are **not applicable** as this feedstock has no land impact.
Market distortion	Some concern	<u>Under which circumstances could this feedstock be problematic?</u> Given that fusel oils currently find use as solvent in industry and have a rigid supply, its use for biofuel could have **distortive effect** on these low grade chemical applications. However, as it is estimated that much surplus is available than currently utilized this effect is expected to be **minimal**. <u>How to mitigate this concern?</u> Inclusion in Annex IXB (see below) would limit the amount of feedstock being used for biofuel production. Auditors should check that facilities are producing an expected ratio of main product (alcoholic beverages or neutral alcohol for industrial applications) to distillery residues and wastes. The auditor should have access to historical data to be able to determine that the ratio of process streams has not materially changed over time. New policy developments would also be required to evaluate that available supply largely exceeds the demand from the chemicals sector.
2030/2050 Potential	2030: 0.6 billion litres (0.18 billion litres ethanol) 2050: 1.5 billion litres (0.45 billion litres ethanol)	The evaluation concluded that there is a potential of approximately **0.6 billion litres in 2030**. This can increase to a potential of **1.5 billion litres in 2050**.

Land demand	Some concern	Under which circumstances could this feedstock be problematic? There is a low risk of market distortion and the need for the production of substitute materials. If a diversion occurs from chemical uses, the ethanol can be substituted with ethanol produced from sugar and starch crops. These substitutes would fall in the medium/medium-low risk category. Overall, this feedstock has a low-medium risk for additional demand for land. How to mitigate this concern? See "Market distortion"
Processing Technologies	Mature (heads and tails) Advanced (fusel oils)	Heads and tails can be directly processed into ethanol. Fusel oils require advanced pre-treatments before being processed into biofuels.

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Brewers’ Spent Grains

1. Technical description

1.1. Feedstock description

Brewers’ spent grain (BSG) is generated by the brewing industry alongside beer as a side product (Mussatto, 2014). This material consists of barley grain husks including parts of the pericarp and seed coat layers of these grains. In some cases, according to the kind of beer that is produced, other cereals such as maize, rice, wheat, oats, rye or sorghum can be used in mixture with the barley malt for the wort elaboration. In such cases, the insoluble part of these grains after the mashing process is separated with BSG. Therefore BSG can be derived from barley malt only or from a mixture of barley malt with other cereal grains.

BSG typically has 80% moisture content and is a lignocellulosic biomass, which comprises 15–27% lignin, 12–25% cellulose, 19.2–41.9% hemicellulose and 14–31% protein on a dry weight basis (Pinheriro et al., 2019). Its exact composition may vary due to a variety of factors, which include the variety of the barley used in the process as well as its harvest time and the conditions under which it was cultivated, the conditions used for malting and mashing and the amount and type of the other cereal grains (adjuncts) added in mixture with the barley malt for the wort elaboration (Mussatto, 2014). BSG is available all year round, but cannot be stored over long periods due to spoilage. Although drying is energy intensive, it can be done for preservation (Chetrariu and Dabija, 2020). This also decreases transport and storage costs due to increased energy density.

1.2. Production process

In the brewing process, grains are soaked in water until they germinate and then dried to produce the malt (malting). The malted grains are milled and steeped in hot water so that enzymes transform the starch into sugars (mashing/saccharification). At the end of this process, the insoluble undegraded part of the barley malt grain, also known as brewer’s spent grain (BSG), is in a mixture with the wort (sugar-rich liquid). The wort is then filtered through the BSG bed formed at the bottom of the mash tun and is transferred to the fermentation tank, while BSG is obtained separately. The resulting wort is then used in the subsequent fermentation stage to produce beer. It is estimated that 21-22 kg of wet BSG are produced per 100 litres of beer (Lynch et al. 2016). The production process is shown in **Figure 37**.

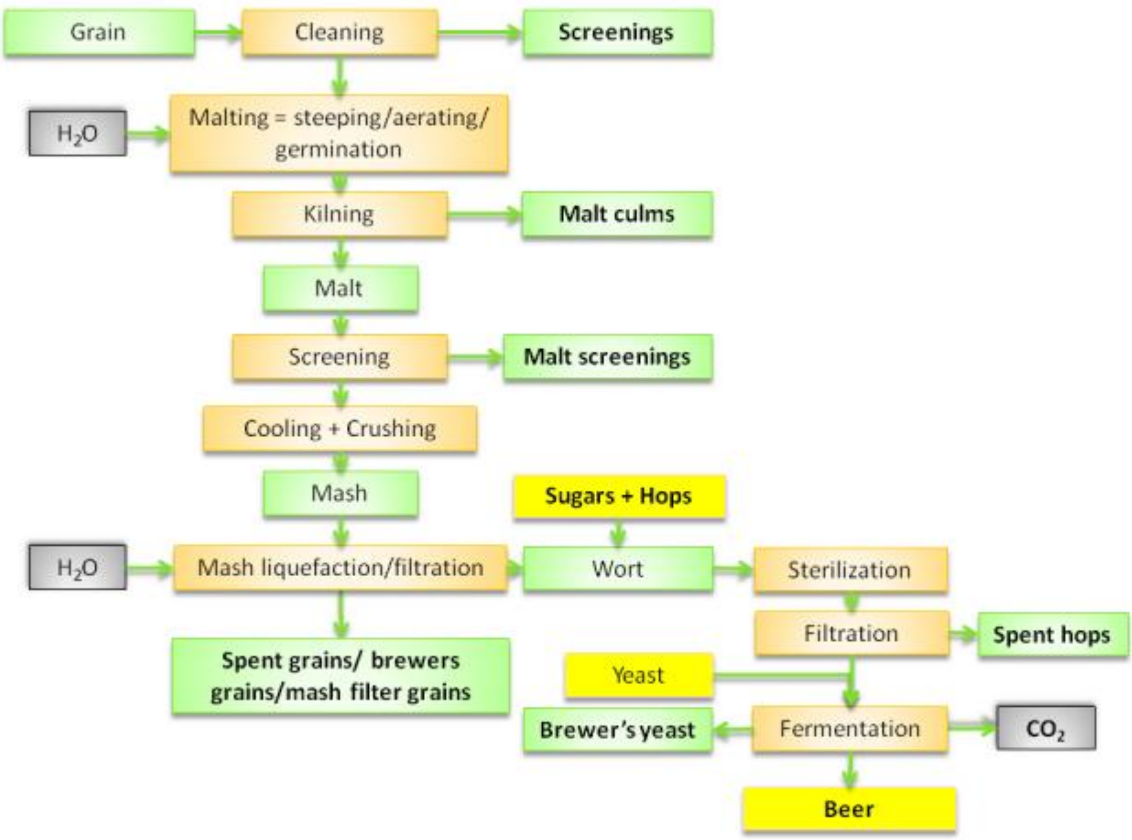

Figure 38. Process scheme of beer brewing process (Heuze et al., 2017)

1.3. Possible uses

Currently, BSG is mainly used by local farmers as **feed**. BSG is suitable as feed for cattle, poultry, pigs and fish (Chetrariu and Dabija, 2020). Because it is wet, it is not profitable to transport it over long distances. Nevertheless, BSG produced in most cases exceeds the demand for feed required by the nearby farmers or in some case no farms exist close to the breweries (Mussatto, 2014). Furthermore, if wet BSG is not used within few days after being produced, microbial growth causes a fast spoilage. In these situations BSG needs to be sent for disposal with no value generated. Finding use for excess BSG in other applications is therefore necessary.

BSG is also used to produce **biogas** via anaerobic digestion (Szaja et al., 2020; Bolwig et al., 2019; Scott, 2016). Currently, biogas production from BSG is only done in larger breweries owing to the economy of scale. Biogas production process by anaerobic fermentation can be divided into two steps: an initial hydrolytic step to promote complete degradation of the material and a methanogenic step for conversion to methane (Mussatto, 2014).

Some breweries also combust dried BSG to meet their **heat and electricity** demands (Mussatto, 2014; Wärtsilä Corporation, 2008).

Moreover, pilot scale experiments have been carried out focusing on the valorization of BSG as a substrate for lignocellulosic **bioethanol** production. One of the challenges in the production of bioethanol from BSG is related to achieving level of yields in bioethanol that allow the process to be economically viable (Rojas-Chamorro et al., 2020; Pinheiro et al., 2019). Additionally, it has been studied to use BSG in the production of **biobutanol** (Lopez-Linares et al., 2019). Furthermore, synthesis of **biocoal** via hydrothermal carbonization of BSG is being investigated which allows converting BSG without pretreatment (Nasir et al., 2021).

The possibility of BSG application in **food** products has been extensively evaluated. Studies report conversion of BSG into flour and use in the manufacture of bakery products such as breads, biscuits, cookies, and cakes. A percentage of up to a maximum of 15% BSG can be used in bakery products; higher concentration would negatively influence taste properties (Chetrariu and Dabija, 2020). The use of BSG in the production of other food products such as frankfurters sausages, fish burgers and beverages has also been evaluated. However, limited evidence can be found that these have been realised commercially.

Wageningen University and Research (WUR) is also working on a project to isolate and valorise BSG's protein content into valuable **food ingredients**, where the remaining part can be utilized for feed or energy (Mulder, 2020). Phenolic compounds can be recovered from BSG and find use as antioxidant (Chetrariu and Dabija, 2020). Arabinoxylans can be attained from BSG which are used as food ingredient with prebiotic effects. This is investigated in lab/pilot scale.

Furthermore, use of BSG for **chemical and material** applications have been investigated. BSG is considered as a suitable raw material for use in the production of pulp and paper. BSG use as an adsorbent material for wastewater treatment appears to be one of the most promising applications. BSG can also be used in fermentation processes for the production of lactic acid and xylitol (Mussatto, 2014). Use of BSG as a substrate for microorganism cultivation and enzyme production has also been a focus of many studies (Chetrariu and Dabija, 2020).

Possible uses of BSG are summarised in **Table 97**.

Table 97 : Summary of possible uses of Brewers' spent grains

Food use	Feed use	Other uses
Limited evidence of commercial implementation of BSG for food products as a flour. Biorefining needs to be applied to separate proteins, arabinoxylans and phenolic compounds from BSG for food ingredients where the remaining feedstock can be used for feed and energy.	Documented evidence of commercial implementation as animal feed.	Biogas/biomethane: Documented evidence of commercial implementation. Heat/electricity: Documented evidence of commercial implementation via CHP at breweries. Bioethanol: Tested at pilot scale. No documented evidence of commercial implementation. Biobutanol: Tested in lab scale. No documented evidence of commercial implementation. Chemical and material: Various applications being investigated including paper, adsorbent, lactic acid and xylitol.

2. Circular economy and waste hierarchy

2.1. Classification of the feedstock as a co-product, residue or waste

BSG can be classified as residues as described below.

Table 98 : Classification of BSG

Evaluation question	Answer	Rationale
Is the feedstock the primary aim of the	No	The beer product is the primary aim of the production process. BSG is not a product that the produces seeks

production process?		to produce and the process in not modified to produce it.
Does the feedstock have any economic value, but is not the primary aim of the process, and therefore a residue?	Yes	BSG has an economic value (significantly lower than the main product) (Buffington, 2014)
Is the feedstock normally discarded, and therefore a waste?	Variable	This is dependent on the availability and demand of nearby farmers. In most cases a significant portion of feedstock, which would in theory be suitable for feed or energy generation, is discarded ending partly in landfills. Drying can be done for preservation and to ease transport.

2.2. Is the use of feedstock to produce biofuel/biogas in line with circular economy principles?

- **Does the feedstock have non-energy (re)uses, which could extend its life or sequester carbon for longer?**

  Answer: No

  Rationale: The primary use for BSG is animal feed which does not differ in terms of sequestering carbon for longer compared to energy use. Use of BSG for biobased chemicals and materials could theoretically be possible, but no evidence of commercial applications exists.

- **Does its use as biofuel/biogas feedstock contribute to nutrient recovery?**

  Answer: Yes

  Rationale: Anaerobic digestion of BSG for biogas production generates a digestate, which retains nutrients. This can be used as fertiliser, thus contributing to decreasing the need for industrial fertiliser production.

- **Does its use as biofuel/biogas feedstock contribute to a more efficient use of resources by avoiding primary material extraction?**

  Answer: Yes

  Rationale: As with all other biomass feedstocks, biofuels and biogas derived from BSG displaces fossil fuels, thus reducing the need for primary material extraction. BSG is utilised in animal feed if it is not supplied to the biofuel market. However, there is much surplus available that its use for biofuel/biogas should not result in additional resource extraction for feed. Therefore, increasing the use of BSG for energy purposes will contribute to a more efficient use of resources and will prevent it from going to waste disposal.

- **Does its use as biofuel/biogas feedstock contribute to reducing waste generation, especially food waste?**

  Answer: Variable.

  Rationale: This is dependent on the availability and demand of nearby farmers. It is intended to use BSG in energy applications when the feed demand of nearby farmers is met. In most cases a significant portion of feedstock, which would in theory be suitable for feed or energy generation, is discarded ending partly in landfills. BSG produced in most cases surpasses the demand for feed required by the nearby farmers. Also, no farms may exist close to the breweries. Furthermore, if wet BSG is not used within few days after being produced, it is spoiled. In these situations use of BSG as biofuel/biogas feedstock contribute to reducing waste generation (Bolwig et al., 2019).

2.3. Is the use of this feedstock for biofuel/biogas production in line with the waste hierarchy?

- **Contribution to increasing waste?**

  Answer: No.

  Rationale. No evidence exists that using BSG for biogas or biofuel production would generate more waste.

- **Can this feedstock be potentially reused?**

  Answer: No.

  Rationale: The relevant applications of BSG are feed and energy, therefore reuse is not applicable.

- **Can this feedstock be potentially recycled?**

  Answer: No.

  Rationale: The relevant applications of BSG are feed and energy, therefore recycling is not applicable.

2.4. Conclusion

Contribution to circular economy

There is no documented evidence of commercial use of BSG for biobased chemicals and materials which can extend product life and sequester carbon for longer than energy uses. Therefore, using BSG as biofuel/biogas feedstocks does neither contribute to, nor contravene circular economy principles. Increasing the use of BSG for energy purposes will contribute to a more efficient use of resources and will prevent it from going to waste disposal.

Alignment with the waste hierarchy

Using BSG for biogas/biofuel is in line with the waste hierarchy. Large amounts of BSG are inevitably produced from the beer brewing process. Re-use and recycling are not applicable. Recycling of nutrients can be achieved by using digestate as fertilizer. Currently, large surplus available in most cases and using them for energy would prevent them going to disposal.

3. Sustainability and Greenhouse gases

3.1. Union sustainability criteria

BSG is a process residue and therefore the Union sustainability criteria are not applicable.

3.2. GHG Savings Criteria

The most typical conversion process considered for BSG is biogas production which provides biomethane for transport. BSG is a process residue and therefore according to REDII considered to have zero life cycle emissions until the point of collection. Default values are provided for biomethane production in REDII Annex VI Part C for wet manure, maize and biowaste[35]. As an initial estimate, default values provided in the RED II for biowaste are considered which show

35 As per Directive 2008/98/EC, 'biowaste' means biodegradable garden and park waste, food and kitchen waste from households, restaurants, caterers and retail premises and comparable waste from food processing plants

based on the technological option a large variation in GHG emission savings is observed (20 – 80%) depending on whether digestate is stored in an open or a closed tank and whether the off-gas is vented or combusted (see **Figure 39**). The GHG savings criteria for new installations require at least 65% GHG savings. This shows that to be eligible, the technology option of close digestate, off-gas combustion should be applied. Failure to meet the minimum GHG savings will be efficiently addressed throughout the certification process by an EU-approved voluntary or national scheme.

BIOMETHANE FOR TRANSPORT (*)			
Biomethane production system	Technological options	Greenhouse gas emissions savings – typical value	Greenhouse gas emissions savings – default value
Biowaste	Open digestate, no off-gas combustion	43 %	20 %
	Open digestate, off-gas combustion	59 %	42 %
	Close digestate, no off-gas combustion	70 %	58 %
	Close digestate, off-gas combustion	86 %	80 %

(*) The greenhouse gas emissions savings for biomethane only refer to compressed biomethane relative to the fossil fuel comparator for transport of 94 g CO_2eq/MJ.

Figure 39. Default GHG emissions savings values provided in REDII for biomethane from biowaste

3.3. Other environmental impacts

BSG is a process residue and therefore have no land management impact. The evaluation of risks of adverse effects on soil, water, air and biodiversity is not applicable.

4. MARKET EFFECTS AND 2030/2050 POTENTIAL

4.1. Market effects

Average annual global production is estimated to be ~39 million tonnes, with ~3.4 million tonnes produced in the European Union (Lunch et al., 2016). China (24%), US (12%), Brazil (7%), Germany (5%) and Russia (4%) are reported as major producing countries (Beroe, 2020). BSG is used primarily as animal feed and is increasingly finding use as a CHP fuel and for biogas production. BSG is therefore is available within Europe. No information exist of its import from outside Europe, therefore this is currently not considered to take place.

BSG has a significantly lower price of around 35 €/ton (Buffington, 2014) compared to the main product (beer). Thus, BSG is considered to have a **rigid supply** since supply is unlikely to increase if demand for BSG increases. This is because beer is the main product with the highest economic value. Thus, it is the demand for beer that ultimately dictates supply of BSG.

Since BSG currently has an established use for animal feed, adding BSG to Annex IX **could have distortive effects** on the animal feed market. However, due to high moisture content it spoils fast. Consequently, it is currently mostly utilized by local farmers in wet form and only a small portion of available BSG gets utilized. Local demand is generally limited, thus leaving a significant portion of feedstock, which would in theory be suitable for feed or energy generation, disposed of. Only in well-developed markets like the UK, Germany, France, is BSG also utilised in dry form in end-use applications due to high cost involved in manufacturing dried products. Therefore, this distortive effect is expected to be **low**.

BSG typically replaces grains (wheat, corn, barley) and oil (soybean and rapeseed) meals used for feed. Whereas grains can be largely sourced within Europe, soybean meal is mostly imported from South America. If a diversion occurs from use of BSG for feed to energy, this would potentially cause BSG to be substituted with grains and oil meals. This could subsequently lead to **potential negative environmental impacts** as additional cultivation of these crops would be required. This would mean land use, water use, fertilizer use and associated additional GHG emissions.

How to mitigate this concern?

Auditors should check that facilities are producing an expected ratio of main product (beer) to other materials. The auditor should have access to historical data to be able to determine that the ratio of process streams has not materially changed over time.

New policy developments would also be required to evaluate local markets and demonstrate that no local demand exists from the feed sector and/or that available supply largely exceeds the demand from the feed sector.

4.2. 2030/2050 Potential

The future potential for BSG will be dictated by future demand for beer. The global beer market is forecasted to grow at a CAGR of 3% per annum in the short term by 2025 (Expert Market Research, 2020), whereas European beer market is expected to register a slightly higher CAGR of 4.3% (Mordor Intelligence, 2020). The introduction of low calorie and alcohol-free variants, along with new flavours are the major trends expected to drive the market growth (Research and Markets, 2020). This would result in a potential production of approximately **51 million tonnes BSG in 2030** (with about 80% moisture content).

Looking at the 2050 potential, several studies consider reduction in barley cultivation due to climate change (Xie et al., 2018; Mozny et al., 2009). The significant drop of barley yields (estimated globally 17%) will cause changes in price and consumption of beer (Archyde, 2020). Over the long term, adaptation efforts may be able to offset mean damages to barley production from climate change through changes in agronomic practices, cultivars, or barley growing areas, however extreme events are difficult to manage under any climate regime. One study reports that hop yield will decrease by 7–9% between 2026 and 2050 (Shin and Searcy, 2018). Potential production of BSG would then be approximately **42 million tonnes BSG in 2050** (with about 80% moisture content).

These volumes provide theoretical BSG that may be available in 2030 and 2050 for all applications. Significant growth in demand for animal feed in the nearby farms of breweries is not anticipated. In contrary, overall demand for animal feeds in EU is expected to decline by around 0.5% over the next decade (European Commission, 2020). This would mean that additional availability for BSG can be expected to be used in the future for energy **without having distortive market effects**.

5. Additional Demand for Land

5.1. Assessment of additional demand for land

For residues we do not expect directly an increased use of land, we instead assess the additional demand for land in producing the likely substitute materials for that feedstock. We take the likely substitute materials identified and assess the risk that increased production of these materials will have for additional demand for land. As described above, if a diversion occurs from use of BSG for feed to energy, this would potentially cause BSG to be substituted with grains and oil meals for feed. In **Table 99**, we list a number of possible substitute materials and categorize their risk level for additional demand for land.

Table 99: Categorization of risk of additional demand for land for various materials

Substitute materials	Risk level
Wheat Maize Barley Soybean meal	Medium

Rapeseed meal	

These substitutes would fall in the medium risk category. However, there is a low risk for this market distortion and the need for the production of substitute materials.

Final result for BSG: low-medium risk for additional demand for land

6. Processing technologies

6.1. Evaluation of processing technology (mature vs advanced)

Currently, the most developed conversion process for BSG is biogas production which provides biomethane for transport. Anaerobic digestion and subsequent biogas upgrading are mature technologies (TRL 9, CRL 5).

Although not currently commercially applied, it is possible to process BSG through fermentation. This processing option would qualify as an advanced technology.

7. Conclusions

Nomenclature:

- No concern = the evaluation did not reveal any significant concern about this feedstock.
- Some concern = the evaluation identified limited conditions under which some concerns may exist, i.e. using this feedstock for biofuel production could be in contradiction with this criterion.
- Significant concern = the evaluation reveals that using this feedstock for biofuel production would be in contradiction with this criterion in most circumstances.
- Not applicable = this criterion is not applicable to the feedstock.

Table 100: Summary of evaluation results

	Evaluation Result	Rationale
Circular economy and waste hierarchy	No concern	No commercial uses exist, which can extend product life and sequester carbon for longer than energy uses. Therefore, using Brewers' Spent Grain (BSG) for biogas/biofuel biofuel/biogas does neither contribute to, nor contravene circular economy principles or the waste hierarchy.
Union sustainability criteria	Not applicable	BSG is a process residue. These criteria are **not applicable** as this feedstock is neither primary agricultural biomass nor agricultural field residue nor forest biomass.
Sustainability GHG	No concern	<u>Under which circumstances could this feedstock be problematic?</u> To be eligible, the technology option of closed digestate, off-gas combustion should be applied for producing biomethane. <u>How to mitigate this concern?</u> Failure to meet the minimum GHG savings will be efficiently addressed throughout the certification process by an EU-approved

		voluntary or national scheme.
Sustainability Others	Not applicable	BSG is a process residue. These criteria are **not applicable** as this feedstock has no land impact.
Market distortion	Some concern	Under which circumstances could this feedstock be problematic? Given that BSG has currently use as animal feed and has a rigid supply, diverting BSG from feed to energy production has a **risk** of having distortive effect on the animal feed market. However, as it is estimated that much more surplus is available than is currently utilised for feed this effect could be **low**. How to mitigate this concern? Inclusion in Annex IXB (see below) would limit the amount of feedstock being used for biogas production. Auditors should check that facilities are producing an expected ratio of main product (beer) to other materials. The auditor should have access to historical data to be able to determine that the ratio of process streams has not materially changed over time. New policy developments would also be required to evaluate local markets and demonstrate that no local demand exists from the feed sector and/or that available supply largely exceeds the demand from the feed sector.
2030/2050 Potential	2030: 51 million tonnes (i.e. 9.7 million tonnes biogas) 2050: 42 million tonnes (i.e. 8 million tonnes biogas)	The evaluation concluded that there is a potential of approximately **51 million tonnes** of BSG in **2030**. This may decrease to a potential of **42 million tonnes** in **2050**.
Land demand	Some concern	Under which circumstances could this feedstock be problematic? The use of BSG for biogas/biofuel may divert this feedstock from animal feed. However, there is **a low risk for this market distortion** and the need for the production of substitute materials. If the diversion were to occur, the farmers may then seek substitute materials such as grains and oil meals. These substitutes would fall in the medium risk category. Overall, this feedstock has a **low-medium risk** for additional demand for land. How to mitigate this concern?

		See "Market distortion"
Processing Technologies	Mature (biogas)	Conversion of BSG into biomethane can be done using anaerobic digestion technology and biogas upgrading technology. These are both **mature processing technologies**.

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Whey permeate

1. Technical description

1.1. Feedstock description

Whey is derived from cheese and casein manufacturing in the dairy industry. Lactose and protein are the major components in whey and account for approximately 75 and 10% of the TS (total solids), respectively (Parashar et al., 2016). Production of whey powder, delactosed whey and lactose has traditionally dominated processing of whey solids (Bylund et al., 2015). However, the increased demand for whey proteins has resulted in approximately 40% of processed whey solids being directed to associated products such as whey protein concentrate (WPC35-80), whey protein isolate (WPI), lactose and whey permeate (Bylund et al., 2015). Whey is processed by ultrafiltration and/or diafiltration (ADPI, n.d.) to extract whey protein and other solids. The remaining liquid, whey permeate[36], is composed mainly of lactose, salts, nonprotein nitrogen, and water (Parashar et al., 2016).

1.2. Production process

Whey permeate is generated alongside whey protein and other solids through the ultrafiltration of whey, followed by a diafiltration process. Larger dairy farms may choose to apply reverse osmosis technology to process the raw whey permeate into **whey permeate concentrate**, which is then sold as liquid feed to regional animal feed markets (European Commission, 2019). Alternatively, liquid whey permeate can be subjected to evaporation followed by spray drying and crystallisation, resulting in **dried or powdered whey permeate** which is sold as animal feed (European Commission, 2019). Food grade whey permeate powder is being produced in commercial scale drying facilities, such as those that have been established in the U.S., where liquid whey permeate can be dried to a powder and sold to the domestic market or exported (O'Keefe, 2020). Whey permeate powder has seen high growth in applications within animal feed and food applications when high-purity lactose is not required and the ash level in permeate is acceptable (Bylund et al., 2015).

Whey permeate can be demineralised and lactose concentration can be achieved using nanofiltration/ diafiltration (Cuartas-Uribe, 2009)[37]. This results in the delactosed whey permeate side stream. However, there is still surplus or excess whey permeate that does not undergo the nanofiltration/ diafiltration process (Sawdekar, 2019). This may be due to the large volumes of the feedstock being generated and the cost-intensive filtration process involved.

The current feedstock assessment considers all forms of whey permeate during milk processing with membranes.

Large volumes of whey permeate are produced at dairy facilities[38], as exemplified in **Figure 40**. Surplus whey permeate is still available since only a portion of the whey permeate is delactosed. The processes used for recovering whey components, such as whey permeate, are shown in **Figure 41**.

[36] Whey permeate is also called dairy product solids, deproteinized whey or modified whey (O'Keefe, 2020).
[37] The use of whey permeate as a direct lactose source has been implemented in some dairy facilities; however, this requires extensive processing, including demineralisation and dewatering (Parashar et al., 2016).
[38] Large amounts of whey are produced annually because approximately 9 kg of whey is obtained per kilogram of cheese produced (Parashar et al., 2016). Furthermore, 1 kg of whey dry solids can yield between 0.83 kg of whey permeate (E4tech calculation based on Bailey, 2020 and Bylund et al., 2015)

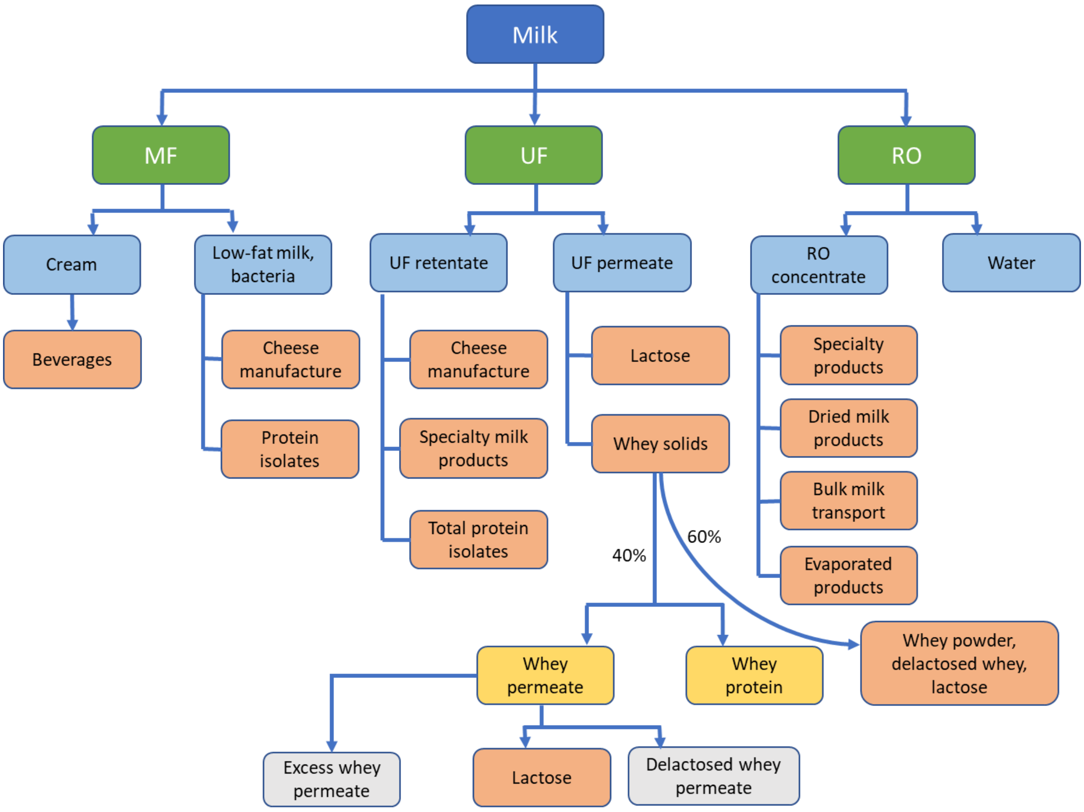

Figure 40: Whey permeate production during milk processing with membranes. MF = Microfiltration, UF = Ultrafiltration, RO = Reverse osmosis (Source: Adapted from Cheryan, 1998; Sawdekar, 2019; Bylund et al., 2015)

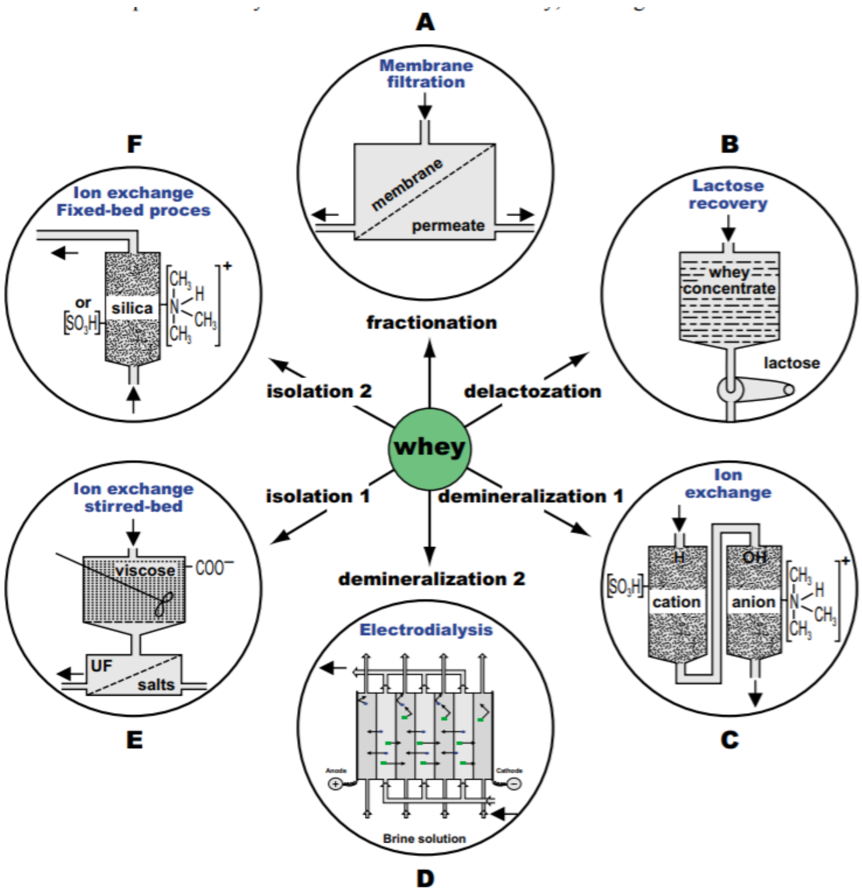

Figure 41: Processes for the recovery of whey components (Source: De Wit (2001) European Whey Products Association (EWPA))

1.3. Possible uses

- Liquid raw whey permeate and liquid whey permeate concentrate can be used as **animal feed** (European Commission, 2019). Whey permeate powder is used in the animal feed industry as a **filler in pet food, pig feed and milk substitutes for calves** (Arion Dairy Products, n.d.). Whey permeate is listed in the EU Feed Materials catalogue (Regulation 2017/1017) (European Commission, 2017). The **raw unconcentrated whey permeate** can also be used as liquid animal feed (European Commission, 2019; Priestley, 2016). This is the route adopted by some small cheese processors who manage the whey permeate generated by supplying it to their milk supplier's farm(s) (European Commission, 2019).
- Whey permeate is also used as a bulking agent in the **food** processing industry, for example for baked products, chocolate, milk beverages, sauces, ready meals as well as alcoholic beverage**s** (Arion Dairy Products, n.d.; Ornua ingredients, n.d.; Société FIT, n.d.; Królczyk et al., 2016; Cornall, 2020). Whey permeate can replace more expensive milk solids such as skimmed milk powder, whey powder and demineralised whey powder or lactose, without altering the taste and texture of food products or requiring changes to processing parameters (Confectionery production, 2016; Cornall, 2020).
    - Whey permeate has been considered as an **additive to food supplements and high energy biscuits**, the latter mainly used for emergency/ disaster relief programmes where access to cooking facilities is limited (Grenov et al., 2012)
- Use of whey permeate for **treatment of metabolic syndrome/ type 2 diabetes** has been investigated. A 2017 patent application claims that the "administration of whey permeate to animals recognised as models for metabolic syndrome/ type 2 diabetes resulted in the

prevention of glucose intolerance and prevention of insulin resistance as well as in a lowering of the triglyceride concentration in the serum" (Krauskopf et al., 2017).

- Production of **lactic acid** from whey permeate has been investigated recently in projects funded by the European Commission. The aim of the H2020 project AgriChemWhey (2018-2022) is to build a first-of-a kind (FOAK), industrial-scale biorefinery with integrated symbiotic industrial and agricultural value chains that will have capacity to valorise over 25,000 tonnes (100% dry matter) per annum of excess whey permeate and delactosed whey permeate to several added value products for markets including lactic acid, polylactic acid, minerals for human nutrition and bio-based fertilisers (AgriChemWhey, n.d.; BBI JU, n.d.). The FOAK plant, with a planned capacity of 20,000 tonnes per annum, is a scale up from a demo plant/ project (75 tonnes per annum) (AgriChemWhey, n.d.).

  The FP7-SME funded project WHETLAC (2008-2011) focused on the development of a new production technology for the transformation of residual whey permeate from cheese manufacturing into lactic acid (European Commission, 2013).

- In 2016 UK-based company First Milk started diverting low-strength wash waters such as process rinses and whey permeate for **biogas and biomethane production** (The Chemical Engineer, 2016). The creamery is Europe's first dairy processing site to feed biomethane generated entirely from cheese process residues to the gas grid (Clearfleau, n.d.). Current operational status is not known. UK-based Wensleydale Cheese Creamery has also announced plans to use whey permeate to produce biogas (McWalter, 2019).

- Utilization of whey permeate in wheat fermentation for **ethanol production** is under investigation (Parashar et al., 2016) as is the **fermentation of lactose (in whey permeate) to ethanol** (Pasotti et al., 2017). The latter has been commercialised by players such as Carbery Group in Ireland (Carbery Group, 2020). Bioethanol produced via whey permeate has been certified as compliant "with the requirements of the RED and the certification system ISCC EU (International Sustainability and Carbon Certification) which is approved by the European Commission" (Carbery Group, 2020 - certificate copy available).

- Whey permeate can also be used to prepare **liquid fertiliser**. Whey2Grow™ fertiliser is produced taking dairy derivatives such as whey and whey permeate and fermenting them with Lactobacillus (Fermented Nutrition, 2020). The product is rich in organic acids and other mineral nutrients. Whey2Grow™ has been certified BioPreferred[39] (Fermented Nutrition, 2020).

  The **recovery of phosphorous** from dairy processing waste water (including whey permeate) and its **recycling into fertiliser products** is being investigated in the H2020 project REFLOW[40] (2019-2022) (European Commission, 2020a; Steffen, 2020).

- Production of **biosurfactants** using whey permeate is under investigation (Decesaro et al., 2020).

Possible uses of whey permeate are summarised in **Table 101**.

Table 101 : Summary of possible uses of whey permeate

Food use	Feed use	Other uses
Documented evidence of commercial implementation as ingredient in baked	Documented evidence of commercial implementation as filler in pet food, pig	Biogas/ biomethane: Documented evidence of commercial implementation. Ethanol: Documented evidence of commercial implementation (lactose

[39] Managed by the U.S. Department of Agriculture (USDA), the goal of the BioPreferred Program is to increase the purchase and use of biobased products (USDA, n.d.).
[40] Phosphorus REcovery for FertiLisers frOm dairy processing Waste

products, chocolate, milk beverages, sauces, ready meals as well as production of alcoholic beverages.	feed and milk substitutes for calves	fermentation to ethanol pathway). Liquid fertiliser: Documented evidence of commercial availability of fertilisers composed of fermented dairy waste (including whey permeate). Phosphorous extraction from dairy waste (including whey permeate) and its recycling into fertiliser products is still at R&D stage. Lactic acid/ PLA: Demo scale production has been achieved. No documented evidence of commercial implementation. Pharmaceuticals: Possible in theory (patent). No documented evidence of commercial implementation. Biosurfactant: Possible in theory. No documented evidence of commercial implementation.

2. Circular economy and waste hierarchy

2.1. Classification of the feedstock as a co-product, residue or waste

On the basis of the feedstock description provided in sub-section 0, its possible uses in sub-section 0, stakeholder feedback and additional references, whey permeate can be classified as a residue or a waste as described in **Table 102**.

Table 102 : Classification of whey permeate

Evaluation question	Answer	Rationale
Is the feedstock the primary aim of the production process?	No	The primary aim of whey processing by ultrafiltration is to produce whey protein concentrates (Chan et al., 2018). Whey permeate is a side stream of this process.
Does the feedstock have any economic value, but is not the primary aim of the process, and therefore a residue?	Yes	As explained in section 0, whey permeate is currently used in limited amounts as a filler in animal feed, as a food additive in bakery and dairy-based products, as a fertiliser, and for generating biogas and biomethane. Demo-scale production of biochemical PLA has been achieved while investigations are ongoing for use of whey permeate in pharmaceuticals, production of ethanol and biosurfactants. Feedstocks with uses such as those listed above are considered to have economic value. Whenever such uses are possible, whey permeate can be defined as **residue.** In practice, a large portion of whey permeate happens to be discarded as dairy effluent following waste water treatment (Parashar et al., 2016) or previously by land spreading[41] (ebrary.net, n.d.; Parashar at al.).
Is the feedstock normally discarded, and therefore a waste?	Variable	

[41] Land spreading is not considered nowadays as although whey permeate is biodegradable, its release into the environment contributes significantly to land and water pollution due to its high biochemical oxygen demand (40,000–48,000 mg/L) and chemical oxygen demand (80,000–95,000 mg/L) (Parashar et al., 2016)

		Whenever that is the case or when dairy facilities have excess whey permeate to discard, whey permeate can be considered as a **waste.** In 2017, the National Oil Reserves Agency (NORA) in Ireland considered whey permeate to be a biodegradable waste following the assessment of an application for biofuel obligation certificates (Carbery Group, 2020; NORA, 2017). Accordingly, Biofuel Obligation Scheme (BOS) Account holders can apply for two Biofuel Obligation Certificates per litre in respect of each litre of biofuel produced from this material and disposed of by sale or otherwise in Ireland (NORA, 2017).

2.2. Is the use of feedstock to produce biofuel/biogas in line with circular economy principles?

- **Does the feedstock have non-energy (re)uses, which could extend its life or sequester carbon for longer?**

  Answer: Variable.

  Rationale: Whey permeate has several current and potential uses as mentioned in section 0. However, contributions from industries to the stakeholder consultation only state its use as animal feed and for the production of biogas and bioethanol. Evidence of the commercial use of whey permeate as feed and food additive are documented. The economic viability of non-energy uses may change in different geographic and economic contexts. In any case, use for food/feed would not constitute a significant extension of the life-time. It would only temporarily extend the life-time of the material, which eventually exits the circular chain by being released into the environment (air, soil and water) through human or animal metabolism, even when manure is collected for biogas production.

  Whey permeate can be used for energy recovery as well as production of fertilisers, bio-based chemicals and pharmaceuticals (see section 0), which would sequester their carbon over a longer period than if these are used to produce biofuel or biogas. However, other than fertilisers, all other chemical/material uses have not been implemented commercially.

- **Does its use as biofuel/biogas feedstock contribute to nutrient recovery?**

  Answer: Variable.

  Rationale: Anaerobic digestion of whey permeate generates a digestate, which retains C, N, P and other important nutrients and can be used as fertiliser, thus contributing to decreasing the need for industrial fertiliser production (IEA Bioenergy, 2015; European Commission, 2019; European Commission, 2019).

  Bioethanol derived from whey permeate has no documented contribution to nutrient recovery.

- **Does its use as biofuel/biogas feedstock contribute to a more efficient use of resources by avoiding primary material extraction?**

  Answer: Variable.

  Rationale: As with all other biomass feedstocks, biofuels and biogas derived from whey permeate displaces fossil fuels and natural gas, thus reducing the need for primary material extraction. When economically feasible, using whey permeate in food/feed chains (rather than as bioenergy) would, however, reduce the need for primary production (e.g. sugar[42]) as well.

[42] Whey permeate can be used as a sweetener in chocolates.

Finally, comparative benefits of using whey permeate for energy rather than in food chains through avoided primary material extraction should be further explored to assess which use should be prioritised at policy level.

- **Does its use as biofuel/biogas feedstock contribute to reducing waste generation, especially food waste?**

  Answer: Variable.

  Rationale: Transforming whey permeate into energy, which eventually displaces fossil fuels, has higher environmental benefits than if these residues/wastes were discarded as dairy effluent. Industry stakeholders reported that whey permeate was being converted into biogas or bioethanol, thus generating additional revenues, which could constitute an incentive against trying to improve dairy facility efficiency to reduce the share of residues or waste. It is possible that operators may skip the lactose extraction (from whey permeate) step altogether. It is, however, unclear whether such extra revenues would be higher than if those were used in food/feed chains instead. Whenever selling residues or waste for energy recovery is the only alternative to discarding whey permeate, using it as biofuel/biogas feedstock does indeed contribute to reducing waste generation.

2.3. Is the use of this feedstock for biofuel/biogas production in line with the waste hierarchy?

- **Contribution to increasing waste?**

  Answer: Variable.

  Rationale. No evidence exists that using whey permeate for biogas or biofuel production would generate more waste. However, there could be a broader risk to create an incentive against reducing waste by offering an extra source of income to operators. It is possible that operators may skip the lactose extraction (from whey permeate) step altogether.

- **Can this feedstock be potentially reused?**

  Answer: No/ not applicable.

  Rationale: Whey permeate is a primary material generated during milk processing and has not been used at that stage. The documentation received during the stakeholder consultation and additional references indicate that whey permeate can be used, primarily as feed and, increasingly, in food chains. This cannot, however, be considered as "reuse".

- **Can this feedstock be potentially recycled?**

  Answer: No/ not applicable.

  Rationale: Whey permeate is a primary material generated during milk processing and has not been used at that stage. Therefore, recycling is not relevant.

2.4. Conclusion

Contribution to circular economy

There is no demonstrated commercial use of whey permeate for material/chemical purposes, which could ensure a significantly longer life time and/or carbon sequestration than energy uses (biogas, biomethane and bioethanol), which can therefore be considered in line with circular economy principles. Using whey permeate to produce long-lasting material (e.g. plastics) would be the only alternative use to energy recovery, which would contribute to a circular economy by maintaining biogenic material in circular chains but no evidence of such use at commercial scale could be found.

With regards to contributing to waste reduction, it can be expected that further encouraging the use of whey permeate for biogas or biofuel risks incentivising producers against improving processes and reducing the amount of residues being generated, and/or being detrimental to non-energy uses (food or feed) of these feedstocks, should these be economically and technically feasible.

Alignment with the waste hierarchy

Using whey permeate for biogas/biofuel is in line with the waste hierarchy under the following conditions:

- Waste do not meet food or feed quality standards.
- Waste, for which a food or feed use is not economically viable for the economic operator or the logistical chains to collect and/or process residues and waste into food or feed chains are not in place, and could not be readily put in place.

Whenever using whey permeate as food or feed ingredient is both logistically and economically possible, using these feedstocks for energy purposes (biogas, biomethane and bioethanol) is not in line with the waste hierarchy.

3. SUSTAINABILITY AND GREENHOUSE GASES

3.1. Union sustainability criteria

The Union sustainability criteria relate to agricultural field residues (Article 29(2)), agricultural biomass (Articles 29 (3) to (5)) and forestry biomass (Articles 29 (6) and (7)), and therefore do not apply to whey permeate which is classified as a process residue/ waste.

3.2. GHG Savings Criteria

The first conversion process considered is biogas production and upgrading, which provide **biomethane** for transport. According to the approach outlined for assessing this criterion, the first consideration is to look for a proxy in existing default values in REDII. Default values are provided for biomethane production in REDII Annex VI Part C for wet manure, maize and biowaste[43]. No default value for biomethane from whey permeate is available. As an initial estimate, default values provided in the RED II for biowaste are considered which show based on the technological option a large variation in GHG emission savings is observed (20 – 80%) depending on whether digestate is stored in an open or a closed tank and whether the off-gas is vented or combusted (see **Figure 42**). The GHG savings criteria for new installations require at least 65% GHG savings. This shows that to be eligible, the technology option of close digestate, off-gas combustion should be applied. Otherwise there is a high risk of non-compliance with GHG saving criteria.

[43] As per Directive 2008/98/EC, 'biowaste' means biodegradable garden and park waste, food and kitchen waste from households, restaurants, caterers and retail premises and comparable waste from food processing plants.

BIOMETHANE FOR TRANSPORT (*)			
Biomethane production system	Technological options	Greenhouse gas emissions savings – typical value	Greenhouse gas emissions savings – default value
Biowaste	Open digestate, no off-gas combustion	43 %	20 %
	Open digestate, off-gas combustion	59 %	42 %
	Close digestate, no off-gas combustion	70 %	58 %
	Close digestate, off-gas combustion	86 %	80 %

(*) The greenhouse gas emissions savings for biomethane only refer to compressed biomethane relative to the fossil fuel comparator for transport of 94 g CO_2eq/MJ.

Figure 42. Default GHG emissions savings values provided in REDII for biomethane from biowaste

The second conversion process considered is fermentation and distillation to produce **bioethanol**. During the stakeholder consultation Carbery Group shared information regarding the GHG savings associated with the bioethanol they produce using whey permeate as feedstock. The GHG calculation spreadsheet has been provided by Carbery Group as a reference. As per that document, analysis by Meo Carbon in Germany shows that Carbery bioethanol has a GHG reference value of 10.93 g CO_2eq/MJ of bioethanol. This means 86.95% GHG emission savings which is in compliance with the GHG savings criteria for new installations i.e. at least 65% GHG savings.

3.3. Other environmental impacts

Whey permeate is a process residue/ waste and therefore has no land management impact. The evaluation of risks of adverse effects on soil, water, air and biodiversity is not applicable.

4. MARKET EFFECTS AND 2030/2050 POTENTIAL

4.1. Market effects

Worldwide liquid whey production is estimated at around 180 to 190 million tonnes per annum (El Tanboly, 2017). As of 2019, around 10% of the world's annual whey production remained unrefined (Bailey, 2020). Much of this unrefined/ unprocessed whey originates from small cheese plants scattered around North America and Europe (Bailey, 2020). Over 4 million tonnes/dry matter of whey are produced in the EU each year (European Dairy Association, 2019). This equates to 65 million tonnes of raw cheese whey, assuming 6% typical solids average (European Whey Products Association, 2017a; European Commission, 2019). Around 50 million tonnes of raw liquid whey was manufactured into whey products across the EU in 2015[44] (European Commission, 2019; Eurostat, 2016). Whether the discrepancy of 15 million tonnes indicate raw whey is not captured for manufacturing, or whether assumptions used to make these estimates are less accurate is uncertain (European Commission, 2019).

Current supply and demand of whey permeate (liquid and powder)

Supply

[44] A production figure of 2 million tonnes of whey powder was reported in 2015-2016, which is 4% by mass of the EU estimate of 49.7 tonnes of liquid whey (European Dairy Association, 2017). This is 2/3rds of the 6% total solids content assumed typical for raw whey (4.5% lactose, 0.5% protein, non-protein nitrogen 0.5% with minerals and ash making up the rest) but some allowance may be given for partial removal of mineral and lactose fractions in this figure (European Commission, 2019).

Between 0.16 and 0.2 million tonnes of whey permeate (mainly powder) are produced each year in the EU, 60% of which goes towards the animal feed market (FEFAC, 2020). Stakeholder feedback also indicates that of the 0.16 million tonnes of powdered whey permeate produced, 90,000 tonnes are consumed in the EU as feed while 75,000 tonnes are exported to China (Carbery Group, 2020). Therefore, the available supply of powder whey permeate for energy uses appear limited.

The United States is the largest whey permeate producer in the world, with an estimated volume of over 0.5 million tonnes in 2019 (USDEC, 2020)[45]. However, this estimate covers both milk permeate[46] and whey permeate. A previous estimate by the International Dairy Federation from 2014 indicates that 0.47 million tonnes of whey permeate powder was produced in North America, along with over 0.02 million tonnes of milk permeate powder (Confectionery production, 2016).

Supply of whey permeate is linked with the volume of whey proteins produced, which is the main product. Therefore, the supply of whey permeate can be considered rigid. However, an increase in the demand for whey permeate may encourage cheese processing companies to increase the processing of whey solids into whey proteins and whey permeate. Incentives could also push producers to further process whey permeate side stream instead of discharging it as an effluent following treatment, thereby adding to the current supply of processed whey permeate. Consequently, whey permeate supply may increase by reducing the amount of whey permeate being discarded.

Demand

Quantitative information related to overall demand for whey permeate by application is not available. However, evidence exists that the demand for whey permeate is currently coming primarily from the food and feed industry (see section 0 for details on uses). The food industry is a growing market for whey permeate as it is increasingly being used by multinational brands, particularly in the production of chocolates and biscuits, but also in hot drinks, dairy and desserts (Cornall, 2020). It is claimed that the number of new products containing whey permeate has more than doubled in recent years, growing from 169 in 2015 to 387 in 2019 (Cornall, 2020). The U.S. Dairy Export Council claims a higher number - 531 products using whey permeate in 2019 globally (O'Keefe, 2020).

Some of the major manufacturers and suppliers operating in the global whey permeate market are Arla Foods, Agri-Dairy Products, Inc., American Dairy Products Institute, Lactalis Ingredients, Arion Dairy Products, Melkweg Holland BV, Havero Hoogwegt B.V., Sloan Valley Dairies Ltd., Arion Dairy Products B.V., Pacific Dairy Ingredients (Shanghai) Co., Ltd. and A.R. Dairy Food Private Limited among others. Apart from the above-mentioned companies, many other manufacturers are entering the whey permeate market, owing to its wide application in the bakery and confectionary industry, resulting in high demand for whey permeate to 2026 (Transparency Market Research, n.d.).

The growth in demand for whey permeate in the food market is linked with the recent development of quality and safety standards related to whey permeate use in food products. The FAO's Codex Alimentarius international standard for dairy permeate powder is a science-based standard that established global criteria for the composition, identity, quality and safety of powdered milk and whey permeate (Cornall, 2017; FAO, 2017). Furthermore, in May 2020, China published an official safety and quality standard for using permeate powders in food processing – signifying that its market was ready to accept imports of the ingredient with immediate effect (Cornall, 2020). The standard applies globally, and permeate from any country may be exported to China provided it complies with the requirements. In 2020, US-based Proliant Dairy, LLC. informed the United States Food and Drug Administration that the intended use of whey permeate as

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[45] Based on calculations, the whey permeate production figures for the EU and the US appear to be that for powdered whey permeate.

[46] Milk permeate is obtained during the production of Milk Protein Concentrate (MPC). This is different from whey permeate which is obtained during the production of Whey Protein Concentrate (MPC).

nutritive carbohydrate sweetener in chocolates, where allowed as optional ingredient, was Generally Recognized as Safe (GRAS)[47], based on scientific procedures (Proliant Dairy, 2020). The intended use of whey permeate as nutritive carbohydrate sweetener in chocolates is therefore not subject to the premarket approval requirements of section 409 of the Federal Food, Drug, and Cosmetic Act (Proliant Dairy, 2020). This can be considered to be a positive signal for both producers and consumers of whey permeate. Whey permeate is also being added to animal feed to increase protein levels (Priestley, 2016).

Conclusion

Since qualitative data on demand for whey permeate by application is not available it is not possible to state whether the demand is matched by the current supply of whey permeate. According to the sources consulted for this assessment, large amounts of liquid whey permeate appear to be discarded, which shows that the supply is significantly above the demand. However, recent modifications in trade regimes and the possibility to import and export powdered whey permeate may increase competition between food/feed uses and energy uses, especially if inclusion in Annex IX further incentivises its use for biofuel production, thus leading to potential market distortions.

Market distortions may push the animal feed industry to use other protein-rich feed materials, such as **soybean meal** and/or rolled or pelleted feed barley, thus requiring additional land (FEFAC, 2020; EC, 2019).

In practise, some or several components of feed may need to be adjusted in case whey permeate were to be replaced. For example, a trial incorporating 6 litres of raw whey permeate per day of a dairy cow's forage-based total mixed rations (TMRs) reduced their use of 1 kg molasses/urea blend and 1kg soda wheat but increased their fresh weight silage intake by 3-4kg (EC, 2019; Priestley, 2016). In case of the food industry, whey permeate can replace more expensive milk solids such as skimmed milk powder, whey powder and demineralised whey powder or lactose, without altering the taste and texture of food products or requiring changes to processing parameters (Confectionery production, 2016; Cornall, 2020). Therefore, if whey permeate were to be diverted towards biofuels production then the food industry would need to start using skimmed milk powder, whey powder and demineralised whey powder or lactose once again in their products. This might entail an increase in production of these primary products and byproducts, and/or their diversion from other uses which would require substitutes. These in turn could lead to significant GHG emissions.

4.2. 2030/2050 Potential

In this assessment the **theoretical potential of raw liquid whey permeate and whey permeate powder** that can be produced in the EU and globally in 2030 and 2050 has been estimated. This is based on the volumes of milk that are estimated to be used in cheese processing, as well as industry conversion factors.

Europe

EU milk production is expected to experience a modest increase over 2018-2030, at 0.8% per annum (EC, 2018). Production is estimated to reach 182 million tonnes by 2030 (EC, 2018). Assuming the same growth rate of 0.8% per annum, EU milk production is estimated to reach 213 million tonnes by 2050. Assuming that over 37% of milk produced in the EU will continue to be used in cheese production (EC, 2020b), the theoretical potential supply of raw liquid whey in 2030

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[47] Under sections 201(s) and 409 of the Federal Food, Drug, and Cosmetic Act (the Act), any substance that is intentionally added to food is a food additive, that is subject to premarket review and approval by the U.S. Food & Drug Administration (FDA), unless the substance is generally recognized, among qualified experts, as having been adequately shown to be safe under the conditions of its intended use, or unless the use of the substance is otherwise excepted from the definition of a food additive (FDA, n.d.).

is around 58 million tonnes[48], rising to over 68 million tonnes in 2050. Assuming the current split of 60% raw liquid whey being processed into whey powder and the remaining 40% being available for whey protein extraction (Bylund et al., 2015), the theoretical potential supply of raw liquid whey available for whey protein extraction in 2030 is estimated to be around 23 million tonnes, rising to over 27 million tonnes in 2050. As 1 tonne of raw liquid whey can yield over 0.8 tonnes of raw liquid whey permeate, the **theoretical potential supply of raw liquid whey permeate in 2030 is estimated to be around 19 million tonnes, rising to around 23 million tonnes in 2050**. We estimate that this feedstock could yield **8.8 million tonnes of ethanol or 3.7 million tonnes of biogas in 2030, and 10.3 million tonnes of ethanol or 4.3 million tonnes of biogas in 2050**.

Note: The estimate given above is for 'raw liquid whey permeate'. As mentioned already, the demand for 'whey permeate powder' is growing both in the feed and increasingly the food market. 1 tonne of raw liquid whey permeate can yield around 0.1 tonne of whey permeate powder (EC, 2019). Therefore, if all raw liquid whey permeate were to be processed into whey permeate powder, then the **EU theoretical potential supply of whey permeate powder in 2030 is estimated to be around 1.2 million tonnes, rising to around 1.4 million tonnes in 2050**. As per stakeholder feedback, production volumes of whey permeate powder in 2030 are estimated to be around 0.14 million tonnes (Carbery Group, 2020). Whey permeate powder production is expected to show a 5-10% reduction between now and 2030 (Carbery Group, 2030). However, the reason for this reduction has not been specified.

Global

Global milk production in 2019 reached 852 million tonnes, an increase of 1.4 percent from 2018 (FAO, 2020). World milk production is expected to grow at 1.7% per annum to 981 million tonnes by 2028 (OECD-FAO, 2019). Assuming the same growth rate of 1.7% per annum, global milk production is estimated to reach around 1,015 million tonnes by 2030 and over 1,421 million tonnes by 2050. Assuming that over 12% of milk produced globally will continue to be used in cheese production (FAO, 2016), the theoretical potential supply of raw liquid whey in 2030 is over 103 million tonnes[49], rising to around 145 million tonnes in 2050. Assuming the current split of 60% raw liquid whey being processed into whey powder and the remaining 40% being available for whey protein extraction (Bylund et al., 2015), the theoretical potential supply of raw liquid whey available for whey protein extraction in 2030 is estimated to be over 41 million tonnes, rising to around 58 million tonnes in 2050. As 1 tonne of raw liquid whey can yield over 0.8 tonnes of raw liquid whey permeate, the **global theoretical potential supply of raw liquid whey permeate in 2030 is estimated to be around 29 million tonnes, rising to around 48 million tonnes in 2050**. We estimate that this feedstock could yield **13.1 million tonnes of ethanol or 5.5 million tonnes of biogas in 2030, and 21.8 million tonnes of ethanol or 9.1 million tonnes of biogas in 2050.**

Note: The estimate given above is for 'raw liquid whey permeate'. As mentioned already, the demand for 'whey permeate powder' is growing both in the feed and increasingly the food market. 1 tonne of raw liquid whey permeate can yield around 0.1 tonne of whey permeate powder (EC, 2019). Therefore, if all raw liquid whey permeate were to be processed into whey permeate powder, then the **global theoretical potential supply of whey permeate powder in 2030 is estimated to be over 1.7 million tonnes, rising to around 3 million tonnes in 2050**.

Given the existing and growing demand for whey permeate in food and feed industries, there is strong competition for the feedstock from existing industries. Therefore, availability of whey permeate for biofuel production, without distortive market effects, could be limited in both 2030 and 2050.

[48] 1 tonne of milk can yield 0.85 tonnes of whey (Bylund et al., 2015)
[49] 1 tonne of milk can yield 0.85 tonnes of whey (Bylund et al., 2015)

5. ADDITIONAL DEMAND FOR LAND

5.1. Assessment of additional demand for land

As identified in Section 4.1, the overall supply of whey permeate is rigid, although increase in demand for this feedstock may encourage dairy processing companies to process the whey permeate side stream instead of treating it as an effluent. Section 4.1 also identified that whey permeate is already being used in non-biofuel commercial applications such as animal feed and food, and thus the increased use of whey permeate in biofuel would lead to those other uses increasing consumption of substitute materials. Section 4.1 identified soybean meal or feed barley as the most likely substitutes for whey permeate diverted from animal feed. Furthermore, skimmed milk powder, whey powder, demineralised whey powder or lactose can substitute for whey permeate diverted from the food industry.

We now assess the additional demand for land due to the increased demand for these substitute materials (soybean meal, skimmed milk powder, whey powder, demineralised whey powder, lactose). As specified in the methodology, soybean meal or soymeal as well as barley fall in the **medium** risk category for additional demand for land. On the other hand, skimmed milk powder, falls in the **high** risk category for additional demand for land. Even though whey permeate requires high iLUC substitutes, given relatively low market distortion risk we conclude that substituting whey permeate in animal feed would pose a **low-medium** risk for additional demand for land for soy meal and/or feed barley. Substituting whey permeate in food products would pose a **medium** risk for additional demand for land to produce skimmed milk powder.

6. PROCESSING TECHNOLOGIES

6.1. Evaluation of processing technology (mature vs advanced)

The first conversion process for liquid whey permeate is **biogas** production followed by upgrading to biomethane for transport. Anaerobic digestion is a mature technology (TRL 9, CRL 5) and so is biogas upgrading via CO_2 removal technologies (TRL 9, CRL 5)[50].

The second conversion process for liquid whey permeate is fermentation to **bioethanol**. As per feedback submitted by Carbery Group, the whey permeate solution generated in their milk processing facility is transferred to a fermentation vessel following which yeast is added to enable conversion of the lactose to ethanol. Following fermentation the yeast is recovered and reused for further fermentation while the bioethanol solution is transferred to a distillation system which concentrates the bioethanol to the desired concentration before final dehydration to achieve concentration of 99.9%v/v prior to storage and shipment to fuel companies. This processing option would qualify as an advanced technology[51] (TRL 7-8, CRL 1-2).

Of the two conversion processes, **biogas/biomethane production** appears to be the more prevalent choice among milk processing facilities at this point in time. For the purpose of this evaluation, the main processing technology for whey permeate can therefore be considered **mature.**

7. CONCLUSIONS

Nomenclature:

- No concern = the evaluation did not reveal any significant concern about this feedstock.

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[50] It should be noted that while biogas upgrading via CO_2 removal technologies are mature technologies, new technologies for biogas upgrading via the utilisation and conversion of CO_2 are not yet mature (Adnan et al., 2019).

[51] Second generation bioethanol is typically produced from lignocellulosic biomass, but it is also possible to use industrial byproducts, such as whey or crude glycerol, as feedstock (Robak and Balcerek, 2018)

- Some concern = the evaluation identified limited conditions under which some concerns may exist, i.e. using this feedstock for biofuel/biogas production could be in contradiction with this criterion.
- Significant concern = the evaluation reveals that using this feedstock for biofuel/biogas production would be in contradiction with this criterion in most circumstances.
- Not applicable = this criterion is not applicable to the feedstock.

Table 103: Summary of evaluation results

	Evaluation Result	Rationale
Circular economy and waste hierarchy	No concern	Using whey permeate for biogas/biofuel does neither contribute to, nor contravene circular economy principles or contravene the waste hierarchy. Use of whey permeate for producing PLA, pharmaceuticals or biosurfactants is not at commercial scale. <u>Under which circumstances could this feedstock be problematic?</u> Using feedstocks which could be used for food/feed purposes would not contravene circular economy principles, but would not be aligned with the waste hierarchy.
Union Sustainability criteria	Not applicable	These criteria are **not applicable** to whey permeate as this feedstock is neither primary agricultural biomass or agricultural field residue or forest biomass. Whey permeate is a process residue/ waste.
Sustainability GHG	No concern	To be eligible with the 65% minimum GHG saving threshold, operators producing **biomethane** from whey permeate should ensure that the resulting digestate is maintained in a closed infrastructure and off-gas combustion is applied. <u>How to mitigate this concern?</u> Failure to meet the minimum GHG savings will be efficiently addressed throughout the certification process by an EU-approved voluntary or national scheme. Analysis by Meo Carbon in Germany shows that Carbery **bioethanol** derived from whey permeate can provide 87% savings and is in compliance with the GHG savings criteria of REDII for new installations i.e. at least 65% GHG savings.
Sustainability Others	Not applicable	Whey permeate is a process residue/ waste. These criteria are **not**

		applicable as this feedstock has no land impact.
Market distortion	Some concern (dry whey permeate) No concern (liquid whey permeate)	Under which circumstances could this feedstock be problematic? Dry whey permeate is currently used as animal feed and is increasingly being used as bulking agent in food products. These markets could be distorted if whey permeate were to be diverted for biofuels production. How to mitigate this concern? Inclusion in Annex IXB (See below) would limit the amount of feedstock being used for biofuel/biogas production. Auditors should check that facilities are producing an expected ratio of main product (whey permeate concentrates) to other materials. The auditor should have access to historical data to be able to determine that the ratio of process streams has not materially changed over time. New policy developments would also be required to evaluate local markets and demonstrate that no local demand exists from the food/feed sector and/or that available supply largely exceeds the demand from the food/feed sector. Large volumes of liquid whey permeate are currently discarded and so the use of this feedstock for biofuels production should have limited market distortion effect.
2030/2050 Potential	2030: Liquid whey permeate: 29 million tonnes (Global) (i.e. 13.1 million tonnes of ethanol or 5.5 million tonnes of biogas); 19 million tonnes (Europe) (i.e. 8.8 million tonnes of ethanol or 3.7 million tonnes of biogas) Whey permeate powder: 1.7 million tonnes (Global); 1.2 million tonnes (Europe - theoretical potential); 0.14 million tonnes (Europe – stakeholder	The **theoretical potential of raw liquid whey permeate and whey permeate powder** that can be produced in the EU and globally in 2030 and 2050 has been estimated. This is based on the volumes of milk that are estimated to be used in cheese processing, as well as industry conversion factors.

	projection) 2050: Liquid whey permeate: 48 million tonnes (Global) (i.e. 21.8 million tonnes of ethanol or 9.1 million tonnes of biogas); 23 million tonnes (Europe) (i.e. 10.3 million tonnes of ethanol or 4.3 million tonnes of biogas) Whey permeate powder: 3 million tonnes (Global); 1.4 million tonnes (Europe)	
Land demand	Some concern	Substituting whey permeate in animal feed would pose a **low-medium risk** for additional demand for land for soy meal and/or feed barley. Substituting whey permeate in food products would pose a **medium risk** for additional demand for land to produce skimmed milk powder. How to mitigate this concern? See "Market distortion"
Processing Technologies	Mature (biogas/ biomethane)	Biogas production via anaerobic digestion of whey permeate, followed by upgrading to biomethane is at high TRL (9) and CRL (5).

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Olive oil extraction residues

1. TECHNICAL DESCRIPTION

1.1. Feedstock description

Olive oil extraction residues and waste includes olive pomace and olive stones. Olive pomace is generated from the first pressing of olive to generate oil. Lower grade oil and other derivatives can be extracted by further processing the pomace. Olive stones are already considered as being covered under Annex IX Part A so this assessment only considers olive pomace and its derivatives.

Olive oil is traditionally obtained by mechanically pressing the fruits, which generates virgin olive oil and a pomace, which still retains some oil, as well as olive pulp, skin and stones. Modern oil extraction methods are using a malaxation unit, followed by centrifugation in a decanter, which increases the yield of virgin oil extracted. According to Petrakis (2006), pomace retains approx. 8% of the oil and requires solvent extraction (e.g. hexane). Three type of modern olive oil processing exists, as described by Mchugh, (2015): three-phase decanter, two-phase decanter and the Sinolea method. The main difference between the three and two-phase decanters is that the latter retain water in the pomace, thus avoiding important volumes of wastewater as in the three-phase decantation (Contreras et al., 2020).

According to stakeholders consulted during this project (Italian Government, 2020), the two-phase (or biphasic) process allows extracting more oil and is more economically attractive, which explains that an increasing number of olive mills are using this process, rather than the three-phase (or triphasic) process. The same Italian stakeholders, however, mention that extracting pomace oil is becoming less economically attractive and as of today, only half (54%) of the total pomace generated in olive mills is used for further oil extraction, the remaining 46% being either used for biogas/biomethane production or as fertiliser. Spain, where an important pomace oil production exists, seems to undergo a similar trend, with olive pomace oil having dropped from 1.90 EUR/kg to 0.6 EUR/kg between 2016 and 2020, thus making production costs higher than revenues (Martinez H., 2020). Between September 2020 and January 2021, crude olive pomace oil prices in Spain went from 0.60 EUR/kg to 0.68 EUR/kg (International Olive Council, 2021).

The processing of olives to produce olive oil and its byproducts are shown in Figure 43.

1.2. Production process

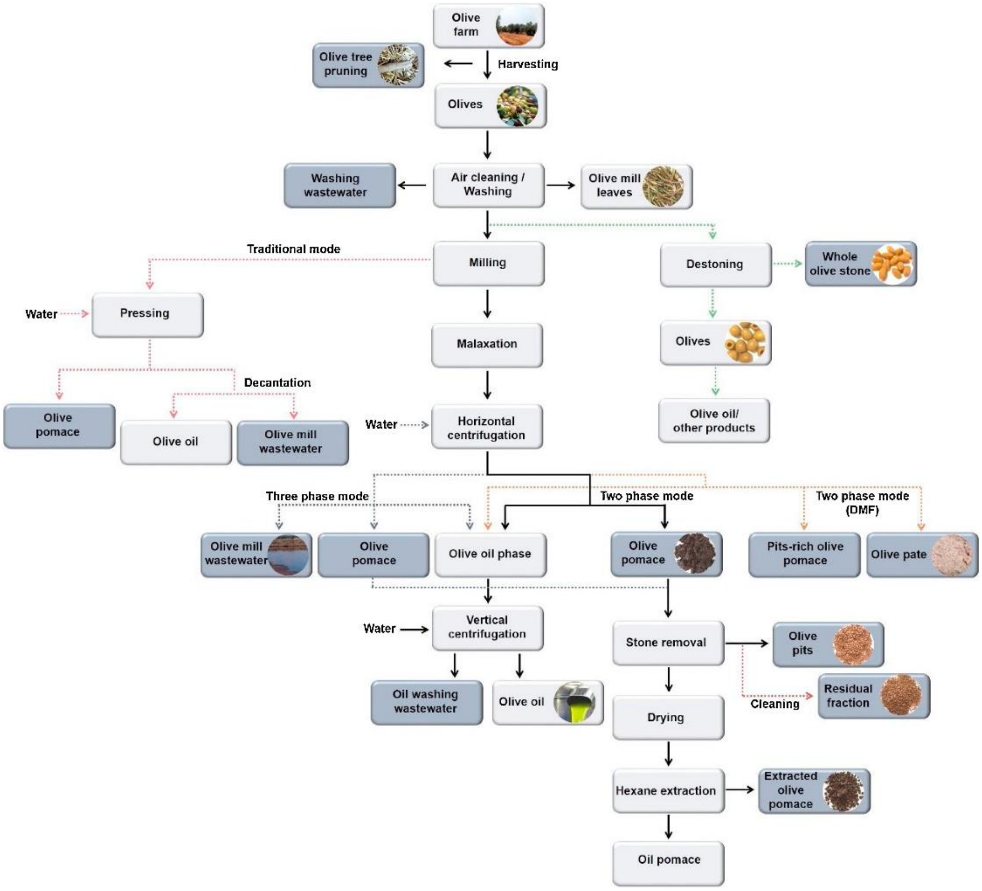

Figure 43 : Production process of olive oil and by-products (Contreras et al., 2020)

1.3. Possible uses

Studies have been conducted to assess the use of olive-derived biomass, including olive pomace, as a source of bioenergy production. Utilisation of olive pomace for biogas production is the most common application reported (Duman et al., 2020). Bioethanol production from olive pomace has reported values of ~8.1 g/L ethanol following pre-treatment to break down the biomass material (Contreras et al., 2020).

Olive pomace oil can be extracted from olive pomace with chemical or physical treatment. The oil has been used for application in biodiesel production, as well as in food consumption provided specifications are met (IOC, 2021).

There is also potential use for olive pomace in the food and pharmaceutical industries because this feedstock contains chemical fractions with interesting properties. Pectin can be extracted from olive pomace and used as a stabiliser, gelling agent and emulsifier. Phenolic compounds can be separated from olive pomace which have antioxidant properties. Other bioactive components that can be obtained provide various beneficial properties including antimicrobial, anti-inflammatory, and anticarcinogenic. Extraction of these substances provides various applications for olive pomace however further development on the separation and purification stages is required. Olive pomace can also be used to produce biosurfactants which have applications in foods, cosmetics and detergents (Contreras et al., 2020).

Although olive pomace has been used in animal feed, the high contents of cellulose and lignin negatively impact the digestibility. Composting of olive pomace can provide environmental benefits, acting as a fertiliser to enrich the nutrients in the soil. However, this utilisation method is not as economically attractive compared to energy use or extraction of the bioactive components to produce value added products (Orive et al., 2021). In addition, studies have found that composting of olive pomace has greater environmental impacts than converting to fuel pellets for energy use, due to the material composition and chemical byproducts (Duman et al., 2020).

Possible uses of olive pomace (with oil) are summarised in **Table 104**.

Table 104 : Summary of possible uses of olive pomace residues

	Food use	Feed use	Other uses
Olive pomace	Use for olive pomace oil suitable for human consumption	Reports of use in animal feed but technical issues with digestibility and not economically attractive	Bioenergy: fuel pellets and biogas (with or without oil) Extraction of olive pomace oil for biodiesel production Composting: less economically attractive and high environmental impact Pharmaceutical: bioactive components promote potential for value added products

2. Circular economy and waste hierarchy

2.1. Classification of the feedstock as a co-product, residue or waste

On the basis of the feedstock description provided in sub-section 0, its possible uses in sub-section 0, stakeholder feedback and additional references, olive pomace can be classified as **residues,** as described below.

Table 105 : Classification of olive pomace residues

Evaluation question	Answer	Rationale
Is the feedstock the primary aim of the production process?	No	The primary aim of the process is the extraction of virgin olive oil.
Does the feedstock have any economic value, but is not the primary aim of the process, and therefore a residue?	Yes	Pomace pellets have an economic value and sell at 40 EUR/t as of January 2020[52].
Is the feedstock normally discarded, and therefore a waste?	No	Pomace is either used for pomace oil extraction, as feed, for biogas/biomethane production or as fertiliser.

[52] https://en.excelentesprecios.com/olive-bone

2.2. Is the use of feedstock to produce biofuel/biogas in line with circular economy principles?

- **Does the feedstock have non-energy (re)uses, which could extend its life or sequester carbon for longer?**

Answer: No.

Rationale: Olive pomace can be used for food (oil) and feed purpose, and as fertiliser. Nevertheless, none of these non-energy uses would significantly extend its life or sequester carbon for longer than energy uses.

- **Does its use as biofuel/biogas feedstock contribute to nutrient recovery?**

Answer: Yes

Rationale: As with any anaerobic digestion, the digestate can be used as fertiliser and thus contribute to nutrient recovery. This assessment did not compare the soil nutritional value of olive pomace anaerobic digestate to olive pomace used directly as fertiliser.

- **Does its use as biofuel/biogas feedstock contribute to a more efficient use of resources by avoiding primary material extraction?**

Answer: Variable.

Rationale: As with all other biomass feedstocks, biogas/biomethane derived from olive pomace displaces natural gas, thus reducing the need for primary material extraction. The use of pomace anaerobic digestate as fertiliser also displaces equivalent amounts of synthetic fertilisers.

- **Does its use as biofuel/biogas feedstock contribute to reducing waste generation, especially food waste?**

Answer: Variable.

Rationale: According to the stakeholders consulted in Task 1 of this project (Italian Government, 2020), about half of the pomace generated by olive mills is not being for further oil extraction and is therefore used for biogas/biomethane production or as fertiliser. In case the counterfactual fate of pomace would be disposal, then using it as biogas/biomethane does contribute to reducing waste generation. The use of biphasic decanters for oil extraction also reduces the amount of wastewater that triphasic decanters would normally generate.

2.3. Is the use of this feedstock for biofuel/biogas production in line with the waste hierarchy?

Olive oil extraction residues are considered as residues for the purpose of this assessment and therefore assessment against the waste hierarchy is not necessary.

2.4. Conclusion

Contribution to circular economy

There is no demonstrated commercial use of olive pomace for material/chemical purposes, which could ensure a significantly longer life time and/or carbon sequestration than energy uses (biogas, bioethanol and biodiesel), which can therefore be considered in line with circular economy principles.

In addition, a possible decrease in the use of olive pomace for oil extraction in certain regions (Italian Government, 2020) may make large amounts locally available for biogas/biomethane production, which also generates a digestate that can be used as fertiliser and contribute to nutrient recovery.

3. Sustainability and Greenhouse gases

3.1. Union sustainability criteria

None of the union sustainability criteria are applicable to olive extraction residues, which are considered as processing residues as per RED II.

3.2. GHG Savings Criteria

The conversion process for olive pomace considered in this section is the production of biomethane via anaerobic digestion and biogas/biomethane upgrading.

No default value exists in REDII for **biomethane derived from olive pomace**. Nevertheless, default values for biomethane production from biowaste can be considered an acceptable proxy, given that biowaste includes, among other things, food and kitchen waste from food processing and restaurants[53].

Based on the values available in RED II for biowaste, GHG emission savings of biomethane derived from olive pomace would range between 20 and 80 %, depending on whether digestate is stored in an open or a closed tank and whether the off-gas is vented or combusted (see **Figure 44**). Therefore, to be eligible with the 65% minimum GHG saving threshold, operators producing biomethane from olive pomace should ensure that the resulting digestate is maintained in a closed infrastructure and off-gas combustion is applied.

BIOMETHANE FOR TRANSPORT (*)			
Biomethane production system	Technological options	Greenhouse gas emissions savings – typical value	Greenhouse gas emissions savings – default value
Biowaste	Open digestate, no off-gas combustion	43 %	20 %
	Open digestate, off-gas combustion	59 %	42 %
	Close digestate, no off-gas combustion	70 %	58 %
	Close digestate, off-gas combustion	86 %	80 %

(*) The greenhouse gas emissions savings for biomethane only refer to compressed biomethane relative to the fossil fuel comparator for transport of 94 g CO_2eq/MJ.

Figure 44. Default GHG emissions savings values provided in REDII for biomethane from biowaste (proxy for olive pomace)

No default value exists in REDII for **biodiesel produced out of olive pomace oil**, but it can be estimated as follows:

$$E = e_{ec} + e_l + e_p + e_{td} + e_u - e_{sca} - e_{ccs} - e_{ccr}$$

Where

E = total emissions from the use of the fuel;
e_{ec} = emissions from the extraction or cultivation of raw materials;
e_l = annualised emissions from carbon stock changes caused by land-use change;
e_p = emissions from processing;
e_{td} = emissions from transport and distribution;

53 As per Directive 2008/98/EC, 'biowaste' means biodegradable garden and park waste, food and kitchen waste from households, restaurants, caterers and retail premises and comparable waste from food processing plants

e_u = emissions from the fuel in use;
e_{sca} = emission savings from soil carbon accumulation via improved agricultural management;
e_{ccs} = emission savings from CO_2 capture and geological storage; and
e_{ccr} = emission savings from CO_2 capture and replacement.

In line with Annex V in RED II, olive pomace oil is considered "to have zero life-cycle greenhouse gas emissions up to the process of collection of those materials irrespectively of whether they are processed to interim products before being transformed into the final product." For the purpose of this calculation, it is assumed that no CO2 capture and storage/replacement (CCS/CCR) is implemented. Finally, emissions in use are assumed to be zero for any biofuel and bioliquid.

Therefore the above formula can be simplified as:

$$E = e_p + e_{td}$$

No disaggregated default value could be found for processing olive pomace oil (e_p), either in RED II, JEC's Well-to-Tank report (Prussi et al., 2020), GREET or academic literature. Therefore, the disaggregated default value for rapeseed processing in RED II is used, which is 16.3 g CO_2eq/MJ for FAME and 15.0 g CO_2eq/MJ for HVO. The disaggregated default values for transport and distribution (e_{td}) of rapeseed FAME and HVO in RED II Annex V are respectively 1.8 and 1.7 g CO_2eq/MJ.

GHG emissions for FAME/HVO derived from olive pomace oil would therefore range between 16.7 and 18.1 g CO_2eq/MJ, which would represent between 80% and 84% GHG savings (using RED II fossil comparator of 94 g CO_2eq/MJ), which is above the required 65% savings for biofuels, biogas consumed in the transport sector, and bioliquids produced in installations starting operation from 1 January 2021. Therefore, the risk of biodiesel based on olive pomace oil not complying with the GHG savings requirement in REDII is considered to be low.

3.3. Other environmental impacts

Olive pomace does not require dedicated land cultivation and therefore have no land management impact. The evaluation of risks of adverse effects on soil, water, air and biodiversity is not applicable.

4. MARKET EFFECTS AND 2030/2050 POTENTIAL

4.1. Market effects

According to FAOSTAT, the global production of olives slightly rose between 2005 and 2018 (**Figure 45**).

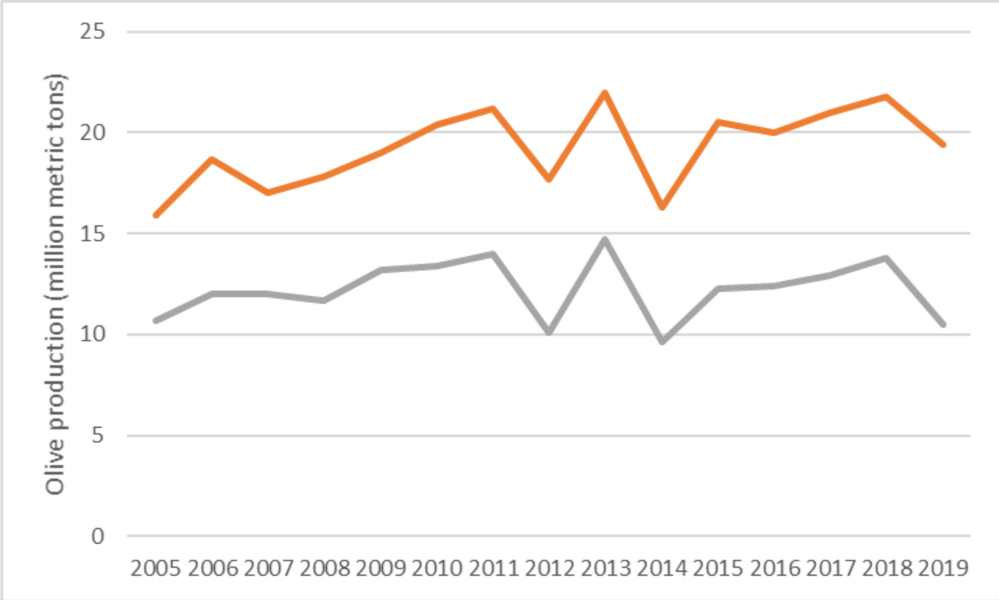

Figure 45: World and EU olive production (in million tons). Source: FAOSTAT

Olives are either used as table olives, which does not generate any pomace, and virgin olive oil extraction, which generates pomace as residue. Pomace is therefore directly dependent on the production of virgin olive oil, which makes its supply rigid.

Since no statistics could be found regarding global or EU production of olive pomace, this can be estimated by deducting the amounts of table olives and virgin olive oil from the total production of olives in the recent years[54] :

- In 2018, the **global and EU** production of olives was respectively 21.8 and 13.8 million tons (FAOSTAT).
- In 2018, the **global and EU** virgin oil production was respectively 3.6 and 2.5 million tons (FAOSTAT).

In 2018, the **global and EU** consumption of table olives was respectively approx. 2.8 million tons and 0.6 million tons (International Olive Council, 2018).We can therefore estimate that the amount of olive pomace in the world and in the EU in 2018 was 15.4 and 10.7 million tons respectively.

According to the Italian Government (2020), 54% of the pomace in Italy is allocated to pomace oil plants (use of pomace oil as food/feed), 31% is used by biogas plants and 15% is used as fertiliser. Assuming a similar pattern in the rest of the European Union, this means that 100% of the current olive pomace production is utilised. Therefore, since the current use of olive pomace for biogas/biomethane appears in balance with other uses, an increase in the use of olive pomace for biogas/biomethane production could create market distortions, unless the demand from other sectors (primarily olive pomace oil) decreases, as suggested by the Italian Government (2020). The economic attractiveness of extracting pomace oil for the food sector appears increasingly limited, but the potential inclusion of olive pomace in Annex IX A could make pomace oil extraction economically attractive, thus accentuating competition with the remaining pomace oil use for food. By limiting the scope of the inclusion in Annex IX to the de-oiled pomace fraction only, which could still serve as a biogas feedstock, market distortions would be limited.

In addition, the possibility to use the digestate from anaerobic digestion of olive pomace as fertiliser could compensate for the amounts of olive pomace not used directly as fertilisers.

[54] Our estimate is based on 2018, as the IOC does not yet have consumption data for 2019.

Therefore, the conditions under which an increased use of olive pomace for biogas/biomethane production could create market distortions requires further investigation.

In light of the above, the risk of market distortion from using olive pomace (with oil) for biogas/biofuel appears moderate to high. The risk of market distortion from using de-oiled olive pomace for biogas appears low.

4.2. 2030/2050 Potential

According to Fortune Business Insights (2020), the market size for olive oil is expected to grow by 3.2% between 2020 and 2027. Applying this growth rate to the estimated amounts of olive pomace in the world and in the EU in 2018 (Section 4.1), the 2030 potential for olive pomace would be 15.9 and 11 million tons for the world and the EU respectively.

No estimate exists for the EU production of olives in 2050, but the population in the European Union is expected to decline by 30 to 40 million people 2050 (i.e. approx. 4-5%), compared to current levels (European Commission, 2012). On this basis, production levels for olive pomace after 2030 will likely remain stable in the EU, although a number of parameters would require additional investigations, namely:

- The effects of climate change and pests (e.g. Xylella) on EU olive production and imports, which directly affects olive pomace production;
- Changes in lifestyle, which could increase/reduce the consumption of olive oil in the EU;
- Price competition with other vegetable oils, which will impact the economic attractiveness of virgin olive oil, which will indirectly impact pomace production, as well as the extraction of pomace oil for food purposes.

Meanwhile, the world population between 2030 and 2050 is expected to grow from 8.55 to 9.74 billion[55], i.e. a growth rate of approximately 13.9. Should the global production of olives follow a similar trend, the amount of available olive pomace in the world by 2050 could go up to 18.1 million tons. This projection does not take into account regional patterns of population growth, in light of dietetic customs, olives and olive oil being primarily consumed around the Mediterranean sea.

Based on the limited evidence gathered in this study, the EU production of olive pomace for biogas/biomethane production would slightly increase through 2030 and remain stable through 2050, while the global olive pomace production could increase continuously through 2050.

5. ADDITIONAL DEMAND FOR LAND

5.1. Assessment of additional demand for land

The identified non-energy uses of olive pomace are primarily the extraction of pomace oil and fertilisation (Italian government, 2020). Other identified uses include chemicals and feed. Based on Section 4, the risk for market distortion from an increased use of olive pomace for biogas/biofuel appears moderate to high if pomace still contains oil. Such risk would be limited with de-oiled pomace, which could only be used for biogas production and not for biodiesel.

Should market distortions occur over olive pomace oil, it would likely be substituted by another vegetable oil similar levels of oleic acid, which is the main fatty acid found in olive pomace oil. Other vegetable oils with similar oleic acid contents are olive oil, high oleic sunflower oil, high oleic safflower oil, high oleic soybean oil and canola oil (Anniya and Widayat, 2018). Unlike pomace oil, the supply of dedicated oilseeds is not rigid and as with other oilseeds, the risk of additional land

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[55] https://ourworldindata.org/world-population-growth

demand is high (Valin et al., 2015) if an increased use of olive pomace for biogas/biomethane or biodiesel production would lead to substitution of olive pomace oil in other sectors.

Should current uses of olive pomace as fertiliser be negatively impacted by an increase in its use as biogas or biodiesel feedstock, limited land use could be expected, given olive pomace would be substituted either by a synthetic fertiliser based on fossil raw material or by a biogenic fertiliser based on biomass waste or residue (e.g. manure, food waste, agriculture, etc), both of which carrying a low risk of additional and demand.

Therefore, the risk of additional demand for land from the use of olive pomace (with oil) as biogas/biofuel feedstock ranges from medium to high, depending on available supply of olive pomace and the demand from other sectors. The risk of additional demand for land from the use of de-oiled olive pomace as biogas feedstock is low.

6. Processing technologies

6.1. Evaluation of processing technology (mature vs advanced)

Stakeholder consultation (Italian Government, 2020) suggests that olive pomace is most commonly converted into biogas via anaerobic digestion. Biogas may then be upgraded into biomethane for transport. Anaerobic digestion and biogas upgrading are **mature technologies** (TRL 9, CRL 5). The extraction and use of pomace oil to produce HVO or FAME via hydrogenation or transesterification would also be considered as **mature** technologies, which would mean this feedstock to be suitable for Part B of Annex IX.

7. Conclusions

Nomenclature:

- No concern = the evaluation did not reveal any significant concern about this feedstock.
- Some concern = the evaluation identified limited conditions under which some concerns may exist, i.e. using this feedstock for biofuel/biogas production could be in contradiction with this criterion.
- Problematic = the evaluation reveals that using this feedstock for biofuel/biogas production would be in contradiction with this criterion in most circumstances.
- Not applicable = this criterion is not applicable to the feedstock.

Table 106: Summary of evaluation results

	Evaluation Result	Rationale
Circular economy	No concern	No demonstrated commercial use of olive pomace for material/chemical purposes, which could ensure a significantly longer life time and/or carbon sequestration than energy uses.
Union sustainability criteria	Not applicable	These criteria are **not applicable** to olive pomace, as this feedstock is neither primary agricultural biomass or agricultural field residue or forest biomass. Olive pomace is a process residue.
Sustainability GHG	No concern	To be eligible with the 65% minimum GHG saving threshold, operators producing **biogas/biomethane** from olive pomace should ensure that the resulting

		digestate is maintained in a closed infrastructure and off-gas combustion is applied. <u>How to mitigate this concern?</u> Failure to meet the minimum GHG savings will be efficiently addressed throughout the certification process by an EU-approved voluntary or national scheme.
Sustainability Others	Not applicable	Olive pomace does not require dedicated land cultivation and therefore have no land management impact.
Market distortion	No concern (de-oiled pomace) Significant concern (pomace with oil)	Stakeholders consulted in Task 1 report stated that all available amounts of olive pomace are currently being used, thus leaving no extra supply available if biofuel use was to increase. <u>Under which circumstances could this feedstock be problematic?</u> A **medium risk** of market distortions could be observed if the use of olive pomace to produce biogas increases without any decrease in the demand from other sectors (food, chemicals, feed, fertilisers). This trend would be further amplified if inclusion in Annex IX was to make pomace oil extraction for biodiesel production economically attractive. <u>How to mitigate this concern?</u> An inclusion in Annex IX limited to de-oiled olive pomace would mitigate the risk of market distortion.
2030/2050 Potential	2030: 15.9 million tonnes (World), i.e. 3 million tonnes of biogas; 11 million tonnes, i.e. 2.1 million tonnes of biogas (EU) 2050: up to 18.1 million tonnes, i.e. 3.4 million tonnes of biogas (World); 11 million tonnes, i.e. 2.1 million tonnes of biogas (EU)	Documented olive production growth through 2027. Estimates for 2050 are based on EU and world population growth scenarios.

Land demand	No concern (de-oiled pomace)	A risk exists that non-energy uses (e.g. food or feed) may be negatively impacted by an increase in biogas/biodiesel uses of olive pomace (with oil). In such case, olive pomace oil would likely be substituted by oilseeds, which are at high risk of creating additional land demand. Under which circumstances could this feedstock be problematic?
	Significant concern (pomace with oil)	Additional land demand subsequent to market distortions could be observed if biogas use of olive pomace increases without any decrease in the demand from other sectors (food, chemicals, feed, fertilisers). This trend would be further amplified if inclusion in Annex IX was to make pomace oil extraction for biodiesel production economically attractive. Being substituted by vegetable oils or meal, pomace would therefore poses a **medium to medium-high risk** of land demand. How to mitigate this concern? An inclusion in Annex IX limited to de-oiled olive pomace would mitigate the risk of additional land use.
Processing Technologies	Mature (Biogas/biomethane)	The conversion technologies of olive pomace into biogas/biomethane are considered to be **mature**, due to high TRL (9) and CRL (5).

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Oil palm mesocarp fibre oil ('PPF oil', formerly 'palm mesocarp oil')

1. Technical description

1.1. Feedstock description

Oil palm mesocarp fibre, also referred to as palm pressed fibre (PPF), is the material remaining following oil extraction by pressing of palm fruits. PPF is primarily lignocellulosic material, but also contains some oily material that is not extracted through pressing (Lee & Ofori-Boateng, 2013; Paltseva et al., 2016; Vijaya et al., 2013). If used as a feedstock for cellulosic biofuel production PPF is considered to be already covered by Annex IX Part A, and thus this assessment relates only to additional oil that may be extracted from PPF (here referred to as PPF oil, it also may be referred to as pressed fibre oil, PFO).

The Malaysian Palm Oil Board (MPOB) (Nadzim & Halim, 2019) reports that PPF oil extracted with a hexane solvent has a lower quality than crude palm oil (CPO). Solvent extracted PPF oil could be blended back into the main CPO stream for further processing, but this may have implications for the refining process due to high phosphorus and relatively high free fatty acid content. The MPOB therefore suggest that alternative applications for this oil should be found. Vijaya et al. (2013) suggest that mechanically extracted PPF oil can have a quality comparable to CPO (in terms of free fatty acids and deterioration of bleachability index) and note that it has a higher typical content of vitamin E and carotenes than CPO (Choo et al., 1996). Studies of solvent extraction approaches (Majid et al., 2012; Neoh et al., 2011) find that the resulting PPF oil has a different fatty acid profile to CPO, with higher lauric acid content in particular. The full fatty acid profiles are shown in **Table 107**.

Table 107 : Fatty acid profile comparison of PPF oil and CPO (Majid et al., 2012)

	PPF oil	CPO
C10:0 caprylic	1.3-1.6	0
C12:0 lauric	20.0-23.6	0.2-0.3
C14:0 myristic	7.9-9.5	1.1-1.2
C16:0 palmitic	30.9-32.6	39.5-39.8
C16:1 palmitoleic	0	0.2-0.2
C18:0 stearic	3.6-5.7	7.6-11.0
C18:1 oleic	24.5-25.1	35.6-38.7
C18:2 linoleic	6.2-6.4	11.4-11.4
C18:3 (1) linolineic	0.2-0.4	0.3-0.3
C18:3 (2)	0.1-0.4	0.4-0.4
C18:3 (3)	0.1-0.3	0.2-0.2

This additional lauric acid content is probably inherited from palm kernels that are incidentally broken during the initial pressing of the palm fruit, introducing palm kernel oil into the PPF. Neoh et al. (2011) suggests that due to this slightly different fatty acid profile PPF oil might be particularly suitable for products such as shortening and margarine. Extracted oil quality is dependent on extraction method – for example, Noorshamsiana et al. (2017) reports that enzymatically extracted PPF oil has lower quality and may not meet the standard for CPO.

1.2. Production process

Palm oil is generally extracted from fresh fruit bunches by a process based on mechanical pressing. In this process, the oil is separated from the fibrous mesocarp of the palm fruits. As the mechanical pressing process is unable to extract 100% of the oil from the fruits, remnant oil constitutes 4-11%[56] by dry mass of the mesocarp fibre.

Most of this remnant oil can be extracted in principle by application of an oil recovery system. A mechanical recovery system is described by Vijaya et al. (2013) (**Figure 46**), while alternative approaches to oil recovery from PPF would be solvent based[57] or enzymatic. Noorshamsiana et al. (2017) considers solvent based approaches to be most efficient but potentially environmentally harmful.

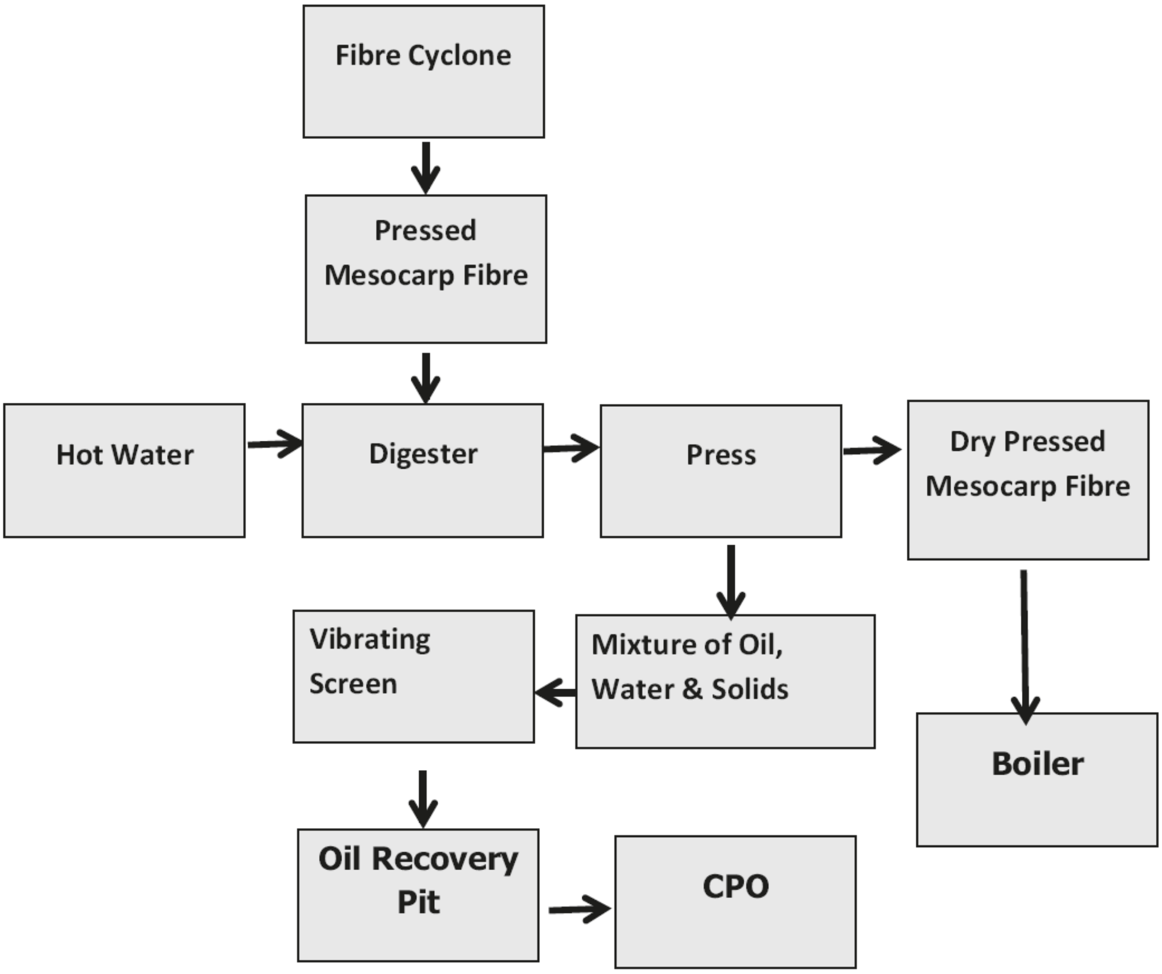

Figure 46 : Flow chart of mechanical oil recovery from oil palm mesocarp fibre (Vijaya et al., 2013). This mechanical system is designed to preserve oil quality and allow the recovered oil to be returned to the main CPO stream.

1.3. Possible uses

As noted above, depending on extraction approach PPF oil may be fit for human consumption with properties comparable to CPO. PPF recovered without solvent could potentially be mixed back into the main CPO stream, after which it would be further refined to serve all the same markets as

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[56] Sources tend to agree on a 4% or 5% minimum oil content. The maximum oil content reported is between 5% and 11%.

[57] See e.g. https://www.mecpro.com/palm-oil-mill.html

‘normal’ palm oil (food, feed, cosmetics, oleochemicals etc.). Alternately, it may be sold as a distinct oil grade servicing similar markets (Nur Sulihatimarsyila et al., 2019). For PPF oil from solvent extraction processes non-edible applications may be most appropriate due to loss of quality. Given the relatively high concentrations of carotene and vitamin E, PPF oil may also be a promising source for extraction of those chemicals (Lik Nang Lau et al., 2008), which would not prevent the rest of the oil being used for other applications.

In the absence of oil recovery, the main use of PPF is as a process fuel for the palm mill, or the material may be returned to the plantation as fertiliser (Teh, 2016).

Table 108 : Summary of possible uses of PPF oil

<table>
<tr><th></th><th>Food use</th><th>Feed use</th><th>Other uses</th></tr>
<tr><td rowspan="4">PPF oil</td><td rowspan="4">Similar or same applications as palm oil (more appropriate for mechanical extraction than for solvent or enzyme extraction)</td><td rowspan="4">Similar or same applications as palm oil (any extraction method)</td><td>Similar or same applications as palm oil (any extraction method)</td></tr>
<tr><td>Carotene and vitamin E feedstock</td></tr>
<tr><td>Process fuel at palm oil (if not extracted)</td></tr>
<tr><td>Fertiliser (if not extracted)</td></tr>
</table>

2. Circular economy and waste hierarchy

2.1. Classification of the product as a co-product, residue or waste

PPF is not a primary aim of oil palm production, however it has value as a fuel or for fertilisation and therefore should not be considered a waste. It is our understating that PPF would generally be used for process energy at the local mill or returned for fertilisation to the surrounding plantations, and would not generally be traded. Price data for traded PPF is therefore not readily available. PPF is therefore considered a residue, as is PPF oil if extracted from it. Note that this characterisation as a residue reflects the current reality that oil recovery from PPF is not generally practiced. If oil extraction from PPF using techniques that do not degrade the quality becomes commonly applied in future, then there may be a point at which PPF oil could be considered a part of the primary product stream rather than a residue. In that case this assessment may need to be revised.

Table 109: Classification of PPF oil

Evaluation question	Answer	Rationale
Is the feedstock the primary aim of the production process?	No	The residual oil content in PPF is a consequence of the palm oil processing system and is not intentional. Up until recently, PPF oil extraction was not generally practiced and it is not yet normative in the industry. PPF itself has relatively low value.
Does the feedstock have any economic value, but is not the primary aim of the process, and therefore a residue?	Yes	The PPF itself has value as a process fuel or for fertilisation even if oil is not extracted. If extracted without loss of quality PPF oil would have about the same value per unit quantity as crude palm oil, if extracted using approaches such as hexane solvents that result in loss of quality the price is expected to be slightly below that of palm oil (no price data was available during the assessment, but based on the described properties of the oil a price not less than that of PFAD would be expected).
Is the feedstock normally discarded, and therefore a waste?	No	It is likely that some fraction of PPF is discarded, but this is not understood to be the common practice for the majority of the resource.

2.2. Is the use of feedstock to produce biofuel/biogas in line with circular economy principles?

- **Does the feedstock have other material (re)uses, which could further extend its life?**

  Answer: Yes

  Rationale: PPF oil has properties comparable to palm oil, and could therefore be used in applications including food, cosmetics and oleochemicals.

- **Does its use as biofuel/biogas feedstock contribute to nutrient recovery?**

  Answer: No.

  Rationale: We are not aware of evidence that oil extraction from PPF would have any impact on nutrient cycling in the palm oil industry.

- **Does its use as biofuel/biogas feedstock contribute to a more efficient use of resources by avoiding primary material extraction?**

  Answer: Yes.

  Rationale: PPF oil extraction is not generally practised in the palm oil industry, and the palm oil industry does not fully utilise a number of its residual streams (Lee & Ofori-Boateng, 2013; Paltseva et al., 2016). Increased recovery of PPF oil would allow an under-utilised resource to be moved to higher value applications. Given the availability of other biomass residues in the palm oil industry, it is considered unlikely that increased PPF oil use for biofuel production would necessitate any additional primary material extraction for mill energy.

- **Does its use as biofuel/biogas feedstock contribute to reducing waste generation, especially food waste?**

Answer: No.

Rationale: No impact is expected on total waste generation.

2.3. Is the use of this feedstock for biofuel/biogas production in line with the waste hierarchy?

PPF oil is considered a residue for the purpose of this assessment and therefore assessment against the waste hierarchy is not necessary.

2.4. Conclusion

The extraction of PPF oil for biofuel use would be consistent with the principles of the circular economy. Given that PPF oil extraction is not yet common practice in the palm oil industry and promoting extraction of PPF oil for biofuel or other applications should allow reductions in primary resource consumption.

3. SUSTAINABILITY AND GREENHOUSE GASES

3.1. Union sustainability criteria

PPF oil is a process residue therefore the mandatory REDII sustainability criteria do not apply.

3.2. GHG savings criteria

There is no default emissions value provided in the REDII for the production of FAME biodiesel or HVO from PPF oil. If treated as a residue PPF oil would not be attributed any emissions from cultivation or from palm oil mill effluent handling (as cultivation and effluent generation would occur before the point of collection of the PPF), while fuel production emissions can reasonably be assumed to be the same as for palm-oil based pathways. The REDII default GHG emissions value excluding cultivation and mill effluent emissions is 25.4 gCO_2e/MJ for palm oil biodiesel and 20.6 gCO_2e/MJ for palm oil HVO. The process of oil extraction from PPF is not understood to be unusually energy intensive and might therefore be anticipated to have comparable emissions to oil extraction processes for other crops – the default values for oil extraction in REDII generally fall in the range 4 to 5 gCOe/MJ (excluding high emissions from palm mill effluent handling). It is therefore considered likely that an PPF oil based biodiesel pathway could deliver emissions below 32.9 gCO_2e/MJ (which equates to the REDII emission reduction threshold of 65% for new facilities).

3.3. Other environmental impacts

PPF oil is considered a process residue and therefore to have no direct land management impact.

There are no other negative environmental impacts anticipated from increased use of PPF oil as a biofuel feedstock.

4. MARKET EFFECTS AND 2030/2050 POTENTIAL

4.1. Market effects

The supply of PPF is rigid, being entirely determined by rates of oil palm production. The supply of PPF oil, in contrast, may be expected to be elastic as there is a large potential to expand implementation of PPF oil recovery.

It is understood that the standard current use for PPF is combustion for energy production in oil mills. Recovery of oil from PPF will reduce the energy available from this material, but that energy can likely be replaced by increased utilisation of other oil palm biomass residue streams without impacting primary material markets. To the extent that PPF oil use for biofuel results in increased oil recovery, there should therefore be no significant market impact.

It is unclear what fraction of mills already practice PPF oil extraction – the literature consistently implies that this is not yet normal practice but we have not found data clearly identifying how widespread the practice currently is. Displacement of the existing supply of PPF oil would be comparable in market effect to increased consumption of palm oil.

4.2. 2030/2050 potential

PPF oil potential is equivalent to between 0.25% and 0.5% of processed oil palm fresh fruit mass[58]. FAO reports global oil palm fruit production of 410 million tonnes in 2019, implying a current global potential for PPF oil extraction of between 1 and 2 million tonnes. (OECD-FAO, 2020) anticipates 1.5% annual growth in palm oil production to 2030. This would imply a potential of 1.2 to 2.4 million tonnes in 2030 (allowing production of 1.2 to 2.4 million tonnes of biodiesel), and if growth continues at that rate a potential of between 1.6 and 3.3 million tonnes in 2050 (allowing production of 1.6 to 3.3 million tonnes of biodiesel).

5. Additional demand for land

5.1. Assessment of additional demand for land

To the extent that additional PPF oil demand is met by increased rates of extraction, there is no expected market displacement and no expected land use impact. If some material already being extracted were to be displaced, this would be likely to have similar land use effects to an increase in palm oil demand, i.e. represent a high land use change risk. Given the understanding that only a small number of palm oil mills are currently extracting PPF oil, the overall land use risk is considered medium.

6. Processing technologies

6.1. Evaluation of processing technology (mature vs advanced)

PPF oil has similar properties to palm oil and could be processed into FAME biodiesel or HVO. The basic technology for extracting PPF oil (use of a hexane solvent) is not considered advanced. If PPF oil is added to Annex IX it would be most appropriately placed in Part B.

7. Conclusions

Table 110: Summary of evaluation results

[58] Assuming 5-10% oil by mass in PPF, cf. Vijaya et al. (2013).

	Evaluation Result	Rationale
Circular economy	No concern	PPF oil is a resource that is largely under-utilised, increasing extraction could avoid some primary resource use and would be consistent with circular economy principles.
Union sustainability criteria	Not applicable	The criteria are not relevant for a process residue.
Sustainability GHG	No concern	It is anticipated that biofuels from PPF oil would be able to meet the GHG emissions threshold of the REDII.
Sustainability Others	No concern	No negative environmental impact is anticipated.
Market distortion	Some concern	Under which circumstances could this feedstock be problematic? In the subset of cases where PPF oil is already being extracted, use of that PPF oil for use as biofuel/biogas feedstock biofuels for the EU market would displace it from its current uses. As extraction is not understood to be normal practice, however, increased demand would be expected to be met primarily by increased deployment of extraction technologies. The market distortion risk is therefore considered low-medium. How to mitigate this concern? There is no simple way to fully avoid diversion of currently extracted material.
2030/2050 Potential	2030: 1.2 – 2.4 million tonnes [1.2 - 2.4 million tonnes biodiesel] 2050: 1.6 – 3.3 million tonnes [1.6 - 3.3 million tonnes biodiesel]	The overall potential can be expected to scale with total palm oil production, although this could change if novel palm pressing technologies allowed increased oil recovery at the initial pressing.
Land demand	Some concern	Under which circumstances could this feedstock be problematic? There is a low-medium risk of market distortion and the need for the production of substitute materials if PPF oil is used for biofuel production. The substitute material is palm oil, which carries a high risk of additional demand for land. Overall, PPF oil has a medium risk for additional demand for land.

		How to mitigate this concern? As with market distortion, there is no simple way to fully avoid diversion of currently extracted material and the associated land demand impact.
Processing Technologies	Mature	The technology for solvent extraction of PPF oil is mature, and the processing technologies to turn that oil into FAME or HVO are also mature.

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Raw methanol from kraft pulping

1. TECHNICAL DESCRIPTION

1.1. Feedstock description

The kraft pulping process, also referred to as the sulphate pulping process, is a process for producing wood pulp from wood. It involves the treatment of wood chips with white liquor, a mixture of hot water, sodium hydroxide and sodium sulphide in order to extract cellulose fibres from lignin.

The kraft paper pulping process is associated with the production of a quantity of methanol as a by-product. The precise rate of methanol formation will depend on the type of wood being processed and pulp being produced, estimates for typical rate of methanol formation for different process variants span a range from about 5-15 kg per tonne of air dry pulp (Valmet, 2020; Warnquist et al., 2019; Zhu et al., 2000). The 'raw' methanol produced in the process is dilute form and is mixed with contaminants including sulphurous organic compounds, ethanol, ammonia and turpentine (Warnquist et al., 2019). Raw methanol therefore may not be supplied to market as a finished methanol product without further purification.

1.2. Production process

Methanol is produced primarily as a result of two chemical mechanisms occurring during the kraft pulping process (Zhu et al., 2000): alkali-catalysed elimination of methanol from 4-O-methylglucuronic acid residues in hemicellulose; and demethylation of lignin and xylan. Following pulping the produced pulp is separated out from process liquor, the remnant dilute material is referred to as weak black liquor. The weak black liquor is sent to an evaporator to reduce the moisture content. Raw methanol is one constituent of the kraft process condensates (also known as foul condensates) produced at this evaporation stage (Lin, 2007). Additional raw methanol may be distilled from condensates gathered at other points of the pulping process (Warnquist et al., 2019).

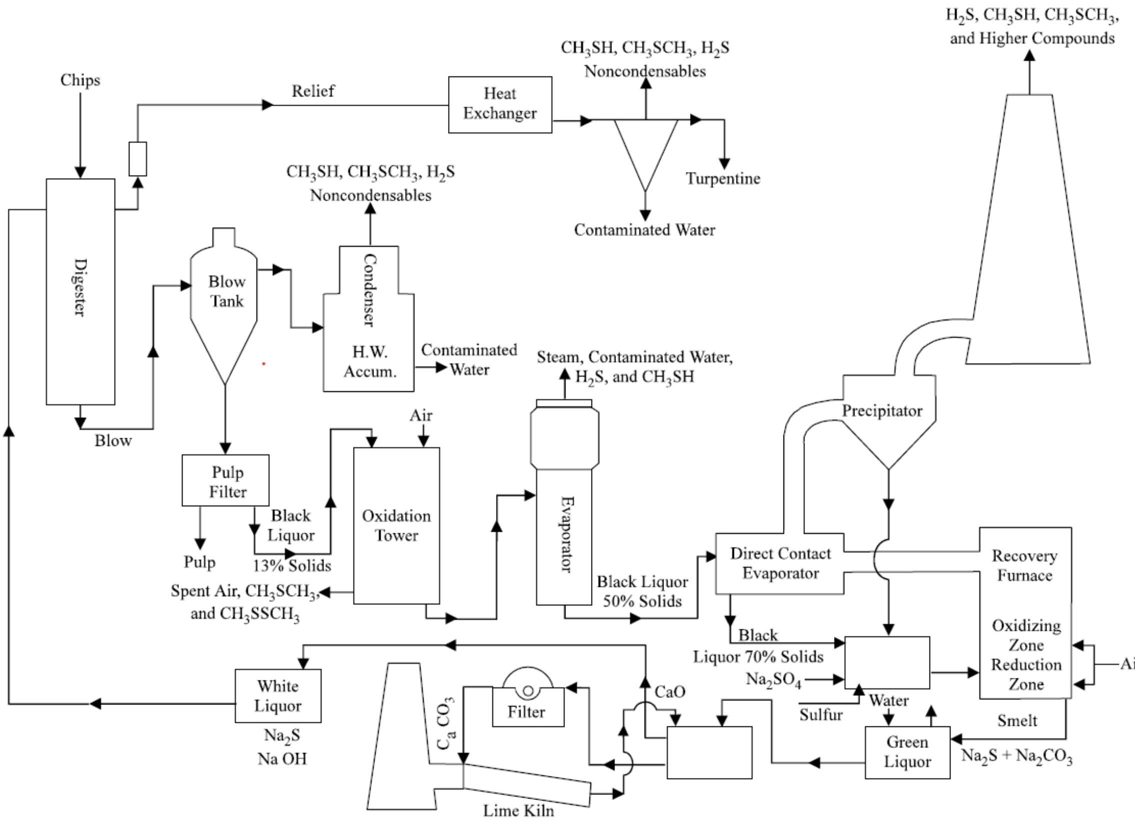

Figure 47 : Kraft pulping process (U.S. EPA Office of Air Quality Planning and Standards, 1995). Methanol is one constituent of the contaminated water identified as an output at the evaporation stage.

The motivations for separating methanol from condensate streams are threefold. Stripping the raw methanol and other contaminants from the condensate allows reuse of the water from the condensate as wash and/or dilution water, reduces air pollution from methanol vaporisation and enables energy recovery (Lin, 2007; Milet, 1993; Valmet, 2018).

1.3. Possible uses

In mills that operate condensate treatment systems to separate methanol from the foul condensate, the raw methanol can be combusted (in the form of 'stripper off-gas') for heat in the lime kiln or recovery boiler. The thermal efficiency of energy recovery in these applications is limited by the relatively high moisture content and because stripper off gas production rates are variable, creating challenges for lime kiln temperature management (Valmet, 2018). Many mills therefore now operate enrichment and treatment systems to liquify and increase the concentration of the methanol stream to around 80%. Valmet (2018) reports that such systems are now standard for mills outside North America. This allows more thermally efficient methanol combustion for heat at the mill. Without further treatment, however, contamination with ammonia and sulphur compounds makes handling difficult and results in increased air pollution emissions from combustion.

In the last decade, a number of developers have started to offer methanol purification systems, although these are not yet widely adopted. Once purified, methanol can be supplied to the same markets as fossil methanol. This could include chemicals applications, use in biodiesel production and direct use as a fuel in transport or stationary applications.

Table 111 : Summary of possible uses of raw methanol

	Food use	Feed use	Other uses
Raw methanol	None	None	Energy recovery in lime

			kiln/recovery boiler
			Purification and supply for chemicals applications
			Purification and supply for biodiesel production
			Purification and supply for direct fuel use

2. Circular economy and waste hierarchy

2.1. Classification of the product as a co-product, residue or waste

Raw methanol produced in the kraft pulp process is generally utilised for energy recovery within the process, its production is thus clearly not a primary aim of the process. It has some economic value as a process fuel and therefore should be considered a residue rather than a waste. The value could be increased through implementing methanol purification. The respondents to the consultation agreed that raw methanol should be considered a residue.

Table 112 : Classification of raw methanol

Evaluation question	Answer	Rationale
Is the feedstock the primary aim of the production process?	No	Methanol formation is not targeted in the kraft pulping process.
Does the feedstock have any economic value, but is not the primary aim of the process, and therefore a residue?	Yes	Raw methanol has some value as a process fuel. It is generally incinerated for energy recovery rather than discarded.
Is the feedstock normally discarded, and therefore a waste?	No	

2.2. Is the use of feedstock to produce biofuel/biogas in line with circular economy principles?

- **Does the feedstock have other material (re)uses, which could further extend its life?**

  Answer: Yes

  Rationale: The MefCO2 project (MefCO$_2$, 2016) reports that 55% of EU methanol consumption is for chemical precursors, including for polymer production and pharmaceuticals. Such uses would generally represent an extended useful life compared to use as a fuel, fuel additive or biodiesel ingredient (34% of methanol is currently used for these applications). The other 11% of methanol is reported as being used in other applications, notably in the energy industry.

  In principle, raw methanol could be purified and put into such chemicals uses, reducing demand for fossil methanol.

- **Does its use as biofuel/biogas feedstock contribute to nutrient recovery?**

  Answer: No.

  Rationale: We are not aware of any evidence that raw methanol purification and use in biodiesel production or as fuel would allow any recovery of useful nutrients.

- **Does its use as biofuel/biogas feedstock contribute to a more efficient use of resources by avoiding primary material extraction?**

  Answer: No.

  Rationale: In general methanol from kraft mills in Europe is combusted in the lime kiln or recovery boiler of the mill. Shifting this renewable energy source into the transport sector would shift rather than reduce demand for alternative primary energy sources.

- **Does its use as biofuel/biogas feedstock contribute to reducing waste generation, especially food waste?**

  Answer: No.

  Rationale: No impact is expected on total waste generation.

2.3. Is the use of this feedstock for biofuel/biogas production in line with the waste hierarchy?

Raw methanol is considered a residue for the purpose of this assessment and therefore assessment against the waste hierarchy is not necessary.

2.4. Conclusion

While in principle it would be possible for raw methanol to be purified for supply to chemicals markets and preferentially utilised in materials applications, at present we have not i. Increased use of raw methanol as a biofuel/biogas feedstock would therefore be likely to require increased rates of raw methanol purification, displacing it from low value energy recovery applications rather than such chemicals applications. It is therefore considered that the purification of raw methanol for use as a fuel, fuel additive or biodiesel ingredient would not present any fundamental conflict with the principles of the circular economy.

3. Sustainability and Greenhouse gases

3.1. Union sustainability criteria

Raw methanol is a process residue therefore the mandatory REDII sustainability criteria do not apply.

3.2. GHG savings criteria

There is no default emission value provided in the REDII for a methanol purification process of this sort. As raw methanol is a process residue, no emissions are allocated to the methanol from the pulping process, and as methanol can be used directly as a transport fuel no additional processing is required once the methanol has been purified. Energy consumption in purification is therefore expected to be the dominant term in the lifecycle analysis. We are not aware of any available lifecycle analysis of the methanol purification process, but based on the process description as given in Jensen et al. (2012) we would expect the GHG emissions associated with the process to be modest, even if using fossil-fuels for heat, as much of the heat required may be recovered. Therefore, compliance with GHG savings criteria (65% for new installations) is expected. Consistent with this expectation the Södra pulp mill, one of the first in the world to implement methanol purification for supply as a transport fuel, has been certified compliant with the EU GHG criteria under the ISCC system based on an actual value GHG assessment and Södra claim that the fuel can deliver a GHG emission reduction of up to 99% (Södra, 2021).

3.3. Other environmental impacts

Raw methanol is considered a process residue and therefore to have no land management impact.

No other negative environmental impact is anticipated from increased purification of raw methanol for biofuel/biogas applications.

4. Market effects and 2030/2050 potential

4.1. Market effects

Valmet (2020) reports that about 15 kg of methanol is generated for every air dry tonne (10% moisture content) of sulphate pulp, but the exact rate of methanol formation will be dependent on the tree species and process characteristics. Zhu et al. (2000) report formation rates between 5 and 15 kg per oven dry tonne of sulphate pulp depending on the tree species and grade of pulp produced (with significantly greater methanol formation for bleachable grade pulp, especially for hardwoods).

In Europe, CEPI (2019) reported 27 million tonnes of sulphate pulp production in 2019, implying in the region of 300 thousand tonnes of associated raw methanol production assuming an average of around 10 kg of methanol per tonne of pulp.

While kraft paper mills are significant consumers of renewable energy, most still consume at least some fossil fuel, for example natural gas or fuel oil for the lime kiln (Ecofys et al., 2009; Kuparinen & Vakkilainen, 2017). Displacing by-product methanol from combustion on-site in order to supply it for biofuel/biogas applications may therefore be expected to result in increased fossil fuel demand for heat. Detailed data was not available on the efficiency of raw methanol combustion in existing applications, though marketing material for one technology provider suggests that purification would allow for more efficient energy recovery (Valmet, 2020). Jensen et al. (2012) suggest that the heating value of dilute raw methanol (at 50% water) is reduced by about 5% due to the energy required to heat the contained water, and provide an indication of value from methanol purification based on one-to-one energy substitution with natural gas given that reduced heating value. We conclude that it is likely that displacement of methanol streams from combustion in lime kiln/recovery boiler would generally result in replacement with fossil fuels, with only a marginal gain in efficiency of methanol use resulting from the purification and transfer to transport fuel markets.

4.2. 2030/2050 potential

Data from the EU pulp and paper industry shows that pulp production has been fairly stable in recent decades (CEPI, 2019). While some segments of paper demand are likely to show continued reductions (e.g. office paper and graphic paper) the overall outlook for pulp demand appears to be somewhat robust, though most growth is expected outside of Europe (Berg & Lingqvist, 2019; UNECE and FAO, 2011). We therefore take the current estimated production of 300 thousand tonnes a year of raw methanol as indicative of potential EU availability through 2030 to 2050.

Globally, FAO (2018) reported 120 million tonnes of sulphate pulp production outside the EU in 2018. Again assuming 10 kg of methanol per tonne of pulp, this implies a global potential of around 1.2 million tonnes of methanol. IEA (2020) forecasts 1.2% annual demand growth for paper products to 2030 – at that rate of growth, the potential extra-EU raw methanol resource would increase to 1.4 million tonnes by 2030 and to 1.8 million tonnes by 2050. With efficient methanol purification systems most of this resource could be made available as transport fuel.

5. Additional demand for land

5.1. Assessment of additional demand for land

The main market effect of increased methanol purification and sale is expected to be substitution with fossil fuels, which has no significant land use implication.

6. Processing technologies

6.1. Evaluation of processing technology (mature vs advanced)

There are several potential routes to methanol use as a transport fuel. Methanol may be used directly as a gasoline blendstock up to 3%, and processes exist to synthesise drop-in gasoline from methanol (National Energy Technology Laboratory, 2021). Methanol is also required for the production of FAME biodiesel – renewable methanol could substitute fossil methanol in that application but under REDII accounting rules this would not affect the volume of fuel reportable as renewable. The use of methanol as a fuel therefore does not require advanced technology.

The purification of raw methanol is a process already in commercial operation by Al-Pac in Canada (opened 2012) (Alberta-Pacific Forest Industries Inc., 2021) and the Södra mill in Sweden (opened 2020) (Södra, 2021). The former project received support from Natural Resources Canada (Natural Resources Canada, 2017). Methanol purification technology appears to be offered commercially by at least three technology providers (A.H. Lundberg Systems, 2021; Andritz, 2020; Valmet, 2020). Given the existence of apparently successful commercial scale examples, we can conclude that the methanol purification process is operating at least at TRL 8, and might be considered as TRL 9. Further consideration of the status of the methanol purification technology may therefore be required to determine whether raw methanol might be considered for inclusion in Part A or Part B of Annex IX.

7. Conclusions

Table 113: Summary of evaluation results

	Evaluation Result	Rationale
Circular economy	No concern	No contradiction was identified between increased purification of raw methanol for biofuel/biogas applications and the circular economy principles.
Union Sustainability criteria	Not applicable	As a process residue the Union sustainability criteria are not applicable.
Sustainability GHG	No concern	It is anticipated that biofuel/biogas from this feedstock would meet the GHG criteria.
Sustainability Others	No concern	Use of this feedstock has no land impact, and is not associated with any other environmental concerns.
Market distortion	No concern	Displacement of raw methanol from existing energy recovery applications is likely to result in replacement by fossil fuel such as natural gas and fuel oil at most mills. This would reduce the potential for net climate benefits by adding raw methanol to Annex IX.
2030/2050 Potential	2030: 300 thousand tonnes (EU); 1.4 million tonnes (outside EU) 2050 : 300 thousand tonnes (EU) ; 1.8 million tonnes (outside EU).	It is assumed that the EU pulp industry remains at a more or less constant output while pulp output in the rest of the world grows at 1.2% per annum. Generation of methanol will be sensitive to total demand for pulp products, to tree types and pulp types being produced and to any changes in the fraction of global pulp production using the kraft process.
Land demand	No concern	No significant impact on land use is expected.
Processing Technologies	Likely considered mature, but further investigation may be appropriate.	One commercial example of raw methanol purification appears to have been operational since 2012, with the first documented EU example becoming operational in 2020. Further investigation would be required to confirm whether this technology should be considered to be at TRL 8 or 9.

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Cover and intermediate crops

1. Technical description

1.1. Feedstock description

There are a number of terms referring to a second crop grown during the year that is not the main crop. Some of these terms include (but are not limited to):

- **Cover** (and ley) **crops**, defined in the REDII as "temporary, short-term sown pastures comprising grass-legume mixture with a low starch content to obtain fodder for livestock and improve soil fertility for obtaining higher yields of arable main crops."

- **Catch crops**, defined by the InterActive Terminology for Europe (IATE) as either "a fast-growing crop planted in a field in a period when no main crops are being grown there, either for market or to prevent the soil losing nutrients" or "a fast-growing crop planted in the same field and at the same time as a primary crop or crops, either for market or to prevent the soil losing nutrients".

- **Rotational crops**. Rotation is defined by the IATE as an "agricultural practice in which different crops are cultivated in succession on the same area of land over a period of time so as to maintain soil fertility and reduce the adverse effects of pests," as well as any field or aquatic crops, which may be produced after the harvest of a pesticide treated primary crop (or in some cases replanting of crops after failure of the pesticide treated primary crop)." (Original Ref: OECD, 2013).

- **Intermediate crops**, defined as "a fast-growing crop planted in a field in a period when no main crops are being grown there, either for market or to prevent the soil losing nutrients" by IATE (Original ref: Eurostat, n.d.).

All of these terms except rotational crops are included in the definition of 'food and feed crops' in the REDII (EU 2018/2001):

'Food and feed crops' means starch-rich crops, sugar crops or oil crops produced on agricultural land as a main crop excluding residues, waste or ligno-cellulosic material and intermediate crops, such as catch crops and cover crops, provided that the use of such intermediate crops does not trigger demand for additional land;

The definitions given for intermediate and catch crops are similar, except that the second definition given for catch crops includes crops grown alongside primary crops rather than between primary crops (also known as 'intercropping'). The definition of cover crops is essentially a sub-category of intermediate crops, distinguished primarily by a consideration of the intention of the farmer to obtain higher yields on the main crop. The definition of rotational crops could include both cases of intermediate cropping and of growing a single crop in a given year as part of a multi-year rotation. Here we use the term "cover and intermediate crops" to refer to **any crop that is not the primary crop cultivated in a field in a given year and that is grown at a different time than the primary crop**. The primary crop in a given year is understood to be the crop harvested in that year that is associated with the highest expected revenue[59].

A great variety of crops are grown as cover and intermediate crops in Europe and North America. This includes legumes (e.g. varieties of clover, vetch, pea, alfalfa, castor bean, soybean, and other beans), brassicas (rapeseed, carinata, mustard, varieties of radish), grains (oats, rye, winter wheat, spelt, triticale), and others (silage maize, sudangrass, buckwheat, millet, teff) (New England Vegetable Management Guide, n.d.).

[59] Reference is made to 'expected' revenue as a crop that fails for some reason may still have been the primary crop.

Importantly, any cellulosic material produced from cover and intermediate crops is already covered in Annex IX under the definition of "other cellulosic material." Thus, for the purposes of this assessment we only consider non-cellulosic materials, including starch, oil, grain, sugar, beans and meals produced from cover intermediate crops. Examples include camelina, Brassica carinata, and castor grown as cover or intermediate crops. Some types of major commodity crops, such as rapeseed, oats, wheat, maize, and soybeans are sometimes also grown as cover or intermediate crops. It is not the crop type, but rather the production system that defines cover and intermediate crops.

1.2. Production process

Cover and intermediate crops are generally produced through similar agricultural practices as main crops. They are sown after the harvest of the main crop. Fertilizer and irrigation can be used in producing cover and intermediate crops but are likely not used as much as for main crops. In the EU in particular, fertilizer and irrigation are typically not used for cover and intermediate crops (Smit et al., 2019), but it is not clear if this is also true for cover and intermediate crops grown outside the EU. In particular, studies have found that water consumption by winter crops in China and Serbia has led to water depletion in arid regions (Krstić et al., 2018; Liu et al., 2007). Indeed, as these crops are sometimes grown for the purpose of reducing nitrate leaching from soils, at least in the EU, fertilizer application may be less common than with main crops. Cover and intermediate crops are sometimes harvested, sometimes used directly as fodder (i.e. allowing livestock to graze the crops), and sometimes ploughed into the soil before the following main crop is sown (Smit et al., 2019).

1.3. Possible uses

The possible uses of cover and intermediate crops include: harvest for food or feed, livestock grazing, use in oleochemicals and other materials applications, and use in biofuel and biogas production. Because cover and intermediate crops are often grown for the purpose of reducing nitrate leaching, increasing soil nitrogen (through nitrogen fixing crops such as clover), and increasing soil organic matter, soil management can be considered another use of these crops.

There is some data on how cover and intermediate crops are used in Spain, France, the Netherlands, and Romania, as reported from survey data by the Joint Research Center (Smit et al., 2019). Among these 4 countries, the JRC reports that 79% of surveyed farmers growing cover and intermediate crops do not harvest these crops, although some of them may allow livestock to graze them. JRC reports that the remaining farmers growing cover and intermediate crops are fairly evenly split between "harvest for selling," "harvest for own use," and "harvest for fodder," with 1% reporting "harvest for bioenergy" and 2% "other." The sum of these percentages exceeds 100 because multiple answers were possible in this survey.

JRC and survey results from an earlier study by Alliance Environment (2017) find that farmers in the EU generally grow cover and intermediate crops because they are required to by national environmental regulation or in order to qualify to receive Common Agricultural Policy (CAP) payments. This helps explain why so many European farmers do not harvest their cover and intermediate crops; revenue from selling them is not the main motivation for growing them.

Because several types of crops that are usually used for food (e.g. wheat) are grown as cover and intermediate crops and a significant share of farmers report selling cover and intermediate crops, it seems inevitable that cover and intermediate crops, when harvested, are sometimes used for food.

A significant share of farmers surveyed by JRC report using intermediate crops for fodder. It is also quite possible that much of the crops harvested and sold could eventually be used as livestock feed. One stakeholder commented that camelina seeds, which contain both oil and protein-rich meal, are useful for animal feeding and have been approved as a cattle feed supplement in the US, citing Gugel and Falk (2006) and Berkhout (2009).

Oil from cover and intermediate crops could in principle be used for oleochemicals and other industrial products. Some stakeholder comments suggested that this is already practiced.

Cover and intermediate crops are sometimes used for bioenergy. One prominent example is the Biogasdoneright project, which uses cover and intermediate crops for biogas production (Dale et al., 2016). Similarly, oil from cover and intermediate crops could be used for fatty acid methyl ester (FAME) or hydrotreated vegetable oil (HVO) production, and sugar and starch from cover and intermediate crops could be used for ethanol production.

Table 114 : Summary of possible uses of cover and intermediate crops

Food use	Feed use	Other uses
Use of cover and intermediate crops in food is very likely.	Documented evidence of use in livestock feed.	Documented evidence of use in bioenergy. Possible use in oleochemicals and other industrial products.

2. CIRCULAR ECONOMY AND WASTE HIERARCHY

2.1. Classification of the feedstock as a co-product, residue or waste

Oils, starch, sugar, meals and proteins from cover and intermediate crops are classified as primary products or co-products, following the rationale in the table below.

Table 115 : Classification of cover and intermediate crops

Evaluation question	Answer	Rationale
Is the feedstock the primary aim of the production process?	Yes	Cover and intermediate crops are the main product.
Does the feedstock have any economic value, but is not the primary aim of the process, and therefore a residue?	No	Cover and intermediate crops are the main product.
Is the feedstock normally discarded, and therefore a waste?	No	Cover and intermediate crops are not discarded.

2.2. Is the use of feedstock to produce biofuel/biogas in line with circular economy principles?

- **Does the feedstock have non-energy (re)uses, which could extend its life or sequester carbon for longer?**

  Answer: Variable

  Rationale: Oils from cover and intermediate crops could potentially be used in oleochemicals and other industrial products, some of which could be long-lived. However, there is little evidence that this is currently a major fate of cover and intermediate crops.

- **Does its use as biofuel/biogas feedstock contribute to nutrient recovery?**

  Answer: Variable

  Rationale: Cover and intermediate crops can sometimes reduce nitrate leaching by incorporating the nitrate into the plant biomass. If these cover and intermediate crops are then ploughed into the soil, that nitrogen could theoretically be returned to the soil in a more stable manner.

- **Does its use as biofuel/biogas feedstock contribute to a more efficient use of resources by avoiding primary material extraction?**

  Answer: Variable

  Rationale: As with all other biomass feedstocks, biofuels and biogas derived from cover and intermediate displaces fossil fuels, thus reducing the need for primary material extraction, unless this effect is offset by market and land use impacts, as discussed below.

- **Does its use as biofuel/biogas feedstock contribute to reducing waste generation, especially food waste?**

  Answer: No

  Rationale: When cover and intermediate crops are not harvested, they are generally ploughed into the soil, which does not result in waste generation.

2.3. Is the use of this feedstock for biofuel/biogas production in line with the waste hierarchy?

Cover and intermediate crops are considered primary products or co-products for the purpose of this assessment and therefore assessment against the waste hierarchy is not necessary.

2.4. Conclusion

Contribution to circular economy

The use of cover and intermediate crops as biogas/biofuel feedstock is likely in line with circular economy principles. There is no documented evidence of commercial implementation for use of cover and intermediate crops in long-lived oleochemicals or industrial products, although this is theoretically possible. Increasing the use of cover and intermediate crops for energy purposes could contribute to a more efficient use of resources, but it will not prevent materials from going to waste disposal.

3. Sustainability and Greenhouse gases

3.1. Union sustainability criteria

A high risk of non-compliance with Union sustainability criteria is not foreseen for this feedstock as described in Table 116.

Table 116: Assessment of cover and intermediate crops

Criterion (all land status assessed in 2008)	Assessment
(2) for wastes and residues derived from agricultural land operators or national authorities have monitoring or management plans in place in order to address the impacts on soil quality and soil carbon	In EU on agricultural land on which CAP payments are claimed farmers are obliged to comply with the minimal requirements for Good Agricultural and Environmental conditions and all statutory requirements. Compliance with these standards is monitored. Outside EU this system does not apply and these monitoring and management plans are not necessarily in place, so a higher risk exists for non-EU feedstocks.
(3) bioenergy from agricultural biomass shall not	Cropping on high biodiversity land with

be made from raw material obtained from land with a high biodiversity value	this crop is possible if it concerns high biodiversity land that is in agricultural use. Not specifically related to the type of biomass. A high risk of non-compliance is not foreseen for this criterion.
(4) bioenergy from agricultural biomass shall not be made from raw material obtained from land with high-carbon stock in January 2008 if the status of the land has changed	Cropping on land with high-carbon stock with this crop is possible. A high risk of non-compliance is not foreseen for this criterion.
(5) bioenergy from agricultural biomass shall not be made from raw material obtained from land that was peatland in January 2008, unless evidence is provided that the cultivation and harvesting of that raw material does not involve drainage of previously undrained soil.	There may be cases in which biomass harvesting could be part of peatland rewetting. A high risk of non-compliance is not foreseen for this criterion.

Criterion (6) and (7) lay down criteria for bioenergy from forest biomass which are not applicable.

3.2. GHG Savings Criteria

Cover and intermediate crops potentially cover a very large number of biofuel and biogas feedstocks. The GHG savings for biofuel and biogas produced from cover and intermediate crops will depend on the specific feedstock used and associated biofuel production pathway. Some feedstocks (grown as a main crop) commonly used in biofuel and biogas production can be processed in supply chains and biorefineries compliant with the GHG savings criteria in the RED II. It is thus very likely that some biofuels and biogas produced from cover and intermediate crops are compliant with the GHG savings criteria in the RED II, but not all biofuels and biogas produced from cover and intermediate crops will necessarily meet the criteria. Examples of types of biofuels and biogas that could be produced from cover and intermediate crops, and their default GHG savings values in the RED II, include: maize ethanol (28-68% GHG savings, depending on process fuel), rapeseed biodiesel (47%), and soybean biodiesel (50%).

3.3. Other environmental impacts

For the risk assessment we score the risks for adverse effects on soil, water, air and biodiversity in a qualitative way as follows:

- Not applicable (in case of secondary residue with no land management impact)
- Low risk
- Medium risk
- High risk
- The example assessment results for cover and intermediate crops are presented in Table 117 below.

Table 117: Overview of evaluation of risks for adverse effects on soil, water, air and biodiversity for cover and intermediate crops

Type of risk to be reviewed according to REDII Art. 29	Aspects to be reviewed in relation to environment and biodiversity	Risk level	Rationale and sources
1. Ban on biomass coming from certain types of land (Art 29, par 3, 4 and 5)	• Land with high biodiversity value, including primary forest and natural wooded land; • Protected areas; • Highly biodiverse	Medium risk	Cover and intermediate crops can in principle be grown anywhere annual crops are grown. Therefore, it is possible they can be grown on these types of land but it is not any more

	grasslands (natural and non-natural); • Wetlands; • Continuously forested areas; • Peatlands.		likely than with main crops used for biofuel and biogas.
2. Adverse impacts on soil quality	2.1 Soil Organic Matter: decline should be avoided 2.2 Nutrient balance: a disturbance of the balance should be avoided 2.3 Soil erosion: should be minimised 2.4: Soil structure: soil compaction and waterlogging should be avoided 2.5: Soil biodiversity: contamination of soils with metals and other toxic component, disturbance of soil structure and decline in soil organic carbon may all lead to a decline in biodiversity and this should be avoided	Low risk	Cover and intermediate crops generally increase soil carbon (Smit et al., 2019; Kim et al., 2020), reduce soil erosion (Kaye & Quemada, 2017; SARE, 2020), can reduce soil compaction (Everts et al., 2005), and can increase soil biodiversity (Kim et al., 2020). If grown for the purpose of environmental protection, they can also improve nutrient balance by reducing nutrient leaching (Tonitto et al., 2006; Smit et al., 2019).
3. Adverse impacts on water quality	3.1 Water quality: ground and surface water quality should not decline through increased leaching and run off of N, P from fertilization and of other contaminants from fertilization and weed and pest control.	Medium risk	Cover and intermediate crops can improve ground and surface water quality by reducing the loss of nutrients, pesticides, and sediment from agricultural fields if grown for the purpose of environmental protection (Dabney et al., 2001), but cover and intermediate crops grown as cash crops could worsen water quality by increasing the amount of fertilizer and pesticides used on the land.
4. Adverse impacts on water quantity	4.1 Water quantity: excessive water consumption in agriculture should not lead to depletion of sweet water resources and salinization.	Medium risk	Cover and intermediate crops can consume water through irrigation, but can also be grown using low/no irrigation (Delgado et al., 2007; SARE,

			2019) and irrigation is typically not used for these crops in the EU (Smit et al., 2019). However, there is evidence that cover and intermediate crops contribute to water depletion in arid regions of China and Serbia (Krstić et al., 2018; Liu et al., 2007).
5. Adverse impacts on air quality	5.1 GHG emissions: GHG emissions from cropping should be minimized 5.2 Ammonia and NOx emissions: should be minimized	Low risk	Cover and intermediate crops can be produced with the use of fertilizer, but it is likely that they are typically grown with less fertilizer than main crops, at least in the EU (Smit et al., 2019). GHG emissions will occur with all activities associated with producing cover and intermediate crops (including when used for biofuel or biogas production) (e.g. machinery use for planting, harvesting), and with the exception of fertilizer, these emissions are likely to be similar to those associated with growing main crops used for biofuel and biogas production.
6. Adverse impacts on biodiversity	6.1 Crop diversity: large scale monocultures decreasing crop diversity strongly in a region should be avoided 6.2 Biodiversity: Direct adverse impacts on flora and fauna should be avoided 6.3 Pollination: Direct adverse impacts on pollinators and their habitats should be avoided 6.4 Invasive species: use of biomass crops that are invasive should be banned	Low risk	Cover and intermediate crops increase available forage and habitat for some animals, especially during the winter when food may be difficult to find (Wilcoxen et al., 2018). Some EU survey respondents noted increased biodiversity for bees and wildlife as a motivator for growing cover and intermediate crops, which could

			improve pollination (Smit et al., 2019). Invasive crops could theoretically be used as cover and intermediate crops, but there is no evidence this is occurring at present.

4. MARKET EFFECTS AND 2030/2050 POTENTIAL

4.1. Market effects

There is relatively poor data availability on the prevalence of cover and intermediate crops. The JRC found that 60% of farmers surveyed had adopted cover and intermediate crops (Smit et al., 2019). However, the researchers note that adoption rates varied widely from 12% in Spain to 99% in the Netherlands, and the 60% average was not weighted by the total number or area of farms in each country. This estimate of 60% is much higher than some others have reported. In an earlier survey conducted in some EU countries in 2010 and 2015, Alliance Environnement found that cover and intermediate cropping was practiced on roughly around 3% of total farm area, although this share varied widely by country (2017). In the U.S., double cropping (meaning cover and intermediate crops according to our definition) has occurred on around 2% of cropped land from 1999 to 2012, with that share remaining fairly flat over time, according to a study by the U.S. Department of Agriculture (Borchers et al., 2014). According to Brazil government statistics, "second crop corn production (safrinha)" now comprises around two-thirds of total maize production in Brazil. In 2020, production of safrinha corn reached 76.7 million tons (Cordonnier, 2020). For context, this is greater than the total amount of maize produced in the EU in 2019 (70 million tons) (*FAOSTAT*, n.d.). One source quoted the Brazilian National Supply Agency as reporting that double cropping increased fourfold since 2000 to 9.6 million hectares (year unknown), and that this is often maize (Duff & Padilla, 2015). Globally, the United Nations Food and Agricultural Organization (FAO) estimates that 12 percent of projected crop growth through 2030 will come from higher cropping intensities (*World Agriculture: Towards 2015/30, n.d.* .

Some researchers have used FAOSTAT data from FAO on harvested area and cropland area to infer changes in double cropping rates over time (Babcock & Iqbal, 2014). Although these data may not be accurate enough to use to calculate literal rates of double cropping or changes over time, they may still give us an indication of double cropping prevalence and trends in some regions. Figure 48 shows the ratio of harvested area to cropland area for the world and selected regions from 2000-2010, with data from FAOSTAT (n.d.). In most cases, this ratio is less than 1, indicating that typically less area is harvested than classified as cropland. This may be because not all cropland is sown every year, and also because sometimes sown area is not harvested due to natural disasters, bad weather, or pest infestations, among other potential reasons. In a few cases shown in **Figure 49**, harvested area exceeds cropland area, in particular in China and Brazil. FAOSTAT states in the metadata associated with harvested area data that multiple cropping on the same land area in the same year will count twice in the harvested area statistics for that year. This suggests high current rates of double cropping in China (greater than 35%) and Brazil (greater than 22%) in 2018.

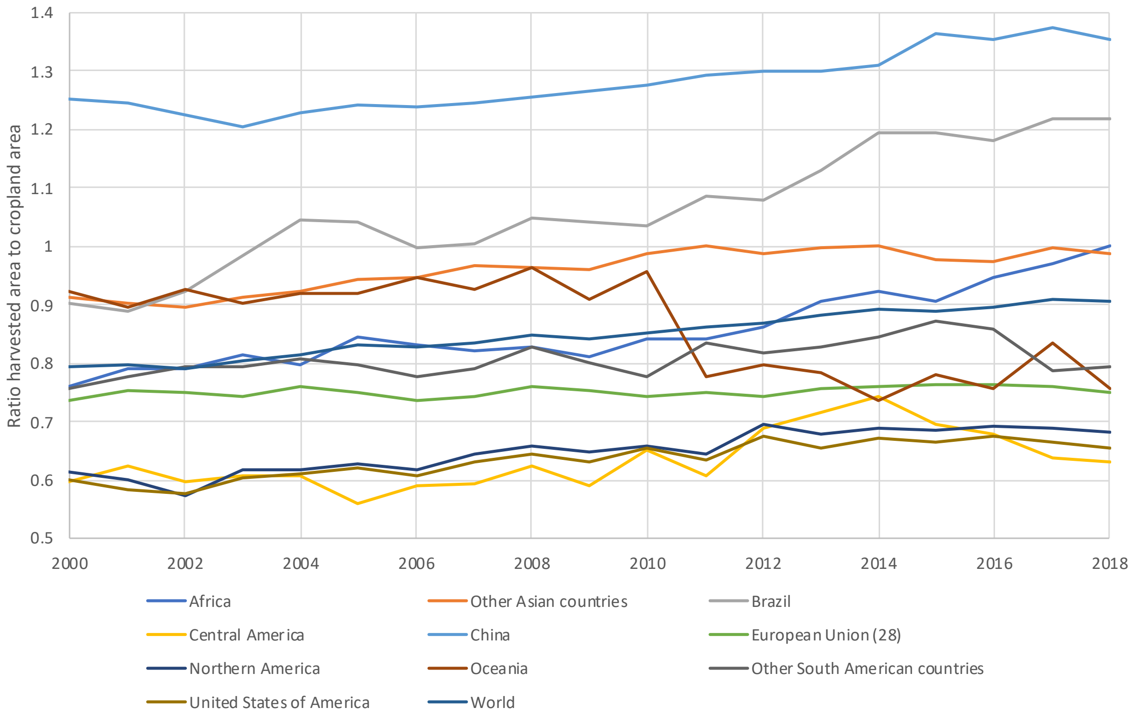

Figure 48: Ratio of harvested area to cropland area for the world and selected regions from 2000-2018. Data from FAOSTAT.

In the U.S., where government data shows double cropping to exist (at 2%), the ratio of harvested to cropland is only 66%. This suggests that a great deal of cropland in the U.S. is not sown every year. It also suggests that significant rates of double cropping could occur for world regions where the harvested:cropland ratio is below 1. In Africa and Asian countries other than China, the harvested:cropland area is around 1 as of 2018, suggesting that there may also be fairly high rates of double cropping on these continents. Using a similar technique comparing harvested and cropland area, Waha et al. (2020) estimated that in tropical and subtropical areas, 44% (49.63 Mha), 13% (24.12 Mha) and 10% (13.49 Mha) of the rice, wheat and maize area, respectively are under multiple cropping. The prevalence of multiple cropping with rice in particular could explain the very high ratio of harvested to cropland area in China and other Asian countries.

Another relevant finding from **Figure 49** is that globally, the ratio of harvested:cropland area is increasing. This could partly be because land is fallowed less over time. Given that the harvested:cropland area has also been clearly increasing in China and Brazil well beyond the ratio of 1, the increase of this ratio globally is likely driven at least in part by an increase in double cropping.

For the EU in particular, the ratio of harvested:cropland is well below 1, at around 75%, and has remained stable over time. This is not necessarily contradictory to the finding by JRC that a high proportion of farms in the EU countries studied planted cover and intermediate crops. Figure 48 only reports harvested crops, and JRC reported that most farmers did not harvest their cover and intermediate crops.

This analysis suggests that:

- Cover and intermediate crops are highly prevalent in some countries and regions.
- These cover and intermediate crops are very often harvested, at least in China and Brazil, but likely also Africa and other Asian countries.
- The planting and harvesting of cover and intermediate crops is increasing over time.

There is some evidence that cover and intermediate crops grown in Brazil, at least, are often major commodity crops. The FAO projects that *"Soybean production will continue to grow over the next decade, and further land use expansion for soybeans is projected at the expense of pasture, although a third of the increase in harvested area will come from double cropping"* (FAO Regional Office for Latin America and the Caribbean, 2019). In addition, while only 2% of U.S. cropland area is double cropped, 80% of these second crops are wheat and rye, which are major commodity crops and thus likely to be harvested and used (Borchers et al., 2014). This projection, as well as the fact that rates of harvesting cover and intermediate crops in Brazil and China appear to be so high, suggest that the practice of planting cover and intermediate crops outside Europe is done for very different reasons than inside Europe. While in Europe, most farmers plant cover and intermediate crops for environmental benefits, outside Europe, it appears much more common that cover and intermediate crops are grown as cash crops and are likely very often if not usually or always supplied to commodity markets for use in food, feed, and other uses (e.g. materials, oleochemicals).

The use of cover and intermediate crops for biofuel will thus likely displace use of those crops for food, feed, and other uses a minority of the time in Europe and perhaps a majority of the time outside Europe. Cover and intermediate crops, especially outside Europe, appear to often or mainly be major commodity crops, in particular maize, soybeans, rice, and wheat. The displacement of these crops from the commodity markets for use in biofuel would thus likely result in increased demand for and production of cereals and soybeans. Substitute material could vary if other types of cover and intermediate crops are used for biofuel production. Increasing demand for cereals and oilseeds is likely to result in additional land being brought into agricultural production. It should also be noted that given that there is a general trend for cover and intermediate cropping to increase over time, adding cover or intermediate crops in some areas may reduce the area available for cover and intermediate crops for other markets.

There is another potential market effect of cover and intermediate crops to consider: the effect of these crops on yields of the main crop. Planting cover and intermediate crops could theoretically have a negative effect on yields of the main crop if the farmer either sows the main crop late (in order to harvest the cover or intermediate crop) or harvests the main crop early (in order to sow the cover or intermediate crop). However, there is little documented evidence of this happening. JRC cites Alvarez et al. (2017) as finding that "*no effects on soybean yield have been found, but maize yield increased significantly when legumes were used as [cover or intermediate crops] and decreased significantly when non-legumes were used as [cover or intermediate crops]*." Thus, the yield effect could in theory go both ways. Presumably when cover and intermediate crops are grown and sold for revenue as opposed to environmental protection, it is more likely that farmers would be willing to accept a reduction in the yield of the main crop in order to maximize profitability of the entire cropping system.

The negative market impacts of using cover and intermediate crops for biofuel and biogas production could be mitigated by adding specific criteria to EU-approved voluntary schemes to ensure that the risk of indirect land-use change from feedstock production and utilisation remains low.[60] Some potential options for criteria that could be used to certify biofuels produced from cover and intermediate crops with low risk of market distortion or land use impacts are discussed below, along with pros and cons:

- <u>Require feedstock to be obtained through additionality measures, similar to those presented in the</u> European Commission's Delegated Regulation on high indirect land-use change-risk feedstocks and the certification of low indirect land-use change-risk biofuels, bioliquids and biomass fuels (2019). The additionality measure in the Delegated Regulation most relevant to cover and intermediate crops is that feedstocks "become financially attractive or face no barrier preventing their implementation only because the biofuels, bioliquids and biomass fuels produced from the additional feedstock can be counted towards the targets for renewable energy under Directive 2009/28/EC or Directive (EU) 2018/2001." The option is therefore that cover and intermediate crops that would not have been financially attractive without the added value of Annex IX eligibility could be added to

[60] There is an ongoing project on addressing low ILUC feedstocks in voluntary schemes for the European Commission. This consortium did not have access to the results of that project and so any findings and recommendations of that project are not reflected here.

Annex IX. This measure, if robustly implemented by voluntary schemes, could be quite effective at minimizing market distortion because the cover and intermediate crops would not have been profitable, and thus would not have existed, for use in non-biofuel applications. This measure would likely exclude all or nearly all existing intermediate and cover crop projects, which are presumably already financially attractive without the added value of Annex IX inclusion. It would present a fairly significant administrative burden on project operators and voluntary schemes.

- Require feedstock to be obtained from new intermediate and cover crop projects begun after the feedstock is added to Annex IX. This option would be much easier to implement administratively than requiring a financial additionality measure. It would somewhat reduce the risk of market distortion because it would prevent the direct diversion of material from existing uses. However, because the practice of intermediate and cover cropping appears to be rapidly rising globally to meet demand for other uses, it is likely that using new intermediate and cover crop projects begun after the feedstock is added to Annex IX would still cause a concerning level of market distortion.

- Require feedstock to be obtained from regions where intermediate and cover cropping is not common. This option would likely present a medium administrative burden on project operators and voluntary schemes. It would first have to be determined a) what prevalence rate should be considered "common" (e.g. [X%] of farms in the region regularly practice intermediate and cover cropping) and b) how a "region" is determined (e.g. at a national, subnational, or multinational scale). The data availability to determine the current prevalence of intermediate and cover cropping in any region could be quite challenging; in this assessment, available data were found to be scarce, especially outside the EU. If these determinations were made and data made available, implementing this option could be quite straightforward; but that is not a given. This measure would be somewhat but not entirely effective at reducing the risk of market distortion. It would eliminate the eligibility of feedstock from regions where very large amounts of cover and intermediate crops are already used for other applications. However, even where intermediate and cover crop prevalence is low, such as the U.S., these crops are often still produced for other uses. This option would be more effective at reducing the risk of market distortion if paired with the above option requiring feedstock to be from new projects. The risk of market distortion would then be reduced to the diversion of feedstock from other uses in regions where intermediate and cover cropping is uncommon but increasing due to non-biofuel market forces. This combination would still not be quite as effective at minimizing risk of market distortion compared to the first option (financial additionality measure), and considering the dearth of data availability, would not necessarily be easier to implement.

For any of these options, one may consider creating an exemption for cover and intermediate crops grown for soil health that are not currently harvested. This exemption would not likely increase the risk of market distortion and could allow more projects to qualify.

Also, for any of these options, it would be necessary for voluntary schemes to further ensure that the production of cover and intermediate crops used for biofuel and biogas does not impact the yield of the main crop. The definition of "food and feed crops" in the RED II (Article 2, paragraph 40), excludes "intermediate crops, such as catch crops and cover crops, provided that the use of such intermediate crops does not trigger demand for additional land." Cover and intermediate crops that cause a reduction in the yield of the main crop would presumably cause indirect land use change by reducing the supply of the main crop. One option for addressing this issue would be for voluntary schemes to compare actual yields of the cropping system after project implementation, including both the main crop and the intermediate or cover crop, with the combined yield projected from a dynamic trendline of historical yields on that plot of land, and only certify the additional biomass as eligible to be counted as cover and intermediate crops for Annex IX.

In conclusion, the risk of negative market impacts of cover and intermediate crops is high, but the expected magnitude of market impacts could be mitigated with specific criteria added to voluntary schemes.

4.2. 2030/2050 Potential

The data available do not allow an estimation of the amount of biomass that could currently be harvested from cover and intermediate crops globally, nor is this amount in 2030 and 2050 possible to accurately forecast. The only quantitative evidence we have about the amount of biomass produced from cover and intermediate crops is 76.7 million tons of corn produced in Brazil in 2020 (Cordonnier, 2020), so it is likely that the global amount of cover and intermediate crops produced at present is much larger than this. It is clear that the amount of cover and intermediate crops is large and increasing over time, with strong evidence of increasing production in Brazil in particular and some evidence of increasing production in China and Africa. The rising use of land for market-driven double cropping could theoretically reduce the potential opportunities for crediting low-ILUC projects over time if technological improvements make double cropping generally more financially attractive. Long-term food price changes will also affect the calculation of whether cover and intermediate crops are additional, and it is difficult to forecast these.

5. ADDITIONAL DEMAND FOR LAND

5.1. Assessment of additional demand for land

Cover and intermediate crops will not directly increase demand for land when planted on fields that were already cultivated with a primary crop. However, cover and intermediate crops are sometimes and likely quite often used in food, feed, and other materials, especially outside the EU. The displacement of cover and intermediate crops from these other uses for biofuel production will likely result in increased production of substitute materials. In addition, if farmers implement multiple cropping systems on newly cleared agricultural land, the cover or intermediate crops in these cases would be directly contributing to additional demand for land.

As discussed in Section 5.1 ("Market effects"), the risk of market distortion can be mitigated through specific criteria added to voluntary schemes. Such measures would similarly reduce the risk of additional demand for land.

In **Table 118**, we list a number of possible substitute materials and categorize their risk level. The substitute materials for cover and intermediate crops are high risk. Combined with the high risk for market distortion, the overall risk for additional demand for land for cover and intermediate crops is high.

Table 118: Categorization of risk of additional demand for land for various materials

Substitute materials	Risk level
Soybean and other vegetable oils	High
Cereals	Medium

Final result: high risk for additional demand for land for cover and intermediate crops. This risk can be mitigated through specific criteria added to voluntary schemes.

6. PROCESSING TECHNOLOGIES

6.1. Evaluation of processing technology (mature vs advanced)

Common cover and intermediate crops globally include wheat, maize, rice, and soybeans, all of which can be converted to biofuel using mature technologies. Cereals would likely be converted to ethanol using fermentation and soy oil would likely be converted to biodiesel using transesterification or hydrotreated vegetable oil using hydrotreating technology. Some cover and intermediate crops, such as silage maize, which is sometimes grown in Europe, can be processed into biogas using anaerobic digestion. All of these technologies are commercial mature. Thus, if cover and intermediate crops were to be added to Annex IX, part B would be most suitable for this feedstock. Cellulosic material from cover and intermediate crops are already covered under "other cellulosic material" in Annex IX, part A.

7. Conclusions

Nomenclature:

- No concern = the evaluation did not reveal any significant concern about this feedstock.
- Some concern = the evaluation identified limited conditions under which some concerns may exist, i.e. using this feedstock for biofuel production could be in contradiction with this criterion.
- Significant concern = the evaluation reveals that using this feedstock for biofuel production would be in contradiction with this criterion in most circumstances.
- Not applicable = this criterion is not applicable to the feedstock.

Table 119: Summary of evaluation results

	Evaluation Result	Rationale
Circular economy and waste hierarchy	No concern	No commercial uses exist that can extend product life and sequester carbon for longer than energy uses. Therefore, using cover and intermediate crops for biogas/biofuel does neither contribute to, nor contravene circular economy principles.
Union sustainability criteria	No concern	Under which circumstances could this feedstock be problematic? It is possible that the production of cover and intermediate crops could occur on land with high biodiversity value or high carbon stocks, or without management plans in place to address soil carbon. How to mitigate this concern? Failure to meet the Union sustainability criteria will be efficiently addressed throughout the certification process by an EU-approved voluntary or national scheme.
Sustainability GHG	No concern	Under which circumstances could this feedstock be problematic? Biofuels and biogas produced from cover and intermediate crops can, but do not necessarily, comply with the GHG reduction criteria in the RED II. For example, production processes with high direct emissions such as use of coal as process fuel would likely not comply with the GHG reduction criteria. How to mitigate this concern? Failure to meet the minimum GHG savings will be efficiently addressed throughout the certification process by

		an EU-approved voluntary or national scheme.
Sustainability Others	No concern	Under which circumstances could this feedstock be problematic? Cover and intermediate crops could potentially be grown on high carbon stock or highly biodiverse land and their production could potentially cause significant GHG emissions, similar to any crop-based biomass, but compliance with RED II sustainability criteria through voluntary scheme certification should in principle prevent this. In addition, cover and intermediate crops could potentially worsen water scarcity if grown in arid regions, and water quality if grown with added fertilizer and pesticides. How to mitigate this concern? Whereas some EU-approved Voluntary Schemes have additional environmental requirements, which could potentially mitigate the identified concerns, new policy instruments would be required to address these consistently and systematically.
Market distortion	Significant concern	Under which circumstances could this feedstock be problematic? While cover and intermediate crops in the EU are typically grown for environmental reasons and usually not harvested, globally most of these crops appear to be cash crops supplying commodity markets. Their use in biofuel would likely cause significant market distortion, similar to all food-based biofuels. How to mitigate this concern? Negative market and land use impacts could be mitigated by adding specific criteria to EU-approved voluntary schemes that ensure that the risk of indirect land-use change from feedstock production and utilisation remains low. This feedstock has been assessed as potentially appropriate for inclusion in Annex IXB. The contribution of Annex IXB feedstocks to national RED transport targets is capped at 1.7% of transport energy. Inclusion under this cap would limit the amount of feedstock likely to be used for biofuel/biogas production and thus mitigate against the most market

		distortive outcomes, but would not fully prevent indirect impacts.
2030/2050 Potential	No projection possible	The potential supply of cover and intermediate crops globally is likely quite large (likely much larger than 77 million tons per year) and increasing, but there is not enough data available to make quantitative estimates or projections.
Land demand	Significant concern for material not certified as low-ILUC Some concern for material certified as low-ILUC	<u>Under which circumstances could this feedstock be problematic?</u> The use of cover and intermediate crops for biofuel production globally will likely divert cereals and soybeans from other uses, leading to increased production of cereals and soybeans and a high risk of additional demand for land. <u>How to mitigate this concern?</u> Negative market and land use impacts could be mitigated by adding specific criteria to EU-approved voluntary schemes that ensure that the risk of indirect land-use change from feedstock production and utilisation remains low. This feedstock has been assessed as potentially appropriate for inclusion in Annex IXB. The contribution of Annex IXB feedstocks to national RED transport targets is capped at 1.7% of transport energy. Inclusion under this cap would limit the amount of feedstock likely to be used for biofuel/biogas production and thus mitigate against the most market distortive outcomes, but would not fully prevent indirect impacts.
Processing Technologies	Mature	Cover and intermediate crops globally tend to be major food and feed crops and can be processed into biofuel or biogas using mature technologies, such as ethanol fermentation, transesterification, hydrotreating of vegetable oil, and anaerobic digestion.

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Biomass from degraded and polluted lands

1. TECHNICAL DESCRIPTION

1.1. Feedstock description

This feedstock category includes non-lignocellulosic and non-cellulosic biomass (e.g. starch, sugars, fruits, vegetables, or vegetable oil) produced out of both degraded lands and polluted lands.

In this assessment the focus is on land that is truly degraded or polluted according to an EU approved certification system.

Degraded lands

For the purpose of this assessment, degraded lands are defined according to Annex V Par.9C of Directive (EU) 2018/2001 (in point 9 of Annex V) as 'severely degraded land', i.e. lands that, for a significant period of time, have either been significantly salinated or presented significantly low organic matter content and/or have been severely eroded. It should be noted, however, that this definition was included for the specific purpose of justifying the use of a GHG emission bonus for using degraded land. According to IPBES (Montanarella et al., 2018), the most important land degradations are soil degradation, including but not limited to erosion, compaction , salinization, loss of organic matter through excessive nutrient extraction and any other mechanism leading to the loss of porous space crucial for holding and exchanging air and water. It should be noted that accurate data and mapping of degraded lands are currently limited, as highlighted by IPCC (Olson et al, 2019).

Polluted lands

Polluted lands can be either affected by **point source pollution** influencing on a limited surface area such as former industrial, mining or land fill sites, or affected by **diffuse pollution**, which usually impacts on a much larger surface.

Lands affected by **point source pollution** are usually contaminated by a limited number of pollutants which are present at high levels. A systematic review is done by EEA and JRC for the EU territory to monitor progress on management of these sites. In total it was estimated from this review that in the EU-28 there could be 2.8 million sites affected by polluting activities (Paya Perez and Rodriguez Eugenio, 2018). A worldwide review of the extend of soil pollution was already done in the 1990s by Oldeman et al. (1991) and it was estimated that 22 million hectares of land globally had been affected by soil pollution. The FAO considers that point source pollution of land is globally underestimated (Rodríguez-Eugenio, 2018).

Areas affected by **diffuse pollution** are much larger, either affected by pollutions spreading through air or as a result of agricultural soil management spreading substances as metals (in fertilisers and manure), nutrients (N and P), biocides or persistent organic pollutants which can be contained in sludge applied to land as well as soil acidifying substances like ammonia emitted from nearby intensive animal husbandry farms (Huber et al., 2008). Lands subject to diffuse pollutions usually do not reach pollution levels that make harvested products reach the thresholds of maximum pollution levels as specified in regulations. Nevertheless, Toth et al. (2016) estimated that 6 % of the agricultural surface of the EU (approx. 137,000 km^2) were affected by high levels of diffuse pollution, which potentially required remediation action.

Given the uncertainty around the pollution levels and monitoring of diffuse pollution, th**is assessment focuses on point source pollution of lands.**

1.2. Production process

Biomass from degraded and polluted lands come from crops that are generally produced through similar agricultural practices as regular crops. Biomass from degraded and polluted lands can be processed into biofuel and biogas through the same technologies as other types of biomass.

Land degradation/pollution may, however, require specific adaptations, which are further detailed below.

Biomass from degraded lands

Land degradations may affect crop yields and therefore require adjustments in the cultivation practices, such as:

- The selection of adapted crops, which can grow effectively in soils with high salinity levels, low organic content and/or low nutrient levels.
- In heavily eroded soils and/or soils with very low soil organic carbon levels several specific crop management measures will need to be taken to stabilise the soil loss, improve the water holding capacity of the soil.
- Adapt water supply and nutrient uses to compensate for land degradation.

Biomass from polluted lands

In addition to potential energy uses, biomass grown on polluted lands may also serve for bioremediation, which is the decontamination of polluted soils through the absorption of pollutants by plants.

The selection of plants that can grow effectively in different polluted environments can however be challenging. Polluted lands where crops or trees grow with the purpose to either decline, extract or stabilise the inorganic pollutants may also deliver biomass which may be used for non-food purposes, including biofuels and biogas.

1.3. Possible uses

Biomass from degraded lands

Biomass from degraded lands can be used for **food** and **feed** purposes. Non-food/feed crops and trees are, however, considered as more adapted to land degradation than most food crops (Cossel et al., 2019; Ciria, 2019; Pulighe et al., 2016; Lewandowski et al., 2016; Ramirez et al., 2017; Ciria et al., 2020). Agro-forestry systems are also considered more suitable to thrive on degraded lands and reduce degradations (e.g. IRENA, 2017; Gichuki et al., 2019; Olson et al., 2019).

Any crop grown on degraded land is also adapted to **energy uses**, such biofuel or biogas**.** This is particularly the case for lands that have become abandoned due to high degradation levels making the continuation of productive food/feed use no longer possible or economically feasible (Montanarella et al., 2018 and Olson et al., 2019). In theory, biomass from degraded lands may also be used for **chemical and material** purposes, but no evidence of commercial use was found.

No evidence was found of a commercial-scale combination of remediation of degraded lands and provision biomass for biofuels/biogas or biobased products. In practice there are however several examples of bringing degraded lands into productive use again and using the biomass for booth food and non food purposes. Reviews of this were for example done by IUCN (2019); IRENE (2017); McCornick et al. (2014) and CIFOR (2016).

Biomass from polluted lands

In spite of potentially toxic levels of contamination and potential damages to human or animal health, biomass from polluted lands may be used as **food** and **feed**. This is for example the case in countries where the identification and management of polluted lands is not well organised and food quality rules are not strictly implemented. Many common food crops, such as wheat, sugarbeet, soya, oil seed rape, grain sorghum and grain maize tend to accumulate pollutants (e.g. metals) in seeds, which would make food or feed uses risky from a health perspective. Acceptable contamination levels in food/feed derived from polluted lands can be based on the EC regulation (EC, regulation no 1881/2006)[61] and other national and international regulations (WHO and FAO, 1995), looking specifically at the following contaminants:

- mycotoxins (aflatoxins, ochratoxin A, fusarium-toxins, patulin, citrinin)
- metals (cadmium, lead, mercury, inorganic tin, arsenic)
- dioxins and Polychlorinated Biphenyls (PCBs)
- Polycyclic Aromatic Hydrocarbons (PAH)
- 3-MCPD
- melamine
- erucic acid
- nitrates

It should, however, be noted that some plants are tolerant to several pollutants and do not accumulate the pollutants in the leaves or fruits. Furthermore, Evangelou et al. (2015) explains that there are even practices known in which fodder plants are grown in soils with high concentrations Selenium (Se) and Zinc (Zn) to be fed to animals that graze in areas deficient of these elements.

Several types of trees and crops are suitable to **bioremediate polluted soils** because they are good in accumulating different types of pollutants (Evangelou et al., 2015; Rodríguez-Eugenio, 2018). A study by the FAO (Rodríguez-Eugenio, 2018) reports that the tree types that are effective in accumulating high amounts of heavy metals, so most effective in extracting pollutions, are silver birch, alder, black locust, willow and conifer trees. Also there are many perennial and annual biomass crops such as miscanthus, reed canary grass, giant reed, switchgrass, biomass sorghum and industrial hemp that have been proven to be tolerant to high concentrations of metalloids and are effective in either uptake or stabilizing the pollution in soils. In this way these crops prevent pollutions to leach to ground water and also provide biomass for energy (Abhilash et al., 2016; Dhawi et al., 2016; Fiorentino et al, 2017; Tang et al., 2012, Barbosa et al., 2015; Evangelou, 2015).

Biomass from the above-mentioned trees and crops could therefore be used for **energy purposes**, although cellulosic and ligno-cellulosic materials are already covered in Annex IX and are therefore not considered in this assessment. Direct (e.g. CHP) or indirect combustion (e.g. biogas or biofuel) of contaminated biomass may however pose certain risks to the environment, which may limit the use of such biomass. Combustion or gasification is likely to be better suited then biochemical conversion to bioethanol or to biogas through anaerobic digestion because certain pollutants may negatively affect the enzymes needed for the breakdown of the biomass (Evangelou et al., 2015). Furthermore, when used in anaerobic digestion high pollution rates may create hazardous digestate which cannot be returned to the soil, nor turned into compost without posing a risk to environment and human health.

Risks to the environment or human health explain that large scale conversion to energy or other biobased products of biomass grown on polluted lands is not taking place at commercial level. There is however a clear increased (research) interest in bioremediation of polluted sites with woody and perennial crops that are candidates for conversion into energy, particularly biofuels (see **Table 120**). The only commercial example found is Vega biofuels in US. It produces 'biobased coal' an energy carrier produced from wood and crops planted on contaminated sites for bioremediation. It is a torrefaction product. A leaching process is applied before the torrefaction to remove the contaminations from the biomass[62].

[61] COMMISSION REGULATION (EC) No 1881/2006 of 19 December 2006 setting maximum levels for certain contaminants in foodstuffs

[62] http://biomassmagazine.com/articles/11218/vega-biofuels-breaks-ground-on-pilot-torrefaction-plant (accessed 11 March 2021)

Table 120 : Summary of possible uses of biomass from degraded and polluted lands

	Food use	Feed use	Other uses
Biomass from degraded lands	Food use is possible	Feed use is possible	Possible use for biogas, bioethanol and biodiesel and also heat and power from biomass grown on degraded lands. Possible use for chemical or material purposes (no evidence found).
Biomass from polluted lands	Food use is possible up to authorised contamination thresholds. Examples exist of food use biomass contaminated beyond such thresholds.	Feed use is possible up to authorised contamination thresholds. Examples exist of feed use biomass contaminated beyond such thresholds	Possible use for biogas, bioethanol and biodiesel and also heat and power from biomass grown on polluted lands. Possible use for chemical or material purposes (no evidence found).

2. CIRCULAR ECONOMY AND WASTE HIERARCHY

2.1. Classification of the feedstock as a co-product, residue or waste

On the basis of the feedstock description provided in sub-section 0, its possible uses in sub-section 0, stakeholder feedback and additional references, biomass produced on degraded or polluted lands can be classified as a co-product, a residue or a waste as described below.

Table 121 : Classification of crops grown on degraded and polluted lands

Evaluation question	Answer	Rationale
Is the feedstock the primary aim of the production process?	Variable	If the extraction of biomass for food, feed or energy purposes is the primary aim of the process, feedstock is considered as a co-product.
Does the feedstock have any economic value, but is not the primary aim of the process, and therefore a residue?	Variable	If the stabilisation or the remediation of degraded or polluted land is the primary aim of biomass cultivation, feedstock is considered as a residue.
Is the feedstock normally discarded, and therefore a waste?	Variable	Biomass from polluted lands may need to be handled as hazardous waste, according to the EU Waste Regulation. This may entail additional disposal costs.

2.2. Is the use of feedstock to produce biofuel/biogas in line with circular economy principles?

- **Does the feedstock have non-energy (re)uses, which could extend its life or sequester carbon for longer?**

  Answer: No

  Rationale: Biomass from degraded and polluted lands could potentially be used in chemicals, material and other industrial products, some of which could be long-lived. However, there is little evidence that this is currently done at commercial scale.

- **Does its use as biofuel/biogas feedstock contribute to nutrient recovery?**

  Answer: Variable

  Rationale: Benefits on nutrient recovery from biomass grown for land stabilisation or bioremediation are independent from end-use. In case biomass from **polluted lands** is turned into biogas, the use of the digestate as fertiliser may be limited because of contamination levels which cannot be returned to the soil, nor turned into compost without posing a risk to environment and human health. However, crops may not have taken up the pollutants, which implies that the residual biomass in the conversion process (e.g. digestate, ash, slack, biochar) still meets minimal requirements to be used as compost (Evangelou et al., 2015; Abhilash et al., 2016).

  Biomass from **degraded lands** is converted into biogas and upgraded to biomethane. The digestate can be used as fertiliser. The same could apply to secondary products (e.g. digestate, ash, slack, biochar) which may be produced in a thermochemical conversion to biofuels.

- **Does its use as biofuel/biogas feedstock contribute to a more efficient use of resources by avoiding primary material extraction?**

  Answer: Variable

  Rationale: Biomass from degraded and polluted lands may be a good alternative for biofuel/biogas feedstock sourcing avoiding biomass supply from fossil sources and from crops and trees grown on land that competes with food production or production or wood for conventional material uses. It may also serve for the stabilisation and bioremediation of degraded and polluted lands, thus leading to higher productivity levels and lower need for agricultural inputs (e.g. fertilisers), as well as reduced needs for disposal/treatment of contaminated biomass.

- **Does its use as biofuel/biogas feedstock contribute to reducing waste generation, especially food waste?**

  Answer: Variable.

  Rationale: Bioremediation may reduce the amount of contaminated soil or biomass, which would normally require decontamination treatments prior to disposal.

2.3. Is the use of this feedstock for biofuel/biogas production in line with the waste hierarchy?

- **Contribution to increasing waste?**

  Answer: No

  Rationale: There is no evidence that biomass from degraded or polluted lands contributes to increasing waste.

- **Can this feedstock be potentially reused?**

  Answer: Not applicable

Rationale: There has not been any prior use of biomass from degraded or polluted lands.

Can this feedstock be potentially recycled?

Answer: Not applicable

Rationale: There has not been any prior use of biomass from degraded or polluted lands.

2.4. Conclusion

Contribution to circular economy

Using biomass from degraded or polluted lands for energy purposes (biogas, bioethanol and biodiesel) does neither contribute to, nor contravene circular economy principles. There is no documented evidence of commercial implementation for use of biomass from degraded or polluted lands in long-lived chemicals, material or industrial products, although this is theoretically possible. Increasing the use of biomass from degraded or polluted lands for energy purposes could contribute to a more efficient use of resources by providing additional benefits on land stabilisation and remediation.

Alignment with the waste hierarchy

Using biomass from degraded or polluted lands for biogas/biofuel is in line with the waste hierarchy. No evidence exists that such use would increase waste generation.

3. Sustainability and Greenhouse gases

3.1. Union sustainability criteria

This considers the Union sustainability criteria laid down in Article 29 (2) to (7).

Table 122: Assessment of *crops grown on degraded or polluted lands*

Criterion (all land status assessed in 2008)	Assessment
(2) for wastes and residues derived from agricultural land operators or national authorities have monitoring or management plans in place in order to address the impacts on soil quality and soil carbon	Crops and their related residues from polluted degraded lands can come from agricultural lands. So impacts on soil quality and soil carbon can be monitored, unless the land is no longer in the agricultural domain according to CAP definitions or land outside the EU. So in most cases for crops grown on degraded lands monitoring and management plans are not necessarily in place**, thus leading to a medium risk of impact.**
(3) bioenergy from agricultural biomass shall not be made from raw material obtained from land with a high biodiversity value	Conversion and subsequent pollution or degradation of high biodiversity land is possible but unlikely after January 1, 2008. **A high risk of non-compliance is not foreseen for this criterion.**
(4) bioenergy from agricultural biomass shall not be made from raw material obtained from land with high-carbon stock in January 2008 if the status of the land has changed	Degraded or polluted lands are not expected to overlap with high carbon stock land. In many case a characteristic of degraded lands is low carbon levels. **A high risk of non-compliance is not foreseen for this criterion.**

(5) bioenergy from agricultural biomass shall not be made from raw material obtained from land that was peatland in January 2008, unless evidence is provided that the cultivation and harvesting of that raw material does not involve drainage of previously undrained soil.	There may be rare cases in which biomass harvesting could be part of degraded or polluted peatlands. **A high risk of non-compliance is not foreseen for this criterion however.**

Criterion (6) and (7) lay down criteria for bioenergy from forest biomass which are not applicable.

3.2. GHG Savings Criteria

Feedstock used: crops grown on degraded or polluted lands

Overall we can assume that crops that are grown on degraded lands with the purpose to produce biomass for commercial use. Stabilising the degradation will generally be the secondary purpose.

The type of crops grown on degraded lands and conversion processes (biofuel/biomethane) can be diverse. When considering biomass from degraded or polluted land as co-product, the following default values (RED II) would apply:

- Corn (maize) ethanol (28% - 68%)
- Sugarbeet ethanol (47% - 76%)
- Other cereals to ethanol (24% - 67%)
- Sugarcane ethanol (70%)
- Maize (whole plant) to biomethane (17% - 63%)
- Farmed wood to FT diesel (82%)
- Farmed wood to dimethylether (DME) (83%)

Given the ranges in GHG savings, it can be concluded that biofuels and biomethane produced from some crops grown on polluted degraded lands will meet the GHG savings criteria of 65%. Whether this is the case can be efficiently captured in the certification process by an EU-approved voluntary scheme. However, low yields that can generally be expected from degraded lands, or additional decontamination process for biomass from polluted land may make reaching the 65% GHG savings difficult if actual values are used.

No significant difference in GHG savings can be expected for feedstocks considered as residues, in a situation where the stabilisation or bioremediation of soils would be the primary purpose, given that the allocation of GHG emissions must be conducted over the different co-products based on energy content.

It can be assumed that biomass from degraded or polluted lands, which would normally be discarded, and therefore considered as waste, would not pose anything significant concern with regards to GHG savings, since all default values for waste-derived biofuel/biomethane (e.g. used cooking oil, waste wood) are above 65%.

3.3. Other environmental impacts

Table 123: Overview of evaluation of risks for adverse effects on soil, water, air and biodiversity for crops grown on degraded or polluted lands

Type of risk to be reviewed	Risk indicator	Risk level	Rationale and sources
Adverse impacts on soil quality	2.1 Soil Organic Matter: decline should be avoided	Low-Medium	Given the pollution and degradation problems the crop choice and management system will generally be aimed at improving Soil organic levels, stopping further soil erosion and or salinization (if applicable). A risk exists, however, that low nutrient content or erosion are compensated by additional use of agricultural inputs. Furthermore, when annuals are used on polluted lands, adverse soil structural and waterlogging impacts, soil erosion can develop more easily because heavy regular use of machines in the land is common. This impact is determined however by additional factors such as soil type, climate, slope (Diaz-Chavez et al., 2013).
	2.2 Nutrient and phosphate balance: a disturbance of the balance leading to strong leaching of nutrients should be avoided	Low-Medium	
	2.3 Soil erosion: should be minimised	Low-Medium	
	2.4: Soil structure: soil compaction and waterlogging should be avoided	Low-Medium	
	2.5: Soil biodiversity: contamination of soils with metals and other toxic component, disturbance of soil structure and decline in soil organic carbon may all lead to a decline in biodiversity and this should be avoided	Low-Medium	
Adverse impacts on water quality	3.1 Water quality: ground and surface water quality should not decline through increased leaching and run off of N, P from fertilization and of other contaminants from fertilization and weed and pest control.	Low-Medium	Biomass grown on degraded or polluted lands generally aim at sustainable land use and soil loss stabilisation and remediation. So if stabilisation of degradation in combination with biomass production is aimed for, one can actually expect that water quality problems will decline overall. A risk exists, however, that low nutrient content or erosion are compensated by additional use of agricultural inputs, which could eventually affect water quality. Scientific literature shows a perennial crop/tree (e.g. willo or poplar) with a deep rooting system is more appropriate than annual crops. It decreases the leaching of nutrients (nitrogen, phosphate) and contaminants to ground and surface water

Type of risk to be reviewed	Risk indicator	Risk level	Rationale and sources
			(McIsaac et al. ,2010; Ferchaud and Mary, 2016; Smith et al.,2013; Robertson et al., 2017; and Sharma and Chaubey, 2017). As to weed and pest control, the risk of it leaching is always present, but generally low, particularly because crops on degraded lands do not need to deliver fruits meeting the food market standards.
Adverse impacts on water quantity	4.1 Water quantity: excessive water consumption in agriculture should not lead to depletion of sweet water resources and salinization.	Low-Medium	Under temperate conditions, this risk is deemed low. In drought circumstances, the risk is considered medium. The deep rooting of perennials may facilitate water extraction and lowering of water tables. Application of irrigation could be another management measure that may deplete local water resources.
Adverse effects on air quality	5.1 GHG emissions: GHG emissions from cropping should be minimized	Low-Medium risk	The crop choice will determine the eventual impacts on air. Overall impacts on air can be expected to be lower with perennials as these require relatively low mechanisation levels and generally lower nitrogen gifts. Because of this low GHG emissions for the use of machines (energy) in the field and also a low emission of N_2O are expected. Air pollution through spreading and pesticides and herbicides is not likely to be large for degraded or polluted land cropping since crops do not need to meet the food quality standards. If stabilisation of the soil degradation is the first objective of growing crops weed and pest control is not a priority.
	5.2 Ammonia and NOx emissions: should be minimized	Low-Medium risk	
	5.3 Air pollution through spreading of herbicides and pesticides should be minimized	Low risk	
Adverse effects on biodiversity	6.1 Crop diversity: large scale monocultures decreasing crop diversity strongly in a region should	Low risk	Large scale monocultures are not foreseen given the low yields and challenges related

Type of risk to be reviewed	Risk indicator	Risk level	Rationale and sources
	be avoided		to the bioremediation of soil.
	6.2 Biodiversity: Direct adverse impacts on flora and fauna should be avoided	Low risk	Biomass cultivation on degraded or polluted land, which was abandoned before, may be detrimental to biodiversity, but it is assumed that degraded or polluted land will generally not allow for high diversity to thrive.
	6.3 Pollination: Direct adverse impacts on pollinators and their habitats should be avoided	Low risk	Crop choice for long flowering (melliferous plants, to provide nectar and pollen to insects like honey bee and wild bees) can help enhance pollinator species.
	6.4 Invasive species: use of biomass crops that are invasive should be banned	Low risk	Then se of invasive species should be avoided also on degraded lands.

4. Market effects and 2030/2050 potential

4.1. Market effects

Potential market effects could be established by evaluating the existing supply of biomass from degraded or polluted lands and compare it to the demand for such biomass by different sectors. Such evaluation appears challenging due to the limited data on the exact areas affected by pollution or degradation in the EU and worldwide. Furthermore, the exact amount of biomass extracted from degraded or polluted land for use as food, feed and other non-energy purposes cannot be accurately established.

This assessment is therefore limited to an estimate of the total areas of degraded and polluted land and a qualitative assessment of the demand for biomass from degraded and polluted lands.

Degraded lands

Land degradation in the EU was measured by the JRC (Cherlet et al., 2013) by using change in land productivity as an indirect indicator. Land productivity was measured through remote sensing information from which the biomass development and change can be measured through the NDVI index (Normalized Difference Vegetation Index). The results showed that 85.1% of the total EU area is currently unaffected by land productivity decline; 7.9% of the total EU area shows a land productivity that is stable but stressed; 5.6% of the total EU area shows early signs of land productivity decline, and 1.5% (6,037,500 ha) is in decline. More specific estimates can be derived from the mapping of marginal lands in the EU in MAGIC[63] following the guidelines of the JRC for areas of Natural Constraints (ANCs). This study showed that 2% of the agricultural land in the EU is marginal because of low soil fertility most often caused by low oil organic carbon levels. High salinization levels occur in 1% of the agricultural lands. Panagos et al. (2015) modelled soil erosion by water and estimated that about 4 million hectares of croplands in the EU have unsustainable soil loss rates occurring through erosion by water.

[63] Magic – Marginal Lands for Growing Industrial Crops (magic-h2020.eu)

While degraded land areas in the EU appear to be limited, a global evaluation of land degradation by IPBES (Montanarella et al., 2018) shows a more dramatic picture, with an estimated 75 % of Earth's land areas being substantially degraded, which increase to 90 % by 2050. Most land degradation will occur in Central and South America, sub-Saharan Africa and Asia. In this same assessment it was indicated that land degradation and climate change could reduce crop yields by an average of 10 % by 2050. This assessment, however, looks at a larger number of land degradation types than the "severely degraded land" definition found in Annex V of red II. Therefore, lands affected by such degradation types likely constitute a smaller area than what the IPBS study suggests.

Polluted lands

As explained in Section 1, polluted lands can be affected by point source pollution influencing on a limited surface area or by diffuse pollution, which usually impacts on a much larger surface. This assessment is, however, limited to point source pollution.

As to contaminated sites (point source pollution) it was estimated that in the EU-28 there could be 2.8 million sites where polluting activities are or took place (Paya Perez and Rodriguez Eugenio, 2018) but the exact area or potential for biomass extraction is unknown.

Globally, FAO and ITPS (2015) identified soil pollution as the third most important threat to soil functions in Europe and Eurasia, the fourth in North Afrika, fifth in Asia, seventh in Northwest Pacific, eighth in North America and ninth in sub-Saharan Africa and Latin America. A worldwide review of the extend of soil pollution was already undertaken in the 1990s by Oldeman et al. (1991) and it was estimated that 22 million hectares of land globally had been affected by soil pollution. In the more recent FAO study (Rodríguez-Eugenio, 2018) it is indicated that this is [likely to be] a vast underestimation.

The **current use of degraded or polluted lands** to produce biomass for food, feed and other non-energy uses cannot be accurately estimated, but it can be assumed that the inclusion of biomass from degraded or polluted lands in Annex IX could create competition between and energy and non-energy uses, thus leading to market distortions. It is therefore recommended to restrict the use of degraded or polluted lands to those lands, which are not currently being used for food, feed and other non-energy purposes, or which are undergoing a bioremediation process. The practical identification of such lands could rely on the "Low ILUC certification" process, which includes the possibility to identify and use abandoned lands for bioenergy production. Whenever only degraded or polluted lands, which were not used before, or which primarily aim at stabilisation or bioremediation, are used to produce biomass for energy purposes, **the risk of market distortion can be considered low**.

4.2. 2030/2050 Potential

As with market effects, an accurate estimate of 2030 and 2050 potential for biomass from degraded or polluted lands is currently difficult, based on external sources. Furthermore, whether pollution or degradation levels prevent the use of biomass for food, feed or non-energy purposes cannot be accurately estimated either.

While the EU may be in a position to stabilise or even reduce degraded or polluted land areas within its boundaries, the IBPS study suggests that climate change and other anthropic activities will likely increase degraded land areas worldwide. Proactive public policies and efforts by the private sectors could however reduce degraded and polluted land areas in the coming decades. The combination of land stabilisation/bioremediation and biomass production for energy purposes could bring about multiple benefits by increasing bioenergy production while contributing to reduce degraded or polluted land areas without relying on energy-intensive excavation and off-site disposal of material (Jiang et al., 2015).

5. Additional demand for land

5.1. Assessment of additional demand for land

As mentioned in Section 4, the inclusion of biomass from degraded or polluted lands in Annex IX may increase the competition between energy and non-energy uses. As a result, non-energy uses may require additional land to produce biomass. On the contrary, a displacement of bioenergy production into abandoned degraded or polluted land would be beneficial for additional land demand, by reducing pressure on existing arable land or natural lands.

As indicated in Section 4, market distortion and additional demand risks could be efficiently mitigated by ensuring that any degraded or polluted land used to produce biomass for energy purpose was previously abandoned or is used primarily for stabilisation or bioremediation. The definition and identification of abandoned lands could rely on the Low ILUC certification approach, which is currently being developed by the EU.

Whenever only degraded or polluted lands, which were not used before, or which primarily aim at stabilisation or bioremediation, are used to produce biomass for energy purposes**, the risk of additional demand for land can be considered low.**

6. Processing technologies

6.1. Evaluation of processing technology (mature vs advanced)

A large variety of crops and trees can be grown on degraded or polluted lands and biomass extracted from such lands can be converted through many processing technologies. While high level of contamination may require specific pre-treatment prior to any bioenergy production, it is assumed that biomass from degraded or polluted land will primarily be processed into biogas, bioethanol or biodiesel using **mature technologies**, such as anaerobic digestion, fermentation, transesterification or hydrogenation.

7. Conclusions

Table 124: Summary of evaluation results for crops from degraded or polluted lands

	Evaluation Result	Additional remarks
Circular economy	No concern	Using biomass from degraded or polluted lands does neither contribute to, nor contravene circular economy principles or the waste hierarchy.
Sustainability Union criteria	No concern	In most cases for crops grown on degraded lands monitoring and management plans are not necessarily in place, this provides some small risk. <u>Under which circumstances could this feedstock be problematic?</u> It is possible that the production of biomass from degraded or polluted lands could occur on land with high biodiversity value or high carbon stocks, or without management plans in place to address soil carbon. <u>How to mitigate this concern?</u> Failure to meet the Union

		sustainability criteria will be efficiently addressed throughout the certification process by an EU-approved voluntary or national scheme.
Sustainability GHG	No concern (co-products)	Biomass from degraded or polluted land may be converted through various processes, thus leading to a wide range of GHG savings. Under which circumstances could this feedstock be problematic? Production processes with high direct emissions such as use of coal/lignite as process fuel would likely not comply with the GHG reduction criteria. How to mitigate this concern? Failure to meet the Union minimum GHG savings will be efficiently addressed throughout the certification process by an EU-approved voluntary or national scheme.
	No concern (waste)	When considered as waste, biomass from degraded or polluted land will likely exceed the minimum 65% GHG savings.
Sustainability Others	No concern	It can be assumed that the use of degraded or polluted lands will generally aim at stabilising or improving on land degradation or pollution, thus reducing the risk of environmental impacts. Under which circumstances could this feedstock be problematic? A risk exists that land degradation or pollution requires adjustments in cultivation practices (e.g. additional nutrients or water use), which could result in causing or aggravating existing degradation or pollution. How to mitigate this concern? Whereas some EU-approved Voluntary Schemes have additional environmental requirements, which could potentially mitigate the identified concerns, new policy instruments would be required to address these consistently and systematically.
Market distortion	No concern	The difficulty to formerly and consistently identify degraded or polluted lands poses some concern as non-degraded or non-polluted lands could be unduly considered as such and diverted from other productions. The risk is considered low because the assumption here is that the focus is

		on land that is truly degraded or polluted according to an EU approved certification system How to mitigate this concern? For degraded lands, feedstock should be certified by EU-approved Voluntary Schemes as coming from a formally identified and identified degraded land. For polluted lands, new policy developments would be required to establish and consistently implement clear pollution threshold and polluted land identification process.
2030/2050 Potential	Unknown	A realistic estimate cannot be made.
Land demand	No concern (low ILUC only)	Whenever only degraded or polluted lands, which were not used before, or which primarily aim at stabilisation or bioremediation (certified as such in an EU-approved certification scheme), are used to produce biomass for energy purposes, the risk of additional land demand can be considered low.
Processing Technologies	Mature	The technologies to convert the different crops grown on degraded or polluted lands to biomethane or liquid biofuels are considered to be Mature.

8. References

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Damaged crops

1. TECHNICAL DESCRIPTION

1.1. Feedstock description

There are many reasons why part of the food production does not enter the food chain and part of the outcome is a large amount of damaged crops unfit for human or animal consumption.

According to the FAO (2019) who created a Food Loss Indicator (FLS) to track progress towards SDG target 12.3 on reducing food loss, 13.8 % of food produced in 2016 was lost from the farm up to, but excluding, the retail stage. Fruits and vegetables are the group with the highest losses because of their highly perishable nature and the need for cold storage and processing to conserve for longer time.

There are many reasons why part of the food production does not enter the food chain and part of the outcome is a large amount of damaged crops unfit for human or animal consumption. Often, crops that are lost for the original purpose of end-use, can still be fed to animals without any health risk. Also there are economic considerations to not let damaged crops enter into the food chain, even though there is no (human or animal) health issue at stake (yet) when consumed. Given the wide variation in reasons why crops become damaged, it is not easy to verify whether damaged crops have been discarded on purpose for economic reasons and whether they are still suitable to be consumed in the food and feed chain. Also, it should be ensured that the production of food waste via damaged crops should be reduced, particularly given the large problems related to food security and GHG emissions. Creating a large demand for damaged vegetables to be used for biofuel production or other non-food uses should not be encouraged.

It is therefore purposed for this assessment to only consider damaged crops defined as crops that are unfit for human or animal consumption because they pose a risk to health.

What is a human health threat can be based on the EC regulation (EC, regulation no 1881/2006)[64] and other national and international regulations on maximum contaminants allowed in food and feed (see e.g. Cheli et al., 2014). In the EC maximum contaminant levels in foodstuff (for feed and food) are set. An important group of contaminants are mycotoxins, but they could also be others like heavy metals or strong presence of residual pesticides. Mycotoxins (aflatoxins, ochratoxin A, fusarium-toxins, patulin, citrinin), that are most typical to occur in crops that become affected by fungi (moulds) before and after harvest, during storage and transport (WHO Factsheet Mycotoxins and Cheli et al., 2014)65. The chance for fungi to affect crops is increased when crops are damaged before and during harvest, transport and storage. The challenge with mycotoxins is that are chemically stable and survive food processing. So, if mycotoxins enter in a crop and have enough time to accumulate, it becomes so damaged that it is no longer suitable to be safely consumed as food or feed (Conte et al., 2020). Furthermore, when animals are fed with feed infected by mycotoxins they can also obtain serious health problems and this also increases the chance for the mycotoxins to enter the food chain (e.g. through milk, milk products and meat) (Conte et al., 2020).

In this feedstock evaluation we therefore propose to narrow the damaged crops group down to a sub-group which is **crops that are damaged because they become affected pre- or post harvest by pests and pathogens which make their consumption as food or feed a health threat.**

[64] COMMISSION REGULATION (EC) No 1881/2006 of 19 December 2006 setting maximum levels for certain contaminants in foodstuffs
[65] https://www.who.int/news-room/fact-sheets/detail/mycotoxins

1.2. Production process

Damaged crops are produced through the same agricultural practices as regular crops but undergo some pre-harvesting or post-harvesting degradation, due to the causes mentioned in the previous section.

1.3. Possible uses

As per the definition used in this assessment, damaged crops are unfit for food and feed use. Therefore, their main use is energy and chemicals. It is difficult to indicate exact uses since damaged crops consists of a very wide diversity of crops. The resource is most comparable to vegetal food waste. Most common conventional non-food/feed uses are for making compost and biogas (Kumar, 2016; Zhang et al. 2018). If the biomass stream concerns damaged crops only the digester route for making biogas (and heat) is the most logical given that the biomass is rather wet.

Kumar (2016) provides an overview of routes converting biowaste into liquid biofuels that are currently under academic and industrial research. Although these conversion options are not yet in large scale and commercial phase, the feasible routes that can become commercial in the near future are the following (Kumar, 2016; Saeed et al., 2018; Zhang et al. 2018):

- Fermentation to biomethane
- Bio-oil (via pyrolysis)
- Bioethanol
- Biodiesel

The conversions to bio-oil and biodiesel are only possible if the damaged crops are oil crops.

It should also be noted that contamination by certain contaminants in damaged crops (e.g. mycotoxins, heavy metals) may adversely affect the bacteria and enzymes needed in the process of fermentation and hydrolysis process.

Table 125 : Summary of possible uses of damaged crops

	Food use	Feed use	Other uses
Damaged crops (unsuitable for human consumption)	Not applicable (see definition)	Not applicable (see definition)	Damaged crops are most comparable to vegetal food waste, and can be as diverse and similar in composition. For food waste there are many conversion routes to organic fertilisers and also liquid and gaseous biofuels. The organic fertiliser conversion is common for food waste, but as to damaged crops this may pose a risk for spreading of pathogens, pests and other pollutions on lands. The conversion routes to gaseous biofuels already have a high TRL and can become economical at large scale in the near future. Commercialisation of liquid

			biofuel routes may take some more time to become commercial. Example conversion routes and their status are discussed in Kumar, 2016; Saeed et al., 2018; Zhang et al. 2018) and include biomethane, biooil, biodiesel and bioethanol.

2. CIRCULAR ECONOMY AND WASTE HIERARCHY

2.1. Classification of the feedstock as a co-product, residue or waste

On the basis of the feedstock description provided in sub-section 0, its possible uses in sub-section 0, stakeholder feedback and additional references, damaged crops can be classified as residues or wastes as described below.

Table 126 : Classification of damaged crops

Evaluation question	Answer	Rationale
Is the feedstock the primary aim of the production process?	No	In principle the production of crops is for food, feed and other commodity markets that have high enough quality to qualify them for the initial purpose. However damaged crops are no longer fulfilling this purpose.
Does the feedstock have any economic value, but is not the primary aim of the process, and therefore a residue?	Variable	Retail/post-consumer food waste streams exist, but no evidence was found that similar chains exist for damaged crops. If these streams are polluted by contaminants (e.g. mycotoxins and other contaminants) they need to be handled as hazardous waste, at least in the EU according to the EU Waste Regulation (see Cheli et al., 2014), which may even entail disposal costs.
Is the feedstock normally discarded, and therefore a waste?	Variable	

2.2. Is the use of feedstock to produce biofuel/biogas in line with circular economy principles?

The following questions apply to damaged crops.

- **Does the feedstock have non-energy (re)uses, which could extend its life or sequester carbon for longer?**

  Answer: variable.

  Rationale: The harvested damaged crops can be used as feedstock for both materials and energy. However, conversion to materials can only be done if the allowed contaminants levels in the final material made from the crops fit with the legal contaminant requirements.

  If contaminant levels are above legal standards, the conversion into biofuels or biogas is an attractive option. Furthermore, given the different review publications (see **Table 125**) it is likely that clean fuel conversion pathways will reach commercial applicability sooner than those to materials such as bioplastics and other polymers.

- **Does its use as biofuel/biogas feedstock contribute to nutrient recovery?**

  Answer: No.

  Rationale: Generally, this will not be the case because side products generated in the conversion to biofuels/biogas are likely to have high contamination levels as this is the reason why they are included in the damaged crop category. Since pollutions (e.g. with mycotoxins, heavy metals and other) are the main reasons to discard the crops it is likely that it is not sustainable to return the crops to the soil, nor turn them into compost without posing a risk to environment and human health.

- **Does its use as biofuel/biogas feedstock contribute to a more efficient use of resources by avoiding primary material extraction?**

  Answer: Yes

  Rationale: Damaged crops unfit for human or animal consumption are likely to be a good alternative for biofuel/biogas feedstock sourcing from dedicated crops and trees grown on land, which may compete with food production or wood production for conventional material uses.

- **Does its use as biofuel/biogas feedstock contribute to reducing waste generation, especially food waste?**

  Answer: Yes.

  Rationale: Damaged crops unfit for human or animal consumption are a form of food waste, so using them for biofuel/biogas would divert them from this waste stream into a biomass resource.

2.3. Is the use of this feedstock for biofuel/biogas production in line with the waste hierarchy?

- **Contribution to increasing waste?**

  Answer: No

  Rationale: In principle the use of these damaged crops will prevent them from entering in the waste stream.

- **Can this feedstock be potentially reused?**

  Answer: Variable

Rationale: If the biomass from damaged crops is converted into a biofuel/biogas it is only used once, but when from the biomass a certain biomaterial is made reuse is an option. No published research or commercial examples of this were found, however.

Can this feedstock be potentially recycled?

Answer: Variable

Rationale: If the biomass from damaged crops is converted into a biofuel/biogas it is only used once. Recycling does not apply.

2.4. Conclusion

Contribution to circular economy

Using damaged crops unfit for human and animal consumption for energy purposes (biogas, bioethanol and biodiesel) is not entirely in line with circular economy principles, since combustion of biofuels/biogas means biogenic material leaves the chain.

However, the conversion of damaged crops unfit for human and animal consumption into a material/chemical is still in experimental phase and no commercially proven use was found in literature. **So the use of this biomass for biofuel/biogas is in line with CE.**

Alignment with the waste hierarchy

Using damaged crops unfit for human and animal consumption for biogas/biofuel is in line with the waste hierarchy under the following conditions:

- The harvested crops do not meet food or feed quality standards (because pollution levels are high and pose a threat to human and animal health).
- There is no economically viable option to process the crop into a biomaterial that can be reused and/or recycled.

3. Sustainability and Greenhouse gases

3.1. Union sustainability criteria

This considers the Union sustainability criteria laid down in Article 29 (2) to (7).

Table 127: Assessment of *damaged crops unfit for human and animal consumption*

Criterion (all land status assessed in 2008)	Assessment
(2) for wastes and residues derived from agricultural land operators or national authorities have monitoring or management plans in place in order to address the impacts on soil quality and soil carbon	Damaged crops come from agricultural land. So when produced in the EU, impacts on soil quality and soil carbon are monitored. In most cases for damaged crops monitoring and management plans are in place in the EU through CAP cross compliance. However, if damaged crops come from outside the EU the risk is larger.
(3) bioenergy from agricultural biomass shall not be made from raw material obtained from land with a high biodiversity value	Damaged crops can come from any agricultural land and these generally do not overlap with high biodiversity land unless very recently converted to crop lands. A high risk of non-compliance is not foreseen for this criterion.
(4) bioenergy from agricultural biomass shall not be made from raw material obtained from land with high-carbon stock in January 2008 if the status of the land has changed	Cropping on land with high-carbon stock for most food and feed crops is possible although not frequently expected. A high risk of non-compliance is not foreseen for this criterion.
(5) bioenergy from agricultural biomass shall not be made from raw material obtained from land that was peatland in January 2008, unless evidence is provided that the cultivation and harvesting of that raw material does not involve drainage of previously undrained soil.	There may be rare cases in which crops that become damaged have been grown on peatland (e.g. damaged oil palm kernels). A high risk of non-compliance is not foreseen for this criterion however.

Criterion (6) and (7) lay down criteria for bioenergy from forest biomass which are not applicable.

3.2. GHG Savings Criteria

Crops that are harvested and become damaged because of infections or other causes that result in too high pollution levels are likely to be discarded as waste. According to REDII, if a feedstock is considered a waste then GHG emissions from cultivation do not need to be considered, only those from the point of collection.

Damaged crops are comparable to vegetal food waste. Accordingly, for biomethane production for transport, as an initial estimate, default values provided in the RED II for biowaste are considered. Based on the technological option, a large variation in GHG emission savings is observed (20 – 80 %) depending on whether digestate is stored in an open or a closed tank and whether the off-gas is vented or combusted. The GHG savings criteria for new installations require at least 65% GHG savings. This shows that to be eligible, the technology option of close digestate, off-gas combustion should be applied.

Examples of types of liquid biofuels that could be produced from damaged crops considered as waste (so setting cultivation emissions to zero), and their default GHG savings values in the RED II, include: maize ethanol (55-95%), sugarbeet (57-86%), rapeseed biodiesel (80%), and soybean biodiesel (72%).

This shows that if damaged crops are considered as a waste, the GHG emission savings in most biofuel production routes are likely to be met.

3.3. Other environmental impacts

This assessment only needs to be done for crops that are grown on land. Damaged crops are grown on land, but could become categorized as food waste. The underneath table is specified for damaged crops that are categorized as main product however.

Table 128: Overview of evaluation of risks for adverse effects on soil, water, air and biodiversity for damaged crops (if categorized as main product)

Type of risk to be reviewed	Risk indicator	Risk level	Rationale and sources
Adverse impacts on soil quality	2.1 Soil Organic Matter: decline should be avoided	Medium/high risk	Damaged crops are likely to be annuals in most cases (e.g. maize, sugarbeet etc). When annuals are used adverse soil structural and waterlogging impacts, soil erosion can develop more easily because heavy regular use of machines in the land is common. This impact is determined however by additional factors such as soil type, climate, slope (Diaz-Chavez et al., 2013).
	2.2 Nutrient and phosphate balance: a disturbance of the balance leading to strong leaching of nutrients should be avoided	Medium/high risk	
	2.3 Soil erosion: should be minimised	Medium/high risk	
	2.4: Soil structure: soil compaction and waterlogging should be avoided	Medium/high risk	
	2.5: Soil biodiversity: contamination of soils with metals and other toxic component, disturbance of soil structure and decline in soil organic carbon may all lead to a decline in	Medium/high risk	

Type of risk to be reviewed	Risk indicator	Risk level	Rationale and sources
	biodiversity and this should be avoided		
Adverse impacts on water quality	3.1 Water quality: ground and surface water quality should not decline through increased leaching and run off of N, P from fertilization and of other contaminants from fertilization and weed and pest control.	Low- high risk	The crop choice in combination with location will determine the eventual impact. If it is an annual crop the chance for adverse impact on water quality is present.
Adverse impacts on water quantity	4.1 Water quantity: excessive water consumption in agriculture should not lead to depletion of sweet water resources and salinization.	Low- high risk	Depends on the hydrological circumstances and the crop type. If drought circumstances cropping and irrigation water consumption may deplete local water resources.
Adverse effects on air quality	5.1 GHG emissions: GHG emissions from cropping should be minimized	Low- high risk	The crop type will determine the eventual impacts on air. For GHG emissions this is determined by mechanisation levels and fertiliser and crop protection gifts. Air pollution through spreading and pesticides and herbicides is can be large in different crops but not all.
	5.2 Ammonia and NOx emissions: should be minimized	Low- high risk	
	5.3 Air pollution through spreading of herbicides and pesticides should be minimized	Low	
Adverse effects on biodiversity	6.1 Crop diversity: large scale monocultures decreasing crop diversity strongly in a region should be avoided	Low - high	The impacts on biodiversity again depend on what crops are used. Crop choice for long flowering (melliferous plants, to provide nectar and pollen to insects like honey bee and wild bees) can help enhance pollinator species.
	6.2 Biodiversity: Direct adverse impacts on flora and fauna should be avoided	Low -high	
	6.3 Pollination: Direct adverse impacts on pollinators and their habitats should be avoided	Low - high	
	6.4 Invasive species: use of biomass crops that are invasive should be banned	Low -high	

4. MARKET EFFECTS AND 2030/2050 POTENTIAL

4.1. Market effects

As reported in section 548 almost 14% of food produced in 2016 was lost from the farm up to, but excluding, the retail stage. Part of these losses end up in damaged crops that are unfit to be consumed by humans or animals for health risks. How much this is, has never been assessed. But if we assume that it at least amounts to 1% of the total crop production in the world the yearly volume could already be 190 million[66] tonnes fresh/year of biomass globally.

The increasing concerns about health problems related to food and feed infected by mycotoxins is likely to enhance identification of large quantities of crops in the chain that are unfit for consumption.

However, in relation to damaged crops unfit for human and animal consumption, we conclude that there is no market developed yet focussing specifically on this type of crop category. Given this we expect a **low risk of using biomass from damaged crops to have a distortive effect on other sectors or industries**.

4.2. 2030/2050 Potential

The volume of crops all over the world that are affected by pathogens and pests are large as is convincingly confirmed by several studies presented in the former. However, it is not known which part of these crops become damaged in such a way that human and animal consumption is unsafe/a health threat. This needs to be established by measuring contaminant levels in the crops. Currently no studies nor data are available to translate this in a potential for biofuel production.

How large the availability of biomass for biofuels from damaged crops will be in 2030 and 2050 is impossible to predict and no studies are available that have tried to estimate this. Still, given the estimates EU wide and globally of food waste and of crops affected by pathogens and pests one can expect that this potential can become very large.

To make a very rough estimate we can take a 1% of the total vegetal food production in 2019 which amounts to 190 million tons fresh/year. If we assume an average yearly yield increase of 1.5% this would then result in 224 million tons fresh/year in 2030 and 301 million tons fresh/year in 2050.

From this we conclude that it is reasonable to assume that the availability of biomass from damaged crops can be considerable by 2030 and certainly by 2050 and that this will have no or limited distortive market effect.

One should however review whether in the future one can expect that the commercial development of using this biomass for biofuel production can enhance practices that make crops become damaged on purpose in order to sell them on a parallel market for conversion to biofuels. This could be particularly attractive if food and feed prices are low and prices paid for biomass used for biofuels are higher. This could then also lead to increased additional land demand. However, this is a purely hypothetical situation at this moment.

5. ADDITIONAL DEMAND FOR LAND

5.1. Assessment of additional demand for land

The material in this example is damaged crops. As already explained in the former the amount of crop losses because of a wide diversity of reasons in the food chain is very considerable. A market

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[66] FAOSTAT data tell us that in 2019 at least 19 billion tons of fruits and vegetables (fresh) was produced. 1% of this is amounts to 190 million ton fresh biomass.

for damaged crops unfit for human or animal consumption is non-existent, except for possible applications in biogas and composting. Utilising these damaged feedstocks for bioenergy production is unlikely to drive additional primary production.

Final result for damaged crops: low risk for additional demand for land

6. Processing technologies

6.1. Evaluation of processing technology (mature vs advanced)

As explained in former section it is difficult to indicate exact uses, since the damaged crops category may cover a wide diversity of crops. The resource is most comparable to vegetal food waste. Currently, the most developed conversion process is biogas production which provides biomethane for transport. Anaerobic digestion and subsequent biogas upgrading are mature technologies (TRL 9, CRL 5) which would mean this feedstock to be suitable to be added to Part B of Annex IX.

Conversion routes towards liquid biofuels (ethanol, biodiesel, HVO) are expected to be an option in the near future, but now they are still under academic and industrial research (Kumar, 2016; Saeed et al., 2018; Zhang et al., 2018).

If damaged crops are sugar or starch crops, they can be converted to ethanol with mature fermentation technology. If damaged crops are oil crops they can be converted to biodiesel and HVO via transesterification and hydrotreating which are also mature technologies.

If damaged crops are highly contaminated by mycotoxins one should further account for the fact that these may adversely affect the bacteria and enzymes needed in the process of fermentation and hydrolysis process.

Based on the fact that biogas production and upgrading and conversion to liquid biofuels are mature technologies (TRL 9, CRL 5), this feedstock is suitable to be added to Part B of Annex IX.

7. Conclusions

Table 129: Summary of evaluation results for damaged crops unfit for human and animal consumption

	Evaluation Result	Additional remarks
Circular economy	No concern	The conversion of damaged crops into a material/chemical is still in experimental phase and no commercially proven use was found in literature. **So the use of damaged crops unfit for human and animal consumption for biofuel/biogas is in line with CE.**
Sustainability Union criteria	No concern	Under which circumstances could this feedstock be problematic? Damaged crops can come from land where impacts on soil quality and soil carbon are not per definition monitored. How to mitigate this concern? Failure to meet the Union sustainability criteria will be efficiently addressed throughout the

		certification process by an EU-approved voluntary or national scheme.
Sustainability GHG	No concern (coproduct)	The mitigation potential calculation depends on whether damaged crops are seen as co-product crop or as vegetal waste. If considered as co-product, the GHG emission savings in most routes are likely to be met. <u>Under which circumstances could this feedstock be problematic?</u> If cultivation emissions need to be allocated to the damaged crops, considering the RED II default values, biofuels and biogas produced from damaged crops can, but do not necessarily, comply with the GHG reduction criteria of 65%. How to mitigate this concern? Failure to meet the Union minimum GHG savings will be efficiently addressed throughout the certification process by an EU-approved voluntary or national scheme.
	No concern (waste)	If considered as a waste, the GHG emission savings in most routes are likely to be met.
Sustainability Others	No concern	Impacts on the environment depend on the type of crop and cultivation practices. <u>Under which circumstances could this feedstock be problematic?</u> Tillage practices, use of agricultural inputs and harvesting practices may cause negative impacts on the environment. <u>How to mitigate this concern?</u> Whereas some EU-approved Voluntary Schemes have additional environmental requirements, which could potentially mitigate the identified concerns, new policy instruments would be required to address these consistently and systematically.
Market distortion	No concern	No competition between energy and other uses is envisioned for damaged crops.

2030/2050 Potential	2030 (global) : 224 million tonnes (i.e. 43 million tonnes of biomethane or 191 million tonnes of HVO), based on biowaste/food waste. 2050 (global) : 301 million tonnes (i.e. 57 million tonnes of biomethane or 256 million tonnes of HVO), based on biowaste/food waste.	No specific data could be found for the damaged crops to biomethane or HVO route. Current biowaste/food waste was used as proxy for conversion to biofuel.
Land demand	No concern	A market for damaged crops unfit for human and animal consumption is non existent. In the future one can expect that the commercial development of using biomass from damaged crops can develop. Should this happen, this can decrease the demand for land suitable for food production.
Processing Technologies	Mature (biomethane, bioethanol, biodiesel, HVO)	Damaged crops can be processed into biomethane or biofuels (ethanol, biodiesel, HVO) using mature technologies.

8. References

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Category 3 Animal fats

1. Technical description

1.1. Feedstock description

Animal products are separated at the slaughterhouse (abattoir) into parts that are fit for human consumption and those that are prohibited from entering the human food chain, collectively termed as Animal By-products (ABP). ABPs can also arise result of the mortality of non-meat animals (e.g. zoo animals).

In the EU, ABPs are categorised into three categories according to their potential risk, following the principles set out in Regulation (EC) 1069/2009.

Table 130 : Animal by-product classification (EFPRA, 2016a).

Category	Material included within category
Category 1 (Highest risk)	• Specified risk material linked to non-classical diseases like BSE & scrapie, this includes the bovine spinal cord and brain • Fallen stock (ruminants) • Any material handled with Category 1 is classified as automatically Category 1
Category 2	• Material not fit for human consumption • Fallen stock (non-ruminants)
Category 3 (lowest risk)	• Fit for human consumption at the point of slaughter • Animal products without a specified disease risk like egg shells, feathers, bristles and horns • Former foodstuffs and catering waste

When products of different categories are mixed, the entire mix is classified according to the lowest category in the mix (e.g. if Category 1 and 3 ABPs are mixed then this is classified as Category 1). It is not possible for Category 1 ABP to ever be reclassified to a higher category. Edible animal fats (i.e. for human consumption) are taken from the carcasses of animals at the slaugherhouse, but kept separate from other lower quality Category 3 material.

ABPs are treated via rendering to sterilise and stabilise animal material. Sterilisation kills harmful microorganisms thus eliminating disease risk. Stabilisation removes water to prevent any further decomposition of by-products and makes them suitable for storage and reprocessing for other uses.

Animal fats are one of the outputs of the rendering process (±12-15% share by mass), along with protein (±25%) and water (55-60%) (Alm, 2021). The output ratios are variable depending on both the type and quality of the material processed.

Animal fats include beef tallow, pork lard and poultry fats. This feedstock assessment focusses on Category 3 animal fats only. Note that the assessment of Category 2 and 3 ABP (not fats) is covered separately.

1.2. Production process

In Europe, most rendering plants have separate process lines to enable the processing of different categories of ABP material. Many rendering plants have typically not operated a dedicated Category 2 line and so the material has often treated in a Category 1 line instead, although there is reportedly a trend towards better segregation of Category 2 material due to increased demand for MBM as fertiliser (Ponseele 2021). In addition, Category 3 rendering plants most frequently operate multi-species lines, where mixed species are processed (e.g. ruminants and pork), or in some cases operate dedicated lines for specific species types or selected materials (e.g. bone fats, tallow, pig fats, pig skin fats). In Europe, poultry species are processed separately to other animal species[67].

A simplified overview of the rendering process is provided in Figure 1. The material is first subject to crushing or grinding using mincers, cutters or breakers to reduce its particle size. The material is then treatment at high temperature (typically at over 100 °C) and pressure to sterilise the material. This kills any pathogenic bacteria, viruses and other microorganisms that may be present.

Following this, the material is dried to remove the water content. Waste water needs to be treated prior to discharge. The residual material is pressed to produce animal fats and protein. Depending on the material category the protein is either classified as meat and bone meal (MBM) or processed animal protein (PAP). PAP is a biosecure feed ingredient with a high protein value arising from Category 3 material, whereas MBM arises from Categories 1 and 2 material and therefore cannot be used as a feed ingredient.

There are several approved rendering processes, known as 'Methods', that can be applied. The method specifies the core process temperature and pressure, and material residence time that material is treated. In the case of Category 3 ABPs, a particle size of between 20 and 150 mm in width and height needs to be treated at a temperature between 80 and 133 °C (Jędrejek et al., 2016).

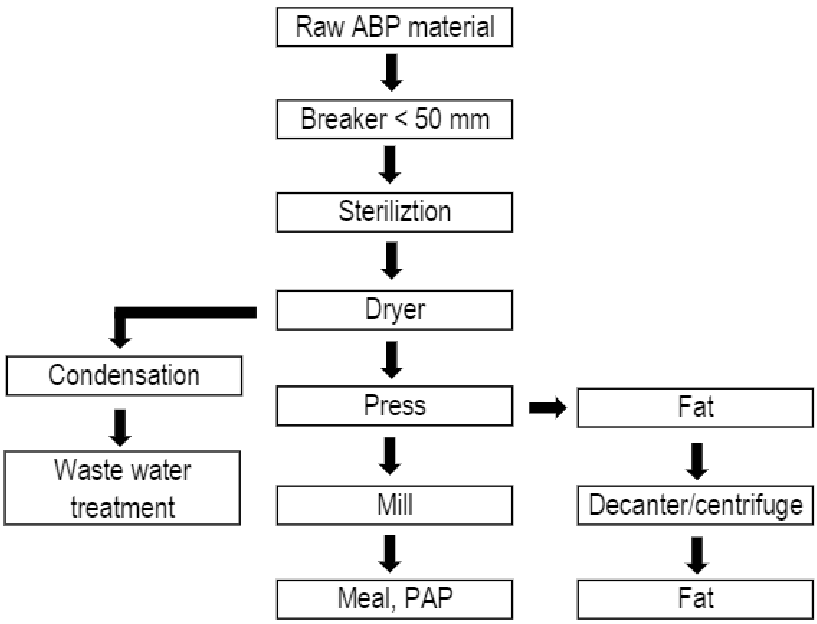

Figure 49. Rendering production flow chart for animal by-product (ABP) material. (Jędrejek et al., 2016).

1.3. Possible uses

Category 3 animals fats have multiple existing end-uses, as summarised in Table 2. These include use for energy, primarily as a feedstock for biofuel production (FAME or HVO) as well as a

[67] This is for historical reasons rather than any requirements stemming from the ABP Regulations.

combustion fuel at the rendering plant. The main non-energy uses are animal feed and oleochemicals, and to a lesser extent use in food (edible animal fats). (See also section 4.)

Use as feed is primarily as an ingredient in (terrestrial) animal feed and pet food, with small volumes also used as fish feed and feed for the fur industry).

Food grade animal fats include lard from pigs, beef dripping, goose and chicken fat. These are used to enhance the flavour of food, and are used in baked goods and as a frying agent. Animal fats reportedly contain significant levels of oleic acids and are a source of vitamins A, D, E and K (EFPRA, 2016b).

The oleochemical industry produces three commodity chemicals from Category 3 animal fats, these are fatty acids, fatty alcohols and glycerine (E4tech, 2016):

- Fatty acids are largely used for making soaps and detergents, other intermediates, plastics, rubber, paper, lubricants, coatings and resins, personal care items, food and candles.
- Fatty alcohols are used for soap and detergents, personal care items, lubricants and amines.
- Glycerine is used for soap, cosmetics and pharmaceuticals, alkyd resins, food, polyurethane, tobacco, explosives

Category 3 animal fats are not widely used as for a substrate for biogas production in Europe. Reported issues are the accumulation of long-chain fatty acids during the digestion process which may cause inhibition of the process, associated with the toxicity of a given number of fatty acids on anaerobic microorganisms. (Martinez et al. 2016; Marchetti et al., 2020)

Table 131 : Summary of possible uses of Category 3 animal fats.

	Food use	Feed use	Other uses
Category 3 animal fats (and Edible animal fats)	Documented evidence of commercial implementation.	Documented evidence of commercial implementation as animal feed and pet food, as well as fish feed and feed for the fur industry.	Biofuel: Documented evidence of commercial implementation, to produce both FAME and HVO. Process fuel: Documented evidence of commercial implementation as a process fuel at rendering plants. Oleochemicals: Documented evidence of commercial implementation.

2. Circular economy and waste hierarchy

2.1. Classification of the feedstock as a co-product, residue or waste

Category 3 animals fats arise as a consequence of the meat production process and from the need to process ABP at the slaughterhouse. They are not the primary aim of the overall production process, which is the production of meat for human consumption. This would suggest to categorise them as a residue.

However, Category 3 animals fats have multiple (non-energy) uses as indicated in Section 0, and command a high economic value. Animal fat prices are closely correlated to prices for vegetable oils, with Category 3 animal fats understood to realise a higher price than Category 1 animal fats. The average price for Category 1 animal fats in 2020 was 622 USD/t, which has increased to 768 USD/t for 2021 YTD in-line with rising vegetable oil prices. (Square Commodities, 2021).

On this basis, this suggests that they should rather be categorised as a co-product. A firm determination as a co-product or residue would require further interpretation of the RED II and additional research beyond the scope of this project.

Table 132 : Classification of Category 3 animal fats and Edible animal fats.

Evaluation question	Answer	Rationale
Is the feedstock the primary aim of the production process?	No	Meat production is the primary aim of the production process.
Does the feedstock have any economic value, but is not the primary aim of the process, and therefore a residue?	Yes	The feedstock has a high economic value. Category 1 animal fats traded at an average price of 622 USD/t during 2020, and the price for Category 3 animals fats is understood to be higher.
Is the feedstock normally discarded, and therefore a waste?	No	The feedstock is not normally discarded. It is utilised in multiple applications including oleochemicals, animal feed, pet food and human food (as well as in biofuel production).

2.2. Is the use of feedstock to produce biofuel/biogas in line with circular economy principles?

- **Does the feedstock have non-energy (re)uses, which could extend its life or sequester carbon for longer?**
  Answer: Yes.

  Rationale: Category 3 animal fats have multiple non-energy uses, including oleochemicals, animal feed, pet food.

- **Does its use as biofuel/biogas feedstock contribute to nutrient recovery?**

  Answer: No.

  Rationale: If Category 3 animal fats were used for biofuel production, there is no contribution to nutrient recovery. Use in biogas production would contribute to nutrient recovery although it is not understood to be a very suitable substrate.

  However, animal fats used for animal feed, pet food or human food would result in a direct use of nutrients.

- **Does its use as biofuel/biogas feedstock contribute to a more efficient use of resources by avoiding primary material extraction?**

  Answer: No.

  Rationale: Using Category 3 animal fats for biofuel or biogas production displaces fossil fuels, but this is not feedstock specific.

- **Does its use as biofuel/biogas feedstock contribute to reducing waste generation, especially food waste?**

Answer: No.

Rationale: Category 3 animal fats are already fully utilised

2.3. Is the use of this feedstock for biofuel/biogas production in line with the waste hierarchy?

Category 3 animal fats are considered a residue for the purpose of this assessment and therefore assessment against the waste hierarchy is not necessary.

2.4. Conclusion

Contribution to circular economy

Use for biofuel production is not in line with circular economy principles, since after combustion the material cannot be returned back to the value chain.

3. SUSTAINABILITY AND GREENHOUSE GASES

3.1. Union sustainability criteria

The Union sustainability criteria relate to agricultural field residues (Article 29(2)), agricultural biomass (Articles 29 (3) to (5)) and forestry biomass (Articles 29 (6) and (7)), and therefore do not apply to Category 3 animal fats which is classified as residue.

3.2. Potential GHG savings

Annex V of the REDII includes default values for FAME biodiesel and hydrotreated oil from animal fats from rendering of 78% and 77% respectively. These default values explicitly relate to biofuels produced from ABP products classified as Category 1 and 2 material in accordance with Regulation (EC) No 1069/2009, for which emissions related to hygenisation as part of the rendering are not considered. Actual value calculations would need to be applied for Category 3 animal fats. On the basis that Category 3 animals fats are process residues then hygenisation emissions would also be excluded from the scope of calculation. Non-compliance with the minimum GHG emission savings criteria of 65% for new installations is therefore also considered to be a low risk.

3.3. Other environmental impacts

Category 3 animal fats are secondary process residues and therefore have no land management impact. The evaluation of risks of adverse effects on soil, water, air and biodiversity is not applicable.

4. MARKET EFFECTS AND 2030/2050 POTENTIAL

4.1. Market effects

In the EU, over 20 million tonnes of ABPs emerge annually from slaughterhouses, plants producing food for human consumption, dairies and as fallen stock from farms. Around 18 million tonnes of this material was processed by rendering organisations that are members of the European Fat Processors and Renderers Association[68] (EFPRA)[69]. Although the overall volume of material produced has remained fairly stable over the past few years, the share of Category 3 animal fats

[68] EFRPA members are located in 27 European countries, including associate members. See: https://efpra.eu/efpras-members/

[69] EFPRA members represent around 90-100% of the European Category 1 and 2 market in Europe, and around 70-75% of the Category 3 market in Europe.

relative to Categories 1 and 2 material has increased (as illustrated in Figure 2). This is probably due to better segregation at the slaughterhouse.

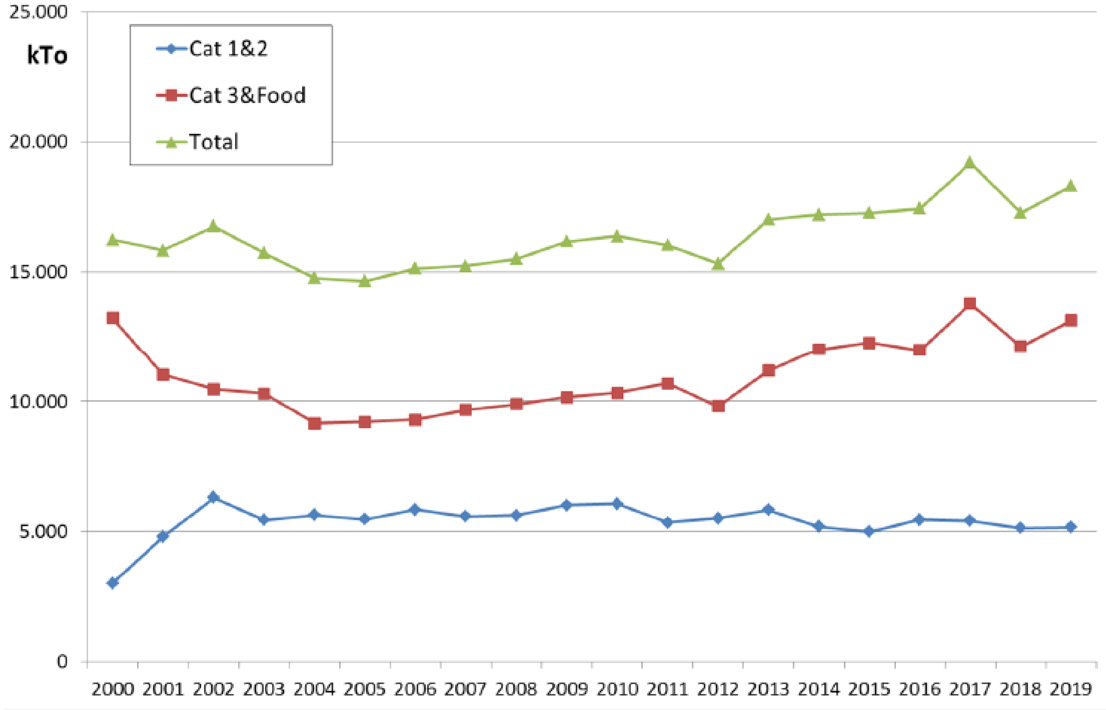

Figure 50. Development of ABP processing between 2000-2019 in 21 European countries (EFPRA, 2020).

The main producers in the EU are Germany and France (around 3 million tonnes each), with significant volumes also in Spain, Italy, the Netherlands and Poland (around 1.5 to 2 million tonnes each). The United Kingdom is also a key producer (around 1.5 million tonnes). (EFPRA, 2017)

EFPRA (2020) report that around 2.9 Mt of animal fats was generated by their members in 2019, of which 2.4 Mt was Category 3 animal fats (including edible fats). The corresponds to around 70-75% of the total EU supply, which implies that the overall supply is around 3.2 to 3.4 million tonnes.

The largest use of Category 3 animal fats was in biofuel production, followed by animal feed, oleochemicals and petfood. Other uses include human food and fuel for combustion. Negligible volumes of Category 3 animal fats were also used in fish feed and feed for the fur industry. (See **Figure 51**.)

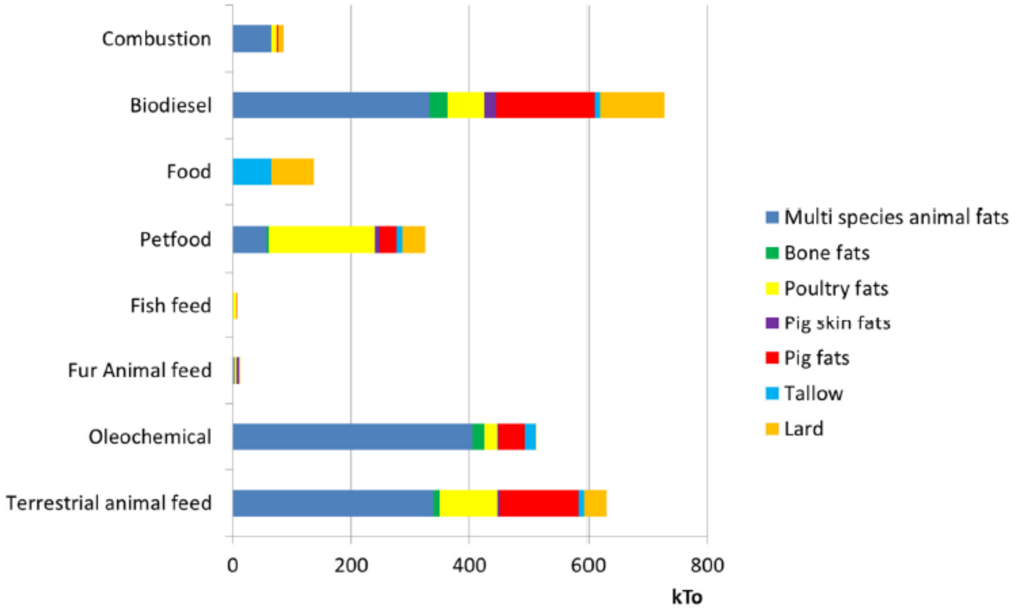

Figure 51. Destination of edible and Category 3 animal fat (EFPRA, 2020).

Use of Category 3 animal fats in biofuel production has steadily increased over time. In 2010, it was around 240 kt, while in 2019 over 700 kt was used (representing 30% of total supply). Use has exceeded 400 kt since 2015. Animal fats (all categories) represented 5% of the total feedstock mix in 2018 (Navigant, 2020).

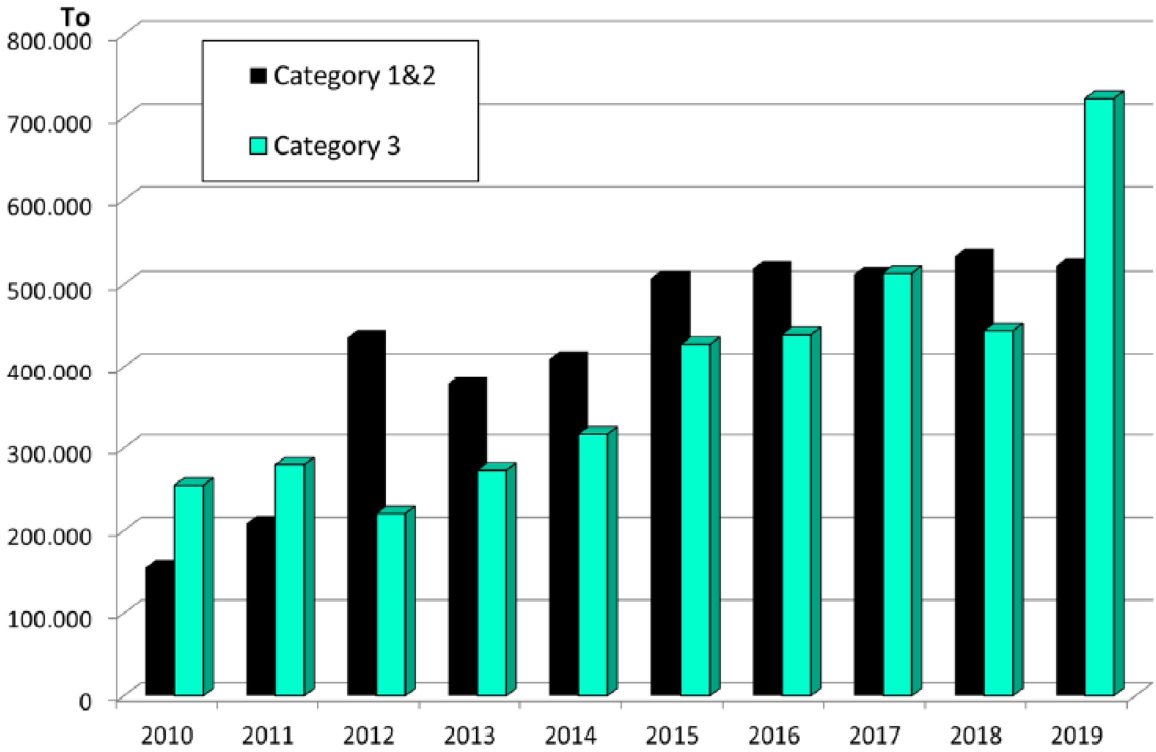

Figure 52. Use of animal fats in biofuel production (EFPRA, 2020).

The supply of animal fats is rigid and is directly related to the number of animals reared for meat (and to a lesser extent dairy) production. An increase in demand for animal fats would not result in more animals being raised. Increased demand of Category 3 animal fats for biofuel production would therefore lead to substitution with alternative oils.

In food and feed applications, vegetable oils would provide the closest substitutes, and with Category 3 animal fats and palm oil having similar fatty acid profiles and prices palm oil would be one possibility. Malins (2017) also suggest that a reduction in Category 3 animal fat availability could lead to a shift in feeding patterns and increased reliance on grains for energy. E4tech (Chudziak and Haye, 2016) identify palm and rapeseed as the most likely substitute oils (along with palm fatty acids).

In the oleochemicals industry, there has been a shift over the last decade from using European animal fats to using palm oil as feedstock (Chudziak and Haye, 2016). Palm oil is a preferred alternative to animal fats for these applications, as it has properties relatively similar to animal fats, and is generally the cheapest available virgin vegetable oil.

Given that the supply of Category 3 animal fats in the EU is rigid, further use of this feedstock for biofuel production is likely to have a high risk of distortive impacts on existing markets.

Global meat production in 2015-2016 stood 258 million tonnes, which realised an estimated 100 million tonnes of animal by-products (fats and protein). (MVO, 2016) Outside of the EU, the key regions of production are China, North and South America (in particular the U.S. and Brazil), as illustrated in **Figure 53** below.

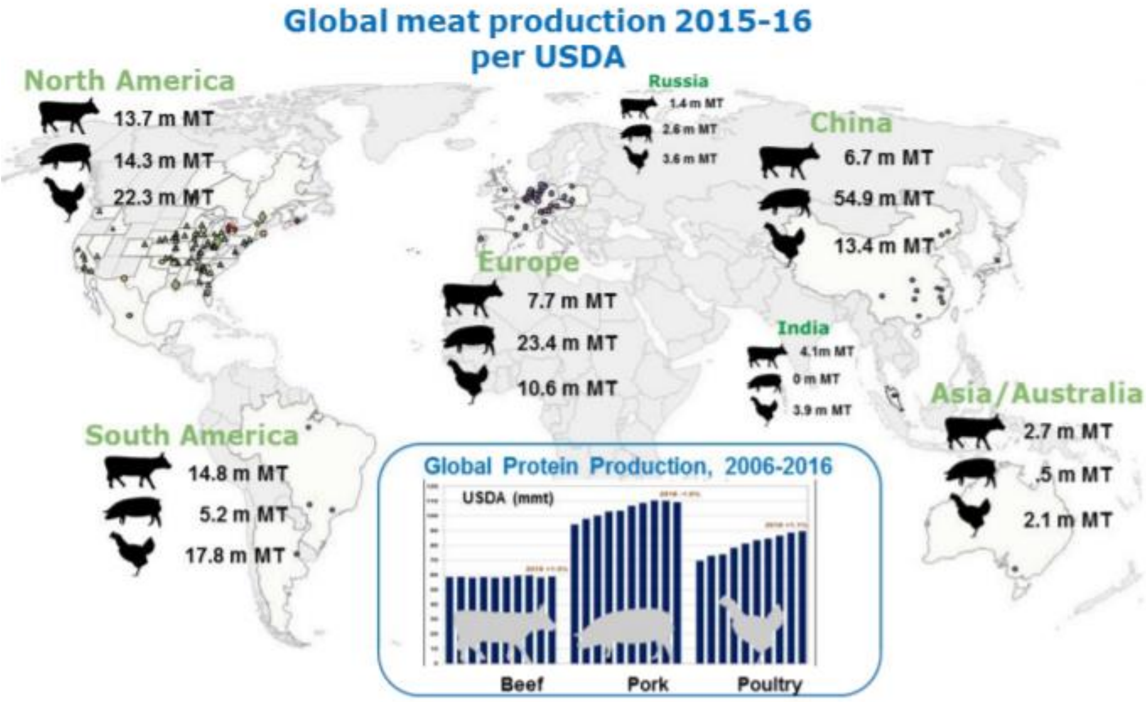

Figure 53. Global meat production 2015-2016 (MVO, 2016).

Export of animal fats to the EU is possible, but challenging due to differences in material treatment methods and handling rules in these markets. To illustrate, all of the animal fats consumed for biofuels production in the EU in 2018 were from reported as EU origin (Navigant, 2020)

Similar to the EU, animal fats are commonly used as animal feed and in the oleochemicals sector. As such, increased demand for biofuel production in the EU will also likely result in distortion to these existing markets.

4.2. 2030/2050 Potential

Meat consumption in the EU is set to decline from 68.7 kg to 67.6 kg retail weight per capita by 2030 (by around 1.6%), accompanied by changing consumer preferences, with consumption of beef continuing to decrease and poultry replacing pig meat. Total meat production is also set to be lower in 2030 by 2.3%. (European Commission, 2021) **The estimated supply is 2030 is 3.1-3.3 million tonnes.**

The longer term trend to 2050 is likely to show a further decrease in meat consumption in the EU driven by concerns over the environment and climate change, and with the increased availability of affordable non-meat substitutes. This will further limit the supply of animal fats.

Correspondingly, the supply of animal fats in the EU is also likely to decrease in the period to 2050 to an estimated 3.0-3.2 million tonnes[70].

While meat consumption has been relatively static in the developed world, annual per capita consumption of meat has doubled since 1980 in developing countries. Globally, world meat production is projected to double by 2050, most of which is expected in developing countries (FAO, 2019).

5. Additional demand for land

5.1. Assessment of additional demand for land

As identified in Section 4.1, the supply of animal fats is rigid. Section 4.1 also identified that Category 3 animal fats are used extensively in non-biofuel commercial applications, primarily oleochemical production and as feed, thus the increased use of Category animal fats in biofuel would lead to those other uses increasing consumption of substitute materials.

Palm and rapeseed oils were identified as the most likely substitutes for Category 3 animal fats diverted from these industries. The additional demand for land due to the increased demand for these substitute materials correspond with a high risk category for additional demand for land.

6. Processing technologies

6.1. Evaluation of processing technology (mature vs advanced)

Category 3 animal fats typically have a FFA content of 1-2%, which can increase to 5% during the summer months due to the oxidation[71]. Category 3 animal fats can therefore be transesterified to FAME biodiesel like other vegetable oils. Companies that are actively targeting the use of animal fats as a feedstock in Europe include the Argent Energy Group[72] and SARIA[73], although these companies also widely use lower quality Category 1 animal fats which typically have a FFA content of over 10%.

Animal fats can also be hydrotreated to produce HVO. ENI[74], Neste[75] and Total[76] are all reportedly using animal fats as a feedstock.

The processing of Category 3 animal fats into biofuel can be considered to be a mature technology.

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[70] Applying a consistent 2.3% reduction up to 2050.

[71] The FFA content in southern European countries is therefore also typically higher.

[72] Argent Energy Group operates three plants. Two in the United Kingdom (Motherwell and Stanlow) and one in the Netherlands (under the name of Biodiesel Argent – this was plant was acquired from Biodiesel Amsterdam in 2018).

[73] Operating under the ecoMotion and Estener names.

[74] https://www.eni.com/en-IT/operations/italy-gela-innovative-biorefinery.html

[75] https://www.neste.com/products/all-products/raw-materials/waste-and-residues#b5e7b9ca

[76] https://www.total.com/energy-expertise/projects/bioenergies/la-mede-a-forward-looking-facility

7. Conclusions

Table 133 : Summary of evaluation results.

	Evaluation Result	Rationale
Circular economy	No concern	No commercial uses exist that can extend product life and sequester carbon for longer than energy uses. Therefore, using Category 3 animal fats for biofuel/biogas production does neither contribute to, nor contravene circular economy principles. Use in biogas production would contribute to nutrient recovery although it is not understood to be a very suitable substrate.
Union sustainability criteria	Not applicable	These criteria are **not applicable** to Category 3 animal fats as this feedstock is neither primary agricultural biomass or agricultural field residue or forest biomass.
Sustainability GHG	No concern	Category 3 animals fats should realise GHG emission savings of around 80%.
Sustainability Others	Not applicable	This criteria is **not applicable** to Category 3 animal fats if this feedstock is categorised as a residue (from processing).
Market distortion	Significant concern	Most Category 3 animals fats are used for food/feed and are considered to have a rigid supply. Increased demand is likely to result in substitution with either palm oil or rapeseed oil in the food and feed sector. Palm oil is likely to be the substitute for use in the oleochemicals. <u>How to mitigate this concern?</u> Inclusion in Annex IXB (see below) would limit the amount of feedstock being used for FAME/HVO production. The contribution of Annex IXB feedstocks to national RED transport targets is capped at 1.7% of transport energy. Inclusion under this cap would limit the amount of feedstock likely to be used for biodiesel production and thus mitigate against the most market distortive outcomes, but would not fully prevent indirect impacts.

2030/2050 Potential	2030: 3.1-3.3 million tonnes (2.8-3 million tonnes FAME, 2.6-2.8 million tonnes HVO) 2050: 3.0-3.2 million tonnes (2.7-2.9 million tonnes FAME, 2.6-2.7 million tonnes HVO)	The current EU supply of Category 3 animal fats is estimated to be around **3.2-3.4 million tonnes**. However, supply is expected to decrease by around 2% in the period to 2050 in-line with reduced meat consumption, with a further decrease expected to 2050. **Significant volumes (700 thousand tonnes in 2019)** are already used in biofuels.
Land demand	Significant concern	The use of additional Category 3 animal fats for biofuel will divert this material from other existing uses, leading to additional demand for palm or rapeseed oil. The risk of additional demand for land for substitute materials has been assessed in previous studies and on that basis, the majority of Category 3 substitutes (palm and rapeseed) would fall in the **high risk category**. How to mitigate this concern? See market distortion.
Processing Technologies	Mature (biofuels)	Biodiesel production from Category 3 animals fats is already commercially practised and both transesterification and hydrotreating are considered **mature technologies**.

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Category 2 and 3 Animal by-products (not fats)

1. Technical description

1.1. Feedstock description

Animal products are separated at the slaughterhouse (abattoir) into parts that are fit for human consumption and those that are prohibited from entering the human food chain, collectively termed as Animal By-products (ABP). ABPs can also arise result of the mortality of non-meat animals (e.g. zoo animals).

In the EU, ABPs are categorised into three categories according to their potential risk, following the principles set out in Regulation (EC) 1069/2009.

Table 134 : Animal by-product classification (EFPRA, 2016a)

Category	Material included within category
Category 1 (Highest risk)	• Specified risk material linked to non-classical diseases like BSE & scrapie, this includes the bovine spinal cord and brain • Fallen stock (ruminants) • Any material handled with Category 1 is classified as automatically Category 1
Category 2	• Material not fit for human consumption • Fallen stock (non-ruminants)
Category 3 (lowest risk)	• Fit for human consumption at the point of slaughter • Animal products without a specified disease risk like egg shells, feathers, bristles and horns • Former foodstuffs and catering waste

When products of different categories are mixed, the entire mix is classified according to the lowest category in the mix (e.g. if Category 1 and 3 ABPs are mixed then this is classified as Category 1). It is not possible for Category 1 ABP to ever be reclassified to a higher category. Edible animal fats (i.e. for human consumption) are taken from the carcasses of animals at the slaugherhouse, but kept separate from other lower quality Category 3 material.

ABPs are treated via rendering to sterilise and stabilise animal material. Sterilisation kills harmful microorganisms thus eliminating disease risk. Stabilisation removes water to prevent any further decomposition of by-products and makes them suitable for storage and reprocessing for other uses.

Animal fats are one of the outputs of the rendering process (±12-15% share by mass), along with protein (±25%) and water (55-60%) (Alm, 2021). The output ratios are variable depending on both the type and quality of the material processed.

Depending on the material category the protein is either classified as meat and bone meal (MBM) or processed animal protein (PAP). PAP is a biosecure feed ingredient with a high protein value arising from Category 3 material, whereas MBM arises from Categories 1 and 2 material and therefore cannot be used as a feed ingredient.

This feedstock assessment focusses on protein only. The assessment of Category 3 fats is covered separately.

1.2. Production process

In Europe, most rendering plants have separate process lines to enable the processing of different categories of ABP material. Many rendering plants have typically not operated a dedicated Category 2 line and so the material has often been treated in a Category 1 line instead, although there is reportedly a trend towards better segregation of Category 2 material due to increased demand for MBM as fertiliser (Ponseele 2021). In addition, Category 3 rendering plants most frequently operate multi-species lines, where mixed species are jointly processed (e.g. ruminants and pork), or in some cases operate dedicated lines for specific species types or selected materials (e.g. bone fats, tallow, pig fats, pig skin fats). In Europe, poultry species are processed separately to other animal species[77], again with dedicated lines for selected materials (e.g. poultry feather meal).

A simplified overview of the rendering process is provided in **Figure 54**. The material is first subject to crushing or grinding using mincers, cutters or breakers to reduce its particle size. The material is then treatment at high temperature (typically at over 100 °C) and pressure to sterilise the material. This kills any pathogenic bacteria, viruses and other microorganisms that may be present.

Following this, the material is dried to remove the water content. Waste water needs to be treated prior to discharge. The residual material is pressed to produce animal fats and protein.

There are several approved rendering processes, known as 'Methods', that can be applied. The method specifies the core process temperature and pressure, and material residence time that material is treated. In the case of Category 3 ABPs, a particle size of between 20 and 150 mm in width and height needs to be treated at a temperature between 80 and 133 °C (Jędrejek et al., 2016).

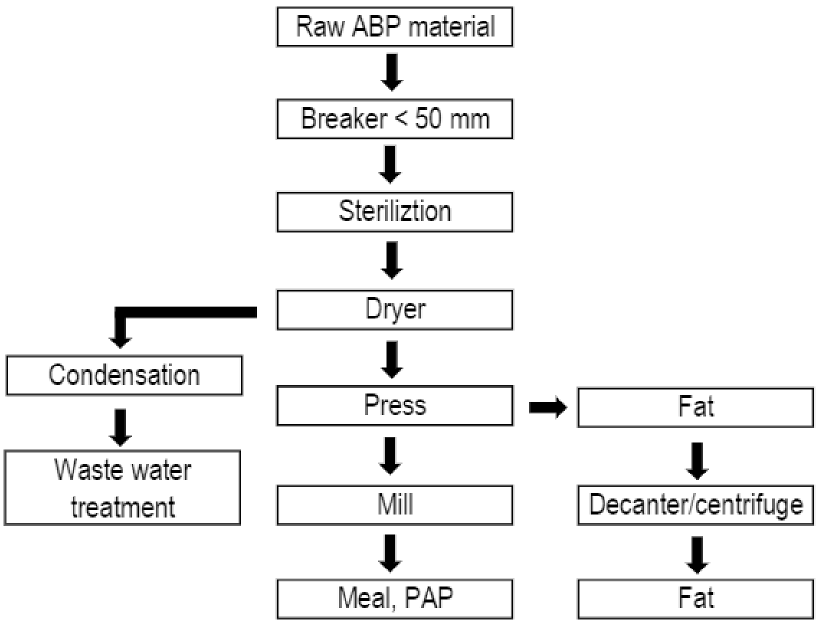

Figure 54. Rendering production flow chart for animal by-product (ABP) material. (Jędrejek et al., 2016)

An alternative method to the above "classical" rendering approach has been proposed by a leading rendering company, specifically for Category 2 ABP (although the approach can also presumably

[77] This is for historical reasons rather than any requirements stemming from the ABP Regulations.

be applied for Category 3 material). In this innovative route, the sterilisation process is completed by a subsequent separation of the Category 2 animal fat fraction. In addition to the Category 2 animal fat fraction, a slurry fraction remains that contains both the water and the proteins, which is referred to as animal by-products (not fat) Cat 2 material (Global rendering company, Personal communication).

1.3. Possible uses

Rendered Category 2 and 3 ABP (not fats) have multiple existing end-uses, as summarised in **Table 136**. Category 3 material is primarily used as an ingredient in pet food, fertilisers (as a source of Nitrogen and Phosphorous) and fish feed (non-ruminant ABP only). Other uses include animal feed, human food and feed for the fur industry. Category 2 material is primarily used as fertiliser. Importantly, it cannot be used in the food or feed sector, with the exception of the fur industry. Use of either Category 2 or 3 material as a process fuel is not considered to be common in the EU (it is for Category 1 material however). (See also section 4 for a more detailed overview.) Importantly, the ABP Regulations place restrictions on the possible uses of Category 2 (not fats), as indicated in **Table 135**.

The ABP Regulations permit the use of Category 2 and 3 ABP (not fats) for biogas production, although no specific evidence of widespread use could be identified in Europe (it is understood that digestate tracts were historically used in some anaerobic digestion plants). Specific issues relating to its use of this material as a substrate are the high ammonia and protein content, which can be toxic to the microorganisms (Alm, 2021). However, these issues could potentially be overcome using the innovative rendering method discussion in section 1.2. In this method, the energy content from the non-fat 2 material can be readily converted to biogas during digestion, and the resulting digestate used as a fertiliser. This reportedly has an additional advantage because it contains the digestate has a higher N/P/K fraction than the meal produced via classical rendering (Ponseele, 2021).

One example of use in biofuel production was identified, using poultry feather meal to produce FAME biodiesel. The company in question, Bio Tech Energy (2021), is located in Pakistan. The UK RTFO list of feedstock classification includes this feedstock under the entry, 'Poultry feather acid oil' (it was listed in July 2016). The feedstock description refers to "… the oil extracted from poultry feathers after acid treatment to remove edible protein", and furthermore states that, "This material is a waste if it can be demonstrated that there are no other non-energy uses for the material. Suppliers must also comply with relevant animal by-product regulations".

Table 135 : Summary of possible uses of Category 2 and 3 ABP (not fats)

	Food use	Feed use	Other uses
Category 2 animal by-products (not fats) – termed 'MBM'	None (not permitted).	Documented evidence of commercial implementation as feed for the fur industry and understood to be declining. (Ponseele, 2021)	Fertilisers: Documented evidence of commercial implementation. Process fuel: Documented evidence of commercial implementation as a process fuel at rendering plants (not understood to be common in Europe). Biogas: Innovative rendering method proposed that can more readily

			produce feedstock suitable for biogas production.
Category 3 animal by-products (not fats) – termed 'PAP'	Documented evidence of commercial implementation (in small volumes).	Documented evidence of commercial implementation as pet food, fish feed, animal feed, as well as feed for the fur industry.	Fertilisers: Documented evidence of commercial implementation. Biofuel: Documented evidence of commercial implementation, to produce FAME (one specific example only and restricted to poultry feathers in Pakistan). Process fuel: Documented evidence of commercial implementation as a process fuel at rendering plants (not understood to be common in Europe).

2. Circular economy and waste hierarchy

2.1. Classification of the feedstock as a co-product, residue or waste

ABP arise as a consequence of the meat production process and from the need to process ABP at the slaughterhouse. They are not the primary aim of the overall production process, which is the production of meat for human consumption. This would suggest to categorise them as residues.

However, Category 2 and 3 animal by-products have multiple (non-energy) uses as indicated in Section 1.3, and command a high economic value. In the US animal proteins comparable to Category 2 and 3 are trading across a wide range of 600 USD/t to over 1,000 USD/t depending on the material. Poultry by-product meal for pet food is trading at around 800 USD/t and both bloodmeal and chicken meal are trading at over 1,000 USD/t[78] (The Jacobsen, 2021). On this basis, this would suggest to categorise Category 2 and 3 ABP (not fats) as a co-product. A firm determination as a co-product or residue would require further interpretation of the RED II and additional research beyond the scope of this project.

Table 136 : Classification of Category 2 and 3 ABP (not fats)

Evaluation question	Answer	Rationale
Is the feedstock the primary aim of the	No	Meat production is the primary aim of the production process.

[78] All prices are on an FOB basis.

production process?		
Does the feedstock have any economic value, but is not the primary aim of the process, and therefore a residue?	Yes	The feedstock has a high economic value. Category 2 and 3 animal proteins are currently trading at between 600 and 1,200 USD/t in the U.S..
Is the feedstock normally discarded, and therefore a waste?	No	The feedstock is not normally discarded. It is utilised in multiple applications including pet food, fertiliser production and fish feed.

2.2. Is the use of feedstock to produce biofuel/biogas in line with circular economy principles?

- **Does the feedstock have non-energy (re)uses, which could extend its life or sequester carbon for longer?**
  Answer: Yes.

  Rationale: Category 2 and 3 ABP (not fats) have multiple established non-energy uses, including pet food, fertilisers, fish feed, animal feed and human food.

- **Does its use as biofuel/biogas feedstock contribute to nutrient recovery?**

  Answer: No.

  Rationale: If Category 2 and 3 ABP (not fats) were used for biofuel production, there is no contribution to nutrient recovery. A possible exception is if fats can be separated from the edible proteins prior to conversion to biofuel, without compromising the nutritional quality of the material. Use in biogas production would contribute to nutrient recovery although it is not understood to be a very suitable substrate.

  However, animal fats used for pet food, animal feed, fish feed or human food would result in a direct use of nutrients.

- **Does its use as biofuel/biogas feedstock contribute to a more efficient use of resources by avoiding primary material extraction?**

  Answer: No.

  Rationale: Using Category 2 and 3 ABP (not fats) for biofuel or biogas production displaces liquid fossil fuels and natural gas, but this is not feedstock specific.

- **Does its use as biofuel/biogas feedstock contribute to reducing waste generation, especially food waste?**

  Answer: No.

  Rationale: Category 2 and 3 ABP (not fats) are already fully utilised in existing markets.

2.3. Is the use of this feedstock for biofuel/biogas production in line with the waste hierarchy?

Category 2 and 3 ABP (not fats) are considered a residue for the purpose of this assessment and therefore assessment against the waste hierarchy is not necessary.

2.4. Conclusion

Contribution to circular economy

There is no demonstrated commercial use of Category 2 and 3 ABP (not fats) for material/chemical purposes, which could ensure a significantly longer life time and/or carbon sequestration than energy uses (biogas, bioethanol and biodiesel), which can therefore be considered in line with circular economy principles.

3. SUSTAINABILITY AND GREENHOUSE GASES

3.1. Union sustainability criteria

The Union sustainability criteria relate to agricultural field residues (Article 29(2)), agricultural biomass (Articles 29 (3) to (5)) and forestry biomass (Articles 29 (6) and (7)), and therefore do not apply to Category 2 and 3 ABP (not fats) which are classified as residues.

3.2. Potential GHG savings

The REDII includes default values for biofuel production (FAME and HVO) from Category 1 and 2 animal fats only, but not for other ABP materials. The UK RTFO Statistics published by the UK Department for Transport (2020) are proposed as an alternative data source. Actual GHG emission savings for FAME biodiesel produced from poultry feather acid oil (Pakistani origin) are shown to range from 83-90% between 2016 and 2019. The GHG savings criteria for new installations require at least 65% GHG savings. Therefore, compliance with GHG savings criteria is expected.

No specific data was identified for using ABPs for biogas production.

3.3. Other environmental impacts

Category 2 and 3 ABP (not fats) are secondary process residues and therefore have no land management impact. The evaluation of risks of adverse effects on soil, water, air and biodiversity is not applicable.

4. MARKET EFFECTS AND 2030/2050 POTENTIAL

4.1. Market effects

In the EU, over 20 million tonnes of ABPs emerge annually from slaughterhouses, plants producing food for human consumption, dairies and as fallen stock from farms. Around 18 million tonnes of this material was processed by rendering organisations that are members of the European Fat Processors and Renderers Association[79] (EFPRA)[80]. Although the overall volume of material produced has remained fairly stable over the past few years, the share of Category 3 animal fats relative to Categories 1 and 2 material has increased (as illustrated in **Figure 55**). This is probably due to better segregation at the slaughterhouse.

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[79] EFRPA members are located in 27 European countries, including associate members. See: https://efpra.eu/efpras-members/

[80] EFPRA members represent around 90-100% of the European Category 1 and 2 market in Europe, and around 70-75% of the Category 3 market in Europe.

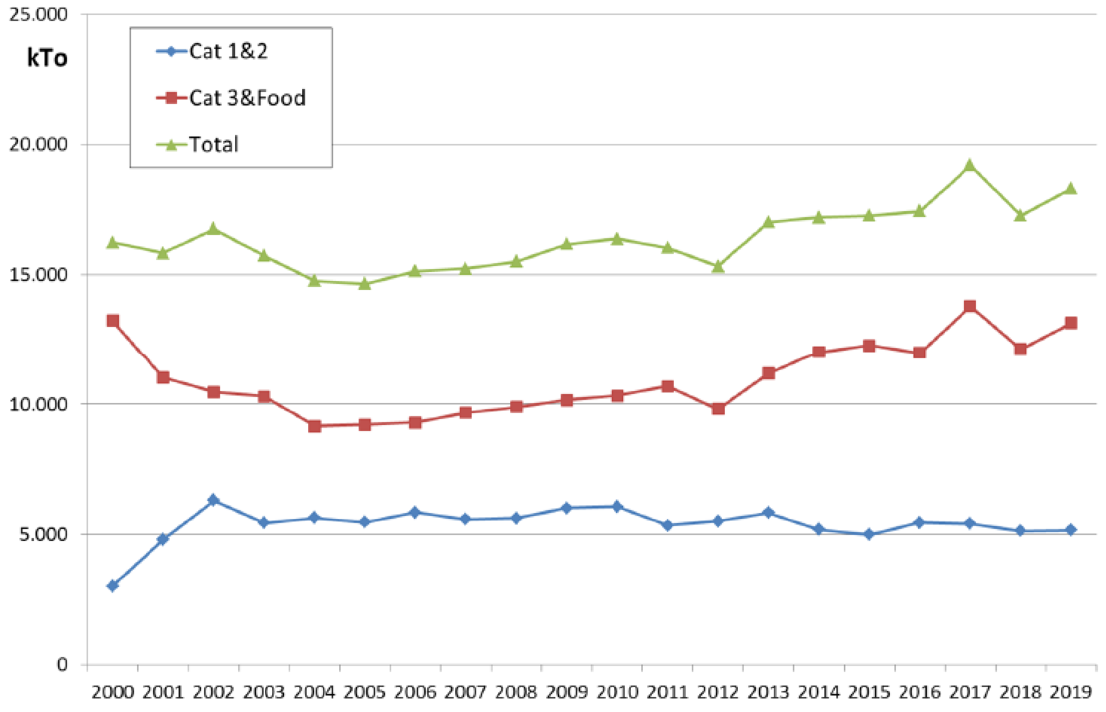

Figure 55. Development of ABP processing between 2000-2019 in 21 European countries (EFPRA, 2020).

The main producers in the EU are Germany and France (around 3 million tonnes each), with significant volumes also in Spain, Italy, the Netherlands and Poland (around 1.5 to 2 million tonnes each). The United Kingdom is also a key producer (around 1.5 million tonnes). (EFPRA, 2017)

EFPRA (2020) report that around 4 Mt of protein (PAP and food grade) was generated by their members in 2019, of which 0.2 Mt was Category 2 protein (MBM). The corresponds to around 70-75% of the total EU supply and 90-100% of the Category 2 supply, which implies that the overall supply is around 5.3 to 5.7 million tonnes.

Figure 56 below provides a summary of the current uses for Categories 1 and 2 ABP (not fats) – also termed MBM. Use in fertiliser production is the main use for Category 2 ABP (not fats), either pure or as an ingredient in a compound fertiliser. Use of MBM in biofuels or biogas production is not reported.

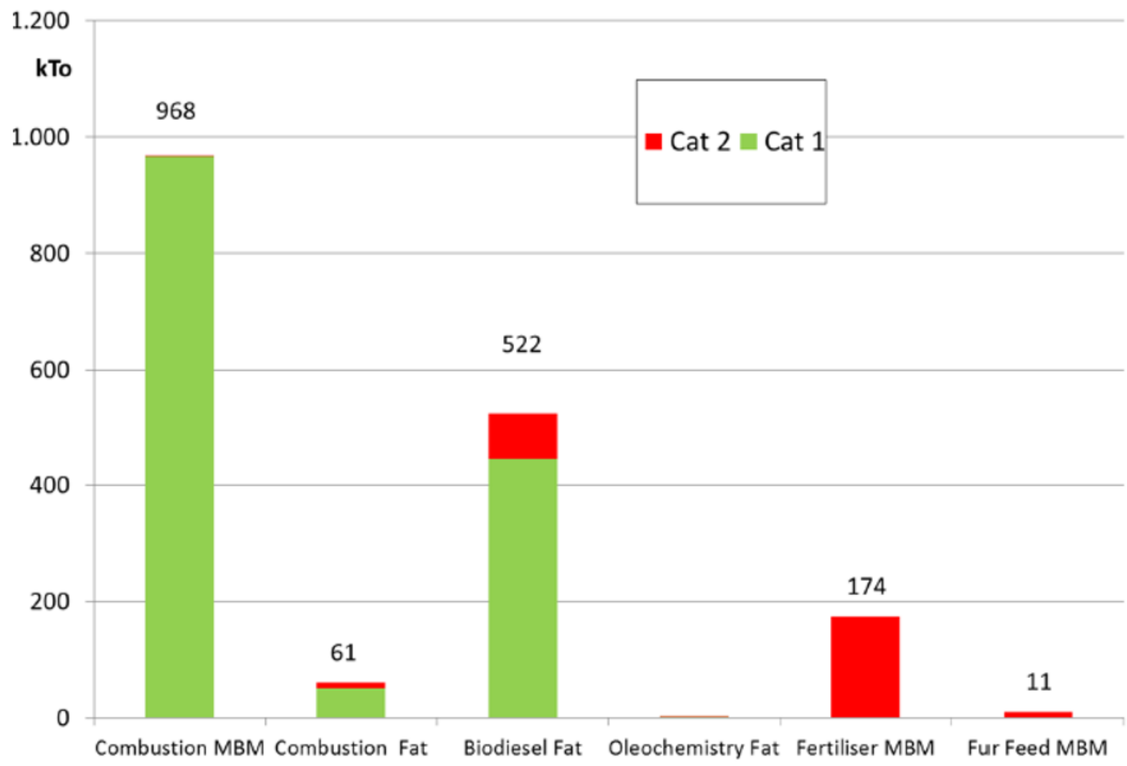

Figure 56. Category 1 and 2 protein (MBM) use (EFPRA, 2020).

In 2019, the largest use of Category 3 and food grade proteins within the EU was in pet food (2.05 million), followed by use as fertiliser (0.53 million tonnes) and fish feed (0.31 million tonnes). Other uses include animal feed, feed for the fur industry and human food. (See **Figure 58**.) In addition, almost 1 million tonnes of protein was exported, amounting to 30% of the total multi-species material. Use of PAP in biofuels or biogas production is not reported.

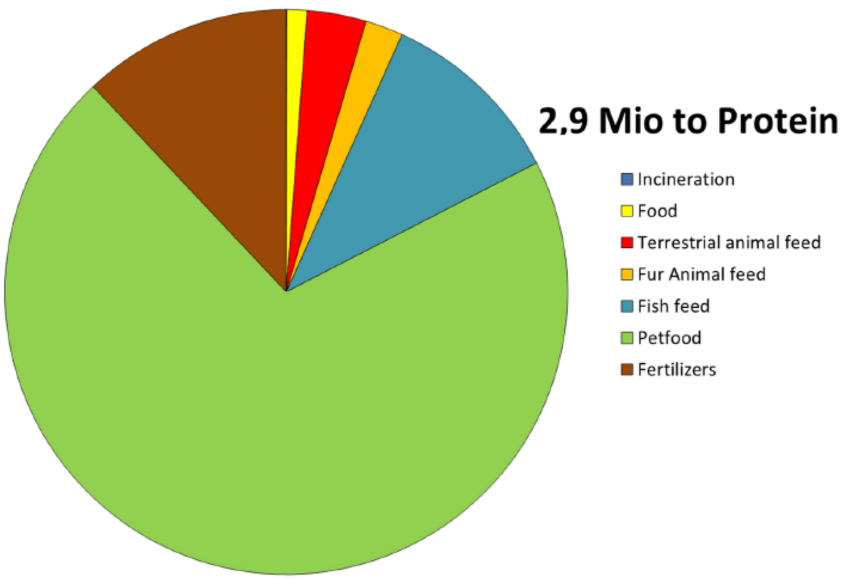

Figure 57. Category 3 protein (PAP) and Food grade protein use (EFPRA, 2020).

Figure 58 below shows the uses of Category 3 protein (PAP) and Food grade protein for each ABP category type. (Poultry) feather meal was primarily used as pet food and fish feed. Use as fish feed increased by 30% on the previous year, and now accounts for 70% of all ABP proteins used in this sector.

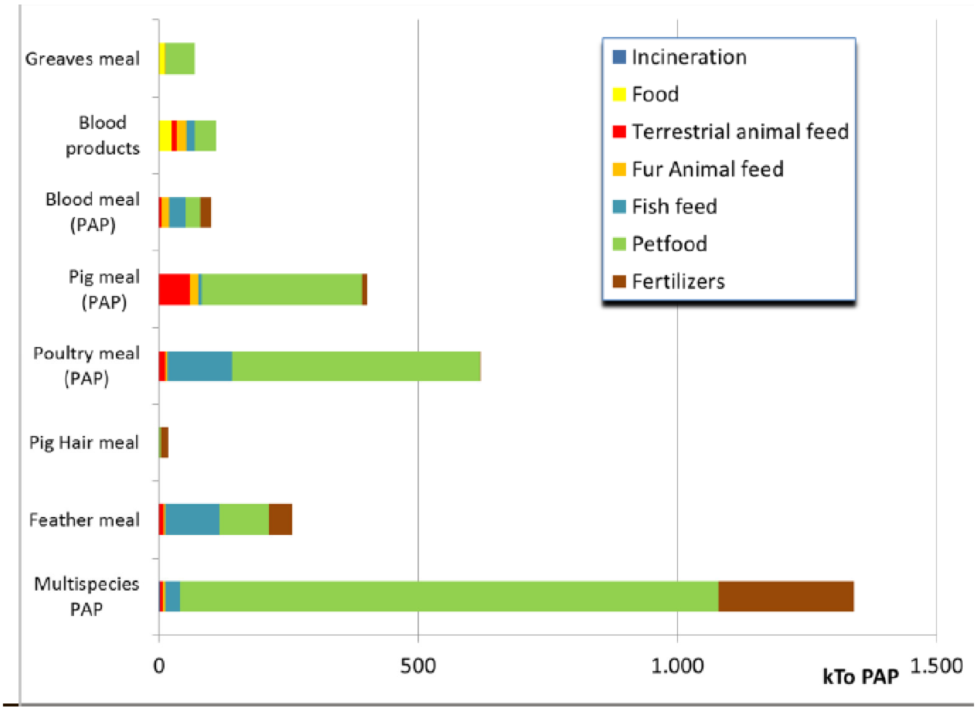

Figure 58. Category 3 protein (PAP) and Food grade protein use (EFPRA, 2020).

The supply of animal fats is rigid and is directly related to the number of animals reared for meat (and to a lesser extent dairy) production. An increase in demand for animal fats would not result in more animals being raised. Increased demand of Category 2 and 3 ABP for biofuel production would therefore lead to substitution with alternatives.

In food and feed applications (primarily relevant for Category 3 material since use of Category 2 material is restricted), meals produced from vegetable oils would provide the closest substitutes. Soy meal is seen as the most likely substitute as it has a high protein composition. Diversion away from use as fertiliser would likely result in increased use of synthetic fertilisers. Although, if ABP (non-fats) are used to produce biogas, as proposed for Category 2 material using the innovative rendering approach, then the resulting digestate can be alternatively applied as fertiliser.

Given that the supply of Category 2 and 3 ABP in the EU is rigid, further use of this feedstock for biofuel production is likely to have a high risk of distortive impacts on existing markets.

Global meat production in 2015-2016 stood at 258 million tonnes, which realised an estimated 100 million tonnes of animal by-products (fats and protein) (MVO, 2016), of which 8.5 million tonnes corresponds to poultry feather waste (Purandaradas 2018). Outside of the Europe, the key regions of production are China, North and South America (in particular the U.S. and Brazil), as illustrated in **Figure 59** below.

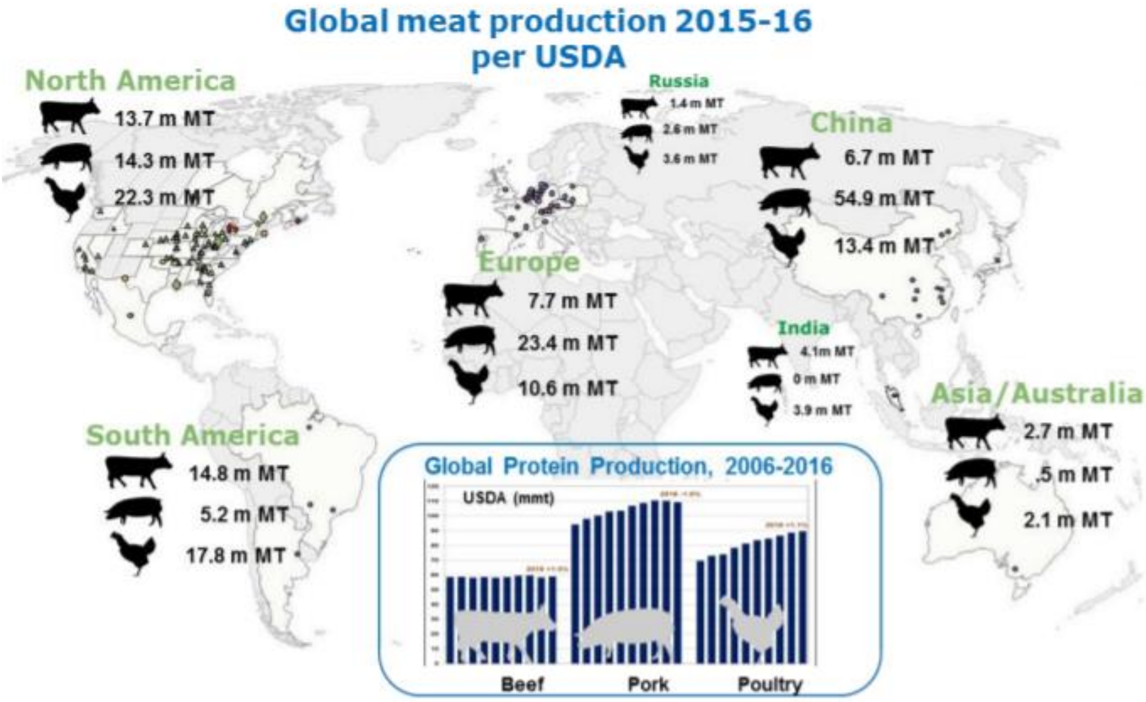

Figure 59. Global meat production 2015-2016 (MVO, 2016).

Outside of Europe, animal proteins are commonly used as animal feed and fertiliser in other geographies (such as North and South Americas). As such, increased demand for biofuel production in the EU will also likely result in distortion to these existing markets.

With respect to poultry feather waste, Purandaradas (2018) indicate that current uses also include landfilling, composting and incineration. Purandaradas (2018) propose to use some of this resource as a feedstock for biofuel production. This may prove to be a viable solution if edible proteins can be extracted from the material prior to conversion to biofuel without compromising the nutritional quality of the material to ensure that the needs of the animal feed market can still be met.

4.2. 2030/2050 Potential

Meat consumption in the EU is set to decline from 68.7 kg to 67.6 kg retail weight per capita by 2030 (by around 1.6%), accompanied by changing consumer preferences, with consumption of beef continuing to decrease and poultry replacing pig meat. Total meat production is also set to be lower in 2030 by 2.3%. (European Commission, 2021) **The estimated supply is 2030 is 5.2-5.6 million tonnes.**

The longer term trend to 2050 is likely to show a further decrease in meat consumption in the EU driven by concerns over the environment and climate change, and with the increased availability of affordable non-meat substitutes. This will further limit the supply of animal fats.

Correspondingly, the supply of animal fats in the EU is also likely to decrease in the period to 2050 to an estimated 4.90-5.3 million tonnes[81].

While meat consumption has been relatively static in the developed world, annual per capita consumption of meat has doubled since 1980 in developing countries. Globally, world meat

[81] Applying a consistent 2.3% reduction up to 2050.

production is projected to double by 2050, most of which is expected in developing countries (FAO, 2019).

5. ADDITIONAL DEMAND FOR LAND

5.1. Assessment of additional demand for land

As identified in Section 4.1, the supply of animal fats is rigid. Section 4.1 also identified that Category 2 and 3 ABP (not fats) are used extensively in non-biofuel commercial applications, primarily fertilisers, in pet food and as feed (primarily relevant for Category 3 material use as feed). Thus the increased use of these materials in biofuel would lead to those other uses increasing consumption of substitute materials.

Soy meal was identified as the most likely substitute for Category 2 and 3 ABP (not fats) diverted from feed or food use. The additional demand for land due to the increased demand for these substitute materials correspond with a medium risk category for additional demand for land.

6. PROCESSING TECHNOLOGIES

6.1. Evaluation of processing technology (mature vs advanced)

As indicated in section 1.3, poultry feather meal was identified as an example of a feedstock that can be used for FAME biodiesel production. We are only aware of the company Bio Tech Energy using this feedstock. The company operates a 45 kt/yr multi-feedstock plant in Pakistan that is capable of processing waste oils with up to 100% FFA and 600 ppm sulphur. Waste animal oils can range between 0.5% and 15% FFA. The biodiesel reportedly meets the EN14214 standard. Bio Tech has supplied the UK market since 2017, albeit in in relatively small volumes (and likely also to other European markets).

Limited details of the process are provided by Bio Tech, other than it is indicated that a pre-esterification step is included, followed by trans-esterification and distillation steps. Presumably there is also first a pre-treatment step to separate out the oil from the meal to leave edible protein that can be used for animal feed. It is understood that an alkaline hydroxide solution is used (e.g. potassium or sodium hydroxide).

Purandaradas (2018) indicate that an acid catalyst is preferred in the transesterification step. This study also concluded that rooster feathers have superior potential to process them into biodiesel than broiler chicken feathers fat because of their higher fatty acid composition values. Das (2013) states that methoxide should be used as a catalyst and that methanol is a suitable solvent for the process. Karlapudi (2015) also clarify that feather meal needs to be washed several times with distilled water to remove dirt and extraneous impurities. The fat is extracted from the solution by centrifuge.

Biofuel produced from fats extracted from Category 2 ABP would be counted under Annex IX Part B[82]. Category 3 fats are currently not covered in Annex IX. An assessment of their eligibility for inclusion in Annex IX can be found in a separate assessment.

Category 2 and 3 ABP (not fats) have been proposed by several stakeholders as candidate feedstocks for anaerobic digestion, which can be considered to be a mature technology. However, we have not identified widespread examples of commercial application in Europe. As indicated in 1.3 it is understood that digestate tracts were historically used in some anaerobic digestion plants. Specific issues relating to the use of this material are the high ammonia and protein content, which can be toxic to the microorganisms (Alm, 2021).

[82] Animal fats classified as categories 1 and 2 in accordance with Regulation (EC) No 1069/2009.

The innovative rendering process discussed in section 1.2 aims to overcome these issues. The reported yield from 1,000 tonnes ABP is approximately 130 tonnes animal fats and 870 tonnes ABP (not fat), which can be used to produce 120,000 Nm^3 biogas (equivalent to a renewable energy content of 710 MWh). The renewable energy yield of the process is the process is 0.82 MWh per tonne (Ponseele, 2021).[83]

7. Conclusions

Table 137 : Summary of evaluation results.

	Evaluation Result	Rationale
Circular economy	No concern	No commercial uses exist that can extend product life and sequester carbon for longer than energy uses. Therefore, using Category 2 and 3 ABP (not fats) for biofuel/biogas production does neither contribute to, nor contravene circular economy principles. Use in biogas production would contribute to nutrient recovery although it is not understood to be a very suitable substrate.
Union sustainability criteria	Not applicable	These criteria are **not applicable** to Category 2 and 3 ABP (not fats) as this feedstock is neither primary agricultural biomass or agricultural field residue or forest biomass.
Sustainability GHG	No concern	Category 2 and 3 ABP (not fats) should realise GHG emission savings of around 80%.
Sustainability Others	Not applicable	This criteria is **not applicable** to Category 2 and 3 ABP (not fats) if this feedstock is categorised as a residue (from processing).
Market distortion	Category 3: Significant concern Category 2: Some concern	Category 2 and 3 ABP (not fats) are considered to have a rigid supply. Increased demand is likely to result in substitution with soy meal in the food and feed sector (this risk is primarily for Category 3 material since use of Category 2 material is restricted). **Use for biofuel production may be possible under specific conditions, for example** if fats can be separated from the edible proteins prior to conversion to biofuel, without compromising the nutritional quality of the material (for example by "washing out" the fats using an alkaline hydroxide solution). Alternatively, it

[83] The figures provided could not be cross-checked with public literature.

		has been proposed to apply an innovative rendering method (for Category 2 material), which produces both a fat fraction and a slurry fraction which can be used for biogas production Synthetic fertilisers would likely replace use as fertiliser, unless the material is used to produce biogas (as proposed for Category 2 material), in which case the digestate can be alternatively applied as fertiliser.
2030/2050 Potential	2030: 5.2-5.6 million tonnes (no reliable data for FAME, 0.1 million tonnes of biogas – assuming 100% innovative rendering method for Category 2 applied) 2050: 4.9-5.3 million tonnes (no reliable data for FAME, 0.1 million tonnes of biogas – assuming 100% innovative rendering method for Category 2 applied)	The current supply of Category 2 and 3 ABP (not fats) in Europe is around **5.3-5.7 million tonnes**. This is expected to decrease by around 2% in the period to 2030 in-line with reduced meat consumption, with a further decrease expected to 2050.
Land demand	Category 3: Significant concern Category 2: Some concern	The use of additional Category 2 and 3 ABP (not fats) for biofuel or biogas will divert this material from other existing food and feed uses, leading to additional demand for soy (this risk is primarily for Category 3 material). The risk of additional demand for land for substitute materials has been assessed in previous studies (Biggs, 2016) and on that basis, this would fall in the **medium risk category**. The overall risk is considered **medium-high**. <u>How to mitigate this concern?</u> See market distortion.
Processing Technologies	Advanced (biofuels produced using oil extracted from poultry feather meal) Mature (biogas)	Biodiesel production from Category 2 and 3 ABP (not fats) is already commercially practised, but only one specific example has been identified in Pakistan. The overall process is considered to be an **advanced technology**[84]. Category 2 and 3 ABP (not fats) have

[84] Note that biofuel produced from Category 2 ABP (fat) would be counted under Annex IX Part B. See previous section for an assessment of the eligibility of biofuel produced from Category 3 ABP (fat).

		been proposed by several stakeholders as candidate feedstocks for anaerobic digestion, which can be considered to be a **mature technology**. However, we have not identified widespread examples of commercial application in Europe.

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Municipal wastewater and derivatives (other than sludge)

1. TECHNICAL DESCRIPTION

1.1. Feedstock description

[This feedstock assessment should be read in conjunction with brown grease.]

The assessment of municipal wastewater and derivatives (other than sewage sludge) includes derivatives extracted from municipal wastewater, such as fats, oils and greases (FOG). This feedstock is sometimes referred to as black grease, to differentiate it from brown grease which is collected in grease traps prior to discharge to the sewers. Note that this feedstock category does not include sewage sludge as this is already included in Annex IX under Part A, point (f).

FOG discharge to the sewers can arise from multiple sources, and then continues through the sewer system until it reaches the wastewater treatment plant (sewage treatment works), as indicated in **Figure 60**.

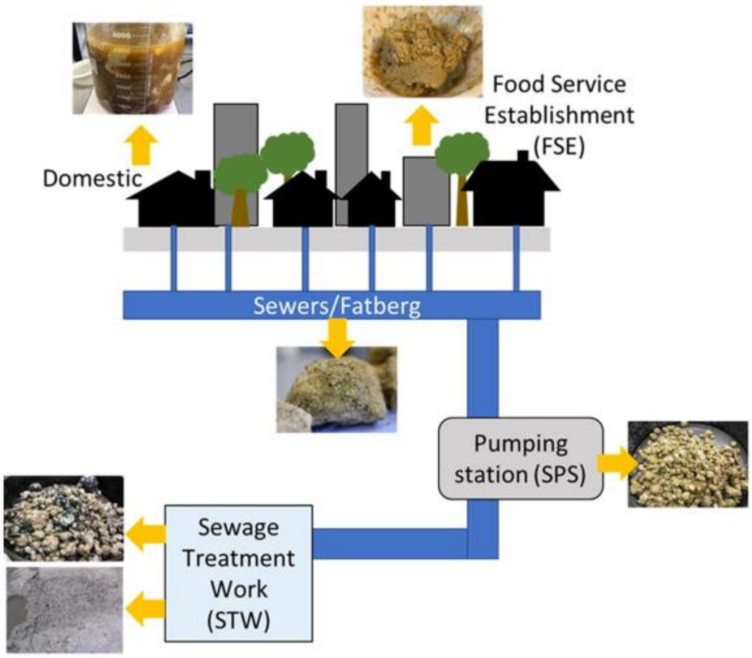

Figure 60. (Collin et al., 2020)

Commercial sources are the main contributor, and FOG within sewers is generally located in areas where commercial premises dominate. Sources primarily include food service establishments (FSE) such as pubs, restaurants, hotels, cafes and takeaways, in locations where grease traps are not widely installed. Domestic sources can also be a major contributor to FOG at certain times of the year, such as the Christmas holiday period. Industrial sources, such as slaughterhouses, rendering plants, and food processors and manufacturers, may also contribute to FOG, although effluent discharge from these sources is generally strictly controlled. (Arthur and Blanc, 2013)

The composition of FOG within the sewer system is variable. A study by Williams et al. (2012) found that the physical characteristics and melting point of FOG collected different distances into the sewer system and from sewage treatment works and pumping stations were similar, but their moisture content was noticeably different. FOG collected at sewage treatment works had higher moisture content. They also found significant differences in the proportions of oil in the FOG deposit, with pumping stations having a mean of about 18%, sewers 9% and sewage works 1.2%. (Arthur and Blanc, 2013)

1.2. Production process

FOG waste causes a number of problems on entering the wastewater system. It can accumulate in the sewer and congeal with other non-flushable waste, such as wet wipes[85], nappies, tampons and cotton buds. This clogs the system by restricting capacity or blocking and damaging pipes. In extreme cases these blockages are referred to as 'fatbergs', a notable example being the Whitechapel fatberg in London which 250 metres in length and weighed 130 tonnes (see Figure 61). These blockages can lead to sanitary sewer overflows, property flooding and contamination of water bodies with sewage. In the UK alone there are 366,000 sewer blockages every year, 70% caused by FOG, with water companies estimating a total cost of £90 million to unblock (SwiftComply, 2019). Excess FOG entering the system may also result in additional capacity and energy requirements at wastewater treatment works to handle.

Figure 61. Section of the Whitechapel fatberg in London (BBC, 2018).

FOG blockages in the sewers have to be either dug out by hand or broken down into smaller pieces using high pressure jets of water jets which process over 45 litres per minute, at a pressure of over 200 bar. The broken up fatberg pieces either continue through to the sewer system, or are otherwise removed from the pipe by manual excavation, powerful vacuumation tanker units, or a combination of both. (Lanes for Drains, no date). This is a very labour intensive job undertaken by specialist companies, and carries significant health and safety risks due to the cramped conditions and toxic nature of the material. FOG collection is typically reactive, however collection from known 'hot spots' of high deposition may be an option allowing recovery for further processing. For example, FOG is collected from sewer pinch-points in London to be used for fuel production by Thames Water at Beckton power station (Arthur and Blanc, 2013).

FOG that continues through the sewer system is separated at the wastewater treatment plant (WWTP) in the skimming tanks, at the first stage of treatment. Additional techniques to remove FOG in WWTPs include dissolved air flotation, centrifugation, filtration, biological removal and ultrafiltration. The FOG that is not removed in the primary skimming tanks can cause blockages in the plant infrastructure causing impedance of treatment processes such as disruption of settlement and clarification facilities. These issues lead to increased operational and maintenance costs. (Wallace et al, 2017)

[85] Research carried out by Water UK showed that wet wipes typically comprise over 90% of the material causing the blockage. (Aqua Tech, 2019).

The EU RecOil Project estimated that 25% of sewage treatment costs can be attributed to the FOG component. The slow degradation of FOG in WWTPs can also affect the activity of micro-organisms at the plant by preventing the transfer of oxygen or slowing down the degradation of other organic material. Failure to remove the FOG can result in its discharge with treated water. (Wallace et al., 2017)

1.3. Possible uses

There are a number of options available for the use of recovered FOG including landfill, land application, composting, rendering for manufacturing lubricants or industrial soaps, incineration (presumably if dewatered), anaerobic co-digestion or biodiesel production. (Arthur and Blanc, 2013) The option applied is likely to be very location specific. For example, in some geographies land application may be prohibited or otherwise restricted.

FOG waste once stabilized is typically disposed of in landfill. Land application is an alternative option, however this is strictly regulated which will limit its potential for disposing in significant volumes. Composting may produce a final product that can be sold for use on the land and will also reduce the potential for methane that would have been produced if the recovered FOG had been landfilled. (Arthur and Blanc, 2013)

One potential option under evaluation is to use collected FOG waste from grease traps, sewers or WWTW as a second feedstock for digestion along with sewage sludge. However, there are operational difficulties that need to be considered (see section 6).

FOG material collected from fatbergs, or from WWTW can be used as a potential feedstock for biofuel production, as practiced by Argent Energy in the UK. The oil content can reportedly make up 40% of the fatberg content (BBC, 2017; UK Grease Traps Direct (2019), however its quality is low and will vary according to the location. An analysis of the Whitechapel fatberg showed a significant share of long chain free fatty acids (53% palmitic, 18% oleic), along with significant concentrations of metal ions, such as calcium. (Cranfield Water Science Institute, 2018) Also, as discussed in section 1.2 FOG can also be used as a feedstock for electricity production.

Finally, in China, FOG collected from the sewers (grease traps or other sources) has previously been resold for cooking purposes (so called 'gutter oil'). This practice has been outlawed for several years, although it may still occur in some cases.

Table 138 : Summary of possible uses of Municipal wastewater and derivatives (other than sludge).

	Food use	Feed use	Other uses
Municipal wastewater and derivatives (other than sewage sludge)	Use of this feedstock is prohibited for use in food applications in many regions globally.	Use of this feedstock is prohibited for use in feed applications.	Landfill or Land spreading (most common) Composting Rendering for manufacturing lubricants or industrial soaps (no documented evidence of commercial application) Incineration Biofuel Biogas

2. Circular economy and waste hierarchy

2.1. Classification of the feedstock as a co-product, residue or waste

FOG material collected from the municipal wastewater system are a waste.

Table 139 : Classification of Municipal wastewater and derivatives (other than sludge).

Evaluation question	Answer	Rationale
Is the feedstock the primary aim of the production process?	No	The arises as a consequence of fats, oils and greases from cooking entering the wastewater system.
Does the feedstock have any economic value, but is not the primary aim of the process, and therefore a residue?	No	The feedstock has no economic value.
Is the feedstock normally discarded, and therefore a waste?	Yes	The feedstock is typically discarded.

2.2. Is the use of feedstock to produce biofuel/biogas in line with circular economy principles?

- **Does the feedstock have non-energy (re)uses, which could extend its life or sequester carbon for longer?**
  Answer: No.

  Rationale: Other than use in bioenergy, the feedstock is typically landfilled or composted.

- **Does its use as biofuel/biogas feedstock contribute to nutrient recovery?**

  Answer: No.

  Rationale: If the feedstock was used for biofuel production, there is no contribution to nutrient recovery. If the feedstock is used for biogas production via digestion, nutrients are retained in the digestate which could be used as fertiliser, and thus could contribute to nutrient recovery.

- **Does its use as biofuel/biogas feedstock contribute to a more efficient use of resources by avoiding primary material extraction?**

  Answer: Yes.

  Rationale: If FOG material is collected from the sewers and used for biofuel or biogas production then this will result in significant energy savings at the WWTP.

- **Does its use as biofuel/biogas feedstock contribute to reducing waste generation, especially food waste?**

  Answer: No.

  Rationale: The use of this feedstock will not contribute to reducing waste generation.

2.3. Is the use of this feedstock for biofuel/biogas production in line with the waste hierarchy?

- **Contribution to increasing waste?**

  Answer: No.

Rationale: The production of this feedstock primarily arises from commercial entities, such as food service establishments, releasing FOG material into the sewers. This material could otherwise be prevented from being discharged to the sewer if a grease trap was installed, and the material instead collected. This option should be prioritised in-line with the waste hierarchy principles. However, the reality is that significant FOG material will continue to be discharged to the sewers in many regions globally for the foreseeable future. Its use as a feedstock for biofuel/biogas production would not lead to an increase in the waste generated.

- **Can this feedstock be potentially reused?**

  Answer: No.

  Rationale: Other than energy generation, and disposal, there are no uses for this feedstocks. However, this cannot be considered as "reuse" given that no primary use of the feedstock was made.

- **Can this feedstock be potentially recycled?**

  Answer: Yes.

  Rationale: This feedstock can be applied to land after composting, enabling the recycling of nutrients.

2.4. Conclusion

Contribution to circular economy

Use of this feedstock for composting or biogas production may result in nutrient recovery and recycling. If the feedstock was used for biofuel production, there is no contribution to nutrient recovery.

Alignment with the waste hierarchy

The use of this feedstock is in line with the waste hierarchy since it has restricted uses outside of energy applications. Initiatives such as preventing the FOG material entering the sewer system in the first instance, through the use of grease traps, should be prioritised though.

3. Sustainability and Greenhouse gases

3.1. Union sustainability criteria

The Union sustainability criteria relate to agricultural field residues (Article 29(2)), agricultural biomass (Articles 29 (3) to (5)) and forestry biomass (Articles 29 (6) and (7)), and therefore do not apply to Municipal wastewater and derivatives (other than sludge) which is classified as waste.

3.2. Potential GHG savings

The REDII does not include specific default values for Municipal wastewater and derivatives (other than sludge), for biofuel or biogas production.

For biofuels, the UK RTFO Statistics published by the UK Department for Transport (2020) indicate that actual GHG emission savings for FAME biodiesel produced from Sewage system FOG (UK origin) are shown to range from 78-82% between 2016 and 2019.

For biogas, the REDII default values for biowaste is considered to be an acceptable proxy. This These range from 20% to 80% depending on whether the digestate system is open/closed and also whether the off gas is combusted or not. The GHG savings criteria for new installations require at least 65% GHG savings. This shows that to be eligible, the technology option of close digestate, off-gas combustion should be applied.

3.3. Other environmental impacts

Municipal wastewater and derivatives (other than sludge) are a waste and therefore have no land management impact. The evaluation of risks of adverse effects on soil, water, air and biodiversity is not applicable.

4. MARKET EFFECTS AND 2030/2050 POTENTIAL

4.1. Market effects

The accumulation of FOG in the wastewater system is a direct consequence of the failure to capture this material prior to discharge, as well as a lack of public awareness of the issues associated with flushing items such as wet wipes down the toilet. Aging infrastructure that has outlived its design capacity also plays a role. For example, some sections of the sewer network in London date back to the Victorian era over 150 years ago.

Although the issue of FOGs and fatbergs has been widely reported in the UK in recent years, this is not a UK specific problem. Fatbergs have also been discovered in cities around the world, including for example in Baltimore and Detroit (U.S.), in Melbourne (Australia) and Singapore. (Michigan Live, 2019; The Age, 2020; UK Grease Traps, 2019; USA Today News, 2017)

Limited information was identified on the FOG potential in the wastewater system. In the UK, an estimated 300 to 400 kt of grease and fat is sent through the UK's sewers and water treatment works each year (BBC, 2017). Collin et al. (2020) estimated that around 95 kt per year of these materials could be recovered from the Thames Water Utilities' catchment alone, one of the most populated in the UK. These materials could produce up to 222 GWh of biogas annually, close to double of what is produced with sewage sludge digestion and around 19% of the company energy needs. Collin et al. (2020) also estimated that even with over 6 million households in the catchment area, 80 kt of the FOG waste was produced by FSEs (over 48,000 premises) compared to only 15 kt from private households.

In the absence of specific data, it is reasonable to assume that the potential across Europe, and in other regions is likely to be significant. An exception will be those locations where the installation of grease traps in FSEs is commonplace.

The collection and use FOG material from the wastewater system will not result in any market distortion since the use of this material is restricted to disposal options such as landfilling, land spreading or use in energy.

4.2. 2030/2050 Potential

Similarly, no estimates of the future potential of FOG potential in the wastewater system could be identified.

The issue of FOG discharge is being given increased attention by water companies and governments around the world in light of the significant cost of treatment and potential health risks associated with sewer overflow. For example, through education and awareness campaigns and more stringent legislation relating to FOG discharge to the sewers. Nonetheless, it is very likely that the problem will persist well into the future without systematic adoption of grease traps and wholesale changes in public behaviour.

5. ADDITIONAL DEMAND FOR LAND

5.1. Assessment of additional demand for land

As identified in Section 4.1, the supply of Municipal wastewater and derivatives (other than sludge is rigid. However, Section 4.1 also identified that Municipal wastewater and derivatives (other than sludge) have very limited uses outside of landfilling, composting or energy. Therefore, use of this feedstock for biofuel or biogas is considered a low risk (no land use change is expected).

6. PROCESSING TECHNOLOGIES

6.1. Evaluation of processing technology (mature vs advanced)

Argent Energy is understood to be the only company globally that is using fatberg material as a feedstock for biodiesel production. The material is collected from sewers and delivered by lorry to the Argent Energy Ellesmere Port plant where it is loaded into a pit and heated to liquefy the fats and oils. The fats and oils are then sieved and filtered to get rid of all solid waste such as debris, sludge and slime. This material is combusted on-site to generate energy for the plant. Water is then removed in a second stage, leaving cleaned oil. The oil is then processed via transesterification to produce FAME biodiesel. A final step is distillation to ensure that the fuel meets the required quality specification (including on sulphur content). The yield of biodiesel from a fatberg is typically between 25% and 40% of the total weight. (Deutsche Welle, no date; UK Grease Traps Direct, 2019)

Argent Energy uses BDI's RepCAP technology, which is able to process feedstocks with a high FFA content (up to 99%).

The processing of Municipal wastewater and derivatives (other than sludge) into FAME biofuel can be considered to be a mature technology (albeit with very limited commercial deployment to date).

Sewage sludge is generally digested on its own, but a number of studies have suggested that co-digestion with other substrates could increase both biogas production and organic matter degradation. One potential option is to use FOG waste collected from grease traps, sewers or WWTW as a second feedstock for digestion. A significant improvement in methane production has been observed when grease trap waste was added as a co-substrate in addition to sludge. For example, the addition of grease trap waste to sewage sludge digesters has shown an increase of the methane yield of 9–27% when 10–30% of sludge from grease traps was added. However, when FOG is added higher concentrations the inhibition of methane generation is commonly observed. (Arthur, S. and Blanc, J. 2013; Tech Briefs, 2018).

Boost Environmental Systems Inc, a spinoff from the University of British Columbia (UBC), has developed a process that aims to overcome this issue. The Microwave Enhanced Advanced Oxidation process (IMPACT™) is a pre-treatment process for FOG in wastewater or sewage sludge for the production of biogas. UBC believe that through pre-treatment, a mixture with a ratio of up to 70% FOG to 30% sewage sludge (or manure) can be treated. The process uses microwave heating up to 110 °C or 120 °C, with the addition of hydrogen peroxide as an oxidant. The hydrogen peroxide is added to break down organic matter and release fatty acids. The microwave oxidation process breaks them into simpler, smaller chain compounds. Bacteria are then used to break down the fatty acids to produce biogas. (Smithsonian Magazine, 2018; Tech Briefs, 2018).

Prior to targeting FOG, UBC had been focusing mainly on treating municipal sewage sludge and animal manure and have conducted demonstration tests in wastewater treatment plants and in an animal/dairy farm in British Columbia. UBC aims to move this technology forward for a full-scale commercialisation. (Smithsonian Magazine, 2018; Tech Briefs, 2018).

Ashleigh Environmental (no date), based in Ireland, is also developing a microwave pre-treatment system (Biowave™) to break down organic by-products prior to being anaerobically digested.

The processing of Municipal wastewater and derivatives (other than sludge) into biogas can be considered to be a mature technology in co-digestion applications at a concentration of up to 30% of the total substrate dry mass. At higher concentrations the technology could be considered as advanced.

The most suitable conversion process for Municipal wastewater and derivatives (other than sludge) is considered to be anaerobic digestion, and depending on the substrate concentration level could either be considered mature or advanced.

7. CONCLUSIONS

Table 140 : Summary of evaluation results.

	Evaluation Result	Rationale
Circular economy	No concern	Use of this feedstock does not contribute to the circular economic, other than in composting or biogas which may result in nutrient recovery and recycling. The use of this feedstock is in line with the waste hierarchy since it has restricted uses outside of energy applications. Initiatives such as preventing the FOG material entering the sewer system in the first instance, through the use of grease traps, should be prioritised though.
Union sustainability criteria	Not applicable	These criteria are **not applicable** to Municipal wastewater and derivatives (other than sludge) as this feedstock is neither primary agricultural biomass or agricultural field residue or forest biomass.
Sustainability GHG	No concern	Municipal wastewater and derivatives (other than sludge) for biofuel production should realise GHG emission savings of around 80%. Municipal wastewater and derivatives (other than sludge) for biogas is expected to realise around 80% GHG emission savings if the digestate is stored in a closed tank and the off-gas is combusted. <u>How to mitigate this concern?</u> Failure to meet the minimum GHG savings will be efficiently addressed throughout the certification process by an EU-approved voluntary or national scheme.
Sustainability Others	Not applicable	This criteria is **not applicable** to Municipal wastewater and derivatives (other than sludge) as this feedstock is a waste.
Market distortion	No concern	Municipal wastewater and derivatives (other than sludge) are considered to have a rigid supply. However, the risk of market distortion is extremely low given that there are very limited uses for this feedstock outside of energy.
2030/2050 Potential	2030: No data	No estimates of either the current or future potential of FOG potential in the wastewater system could be identified

	2050: No data	in the literature.
Land demand	No concern	The use of Municipal wastewater and derivatives (other than sludge) has a **low high risk category** of land use change.
Processing Technologies	Mature (biodiesel) Mature (biogas <30% concentration) Advanced (biogas >30% concentration)	Biodiesel production from Municipal wastewater and derivatives (other than sludge) is commercially practised, but only on a limited scale and restricted to transesterification. This is considered a **mature technology**. The processing of Municipal wastewater and derivatives (other than sludge) into biogas can be considered to be a **mature technology in co-digestion applications at a concentration of up to 30%** of the total substrate dry mass. **At higher concentrations** the technology could be considered as an **advanced technology**.

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Soapstock and derivatives

1. Technical description

1.1. Feedstock description

This feedstock includes soapstock and its derivatives, including acid oil, free fatty acids, glycerides, acylglycerols, pigments, and other lipophilic materials. These materials are further described in the section on Production process below.

1.2. Production process

Soapstock is produced in the vegetable oil refining process, as shown in Figure 62, which is taken from Casali et al. (2021). It is separated from the vegetable oil in the neutralization stage. During this stage, the oil is treated with a dilute alkali solution, which separates the free fatty acids (FFA) as soaps. The mixture is then centrifuged, which separates the water and soap (soapstock) from the oil. Soapstock represents around 6% of the crude vegetable oil input by volume (Piloto-Rodriguez et al., 2014). Soapstock is an emulsion of FFAs, glycerides, and water (compromising about 50% of the total mixture), and it is alkaline (Piloto-Rodriguez et al., 2014; Haas, 2015).

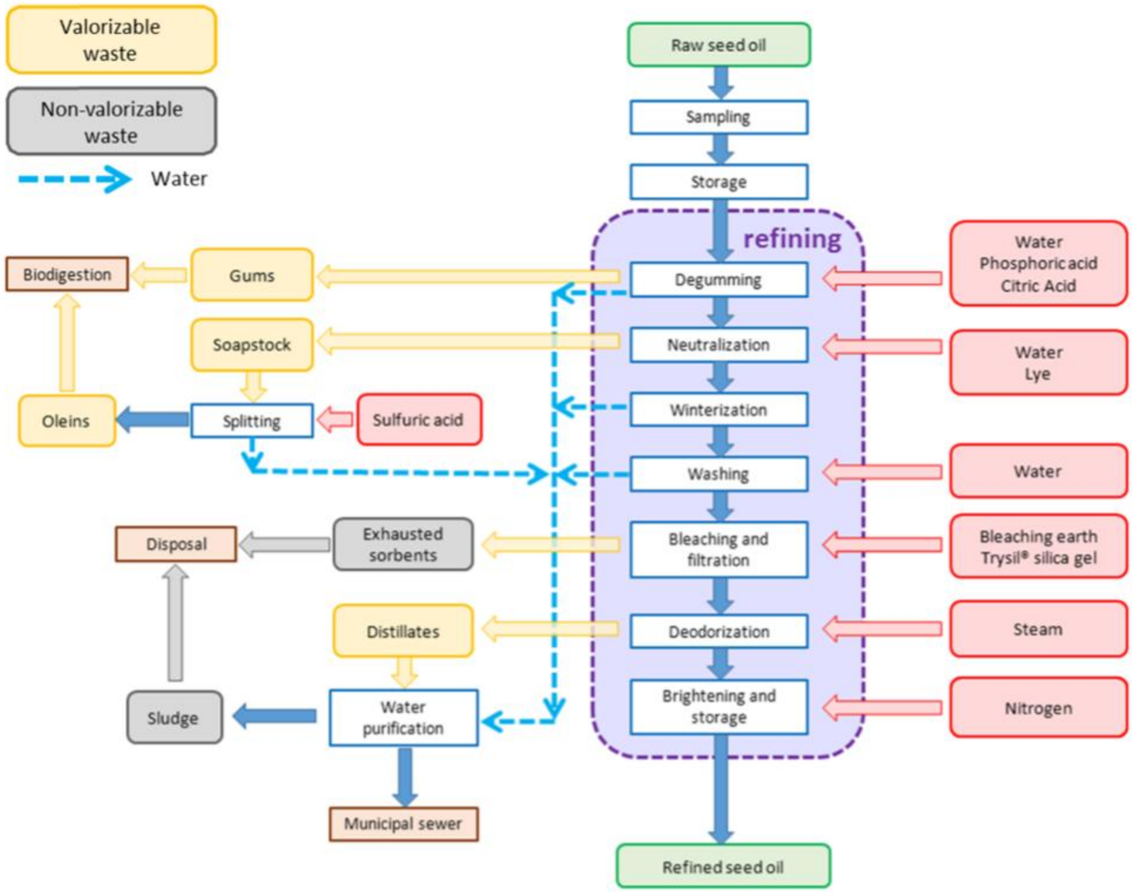

Figure 62: The vegetable oil refining process. Source: Casali et al. (2021)

After separation from the vegetable oil, soapstock is often acidulated. In acidulation, sulfuric acid and high-pressure steam are added to the soapstock. This process converts the fatty acids from soaps to free acids, which reduces its emulsive properties. The acidic water can then be removed, leaving acid oil, which is free of water. Acid oil is a mixture of FFA, acylglycerols, pigments, and other lipophilic materials (Haas, 2005).

Here, we define “soapstock” as the emulsion of water and soaps prior to acidulation, and “derivatives” as acid oil and any of the components of acid oil that may be separated from the mixture.

The term “palm acid oil” is sometimes used to refer to oil extracted from palm oil mill effluent (POME) (Fox40, 2020). Extraction of oil from POME is a different process than the one outlined in Fig. 1. For the purposes of this assessment, we define acid oil as the material produced from the acidulation of soapstock. In Task 1 of this project, the Consortium determined that palm sludge oil (which we defined as the oil removed from POME) is already covered in Annex IX, part A.

1.3. Possible uses

Soapstock reportedly was discarded historically, but in recent years has become “a valuable source of fatty acids for the soapmaker and the fatty acid distiller” (Haas 2005). Soapstock has been identified as an animal feed additive, but because its long chain fatty acids are difficult to digest by animals, it should only be added in small amounts up to 3.5% (Casali et al., 2021). Acid oil from soapstock is listed in the EU Feed catalogue (Commission Regulation 2017/1017). Acid oil can be used to make rumen protected fats for cattle (Naik, 2007). Fats and oils in general can interfere with fibre digestion in the rumen. Rumen protected fats have a higher melting point, which allows them to ‘bypass’ the rumen in a solid state and be digested in the small intestine. The addition of rumen protected fats to cattle feed improves milk production, reproduction, and general performance of dairy cattle (Kemin, n.d.)

Soapstock can be used to produce fertilizer (Daniels, 1997), although we did not find any evidence or receive any stakeholder feedback indicating that this occurs at a significant scale. Soapstock can also be used in the production of high-value chemicals, such as surfactants, wax esters (used in pharmaceuticals and cosmetics), plasticizers, and additives. Epoxide derivatives of fatty acids and acylglycerols can also be used as diluents for paints, intermediates for polyurethane-polyol production, corrosion protecting agents and additives for lubricating oils (Casali et al., 2021). It is not clear whether FFA can be or is commonly purified from acid oil for any uses.

Soapstock can be used to produce biodiesel, but additional steps before esterification, including drying, acidification, and/or hydrolysis, are typically needed. Soapstock can also be converted to biogas through anaerobic digestion (Casali et al., 2021).

There is little information available about the relative shares of soapstock and derivatives in each of these possible uses, and whether any significant amounts of soapstock is still disposed of. In the stakeholder consultation, all respondents indicated that soapstock and acid oil are not wastes. Some stakeholders say the ‘main use’ of acid oil is for FAME production, and several others list FAME as an existing use. Stakeholders also list oleochemical applications as another existing use of acid oil.

Table 141 : Summary of possible uses of soapstock and derivatives

Food use	Feed use	Other uses
No evidence of use in food.	Strong evidence of use in livestock feed.	Strong evidence of use in biofuel. Possible use in oleochemicals and fertilizer.

2. Circular economy and waste hierarchy

2.1. Classification of the feedstock as a co-product, residue or waste

Soapstock and derivatives is classified as a residue, following the classification below:

Table 142 : Classification of soapstock and derivatives

Evaluation question	Answer	Rationale
Is the feedstock the primary aim of the production process?	No	Refined vegetable oils is the primary aim of the production process. Soapstock and derivatives is produced in much lower quantities than refined vegetable oil and is of lower value per unit volume or weight.
Does the feedstock have any economic value, but is not the primary aim of the process, and therefore a residue?	Yes	Soapstock and derivatives have economic value and existing uses.
Is the feedstock normally discarded, and therefore a waste?	No	Soapstock and derivatives reportedly were historically discarded but no longer are

2.2. Is the use of feedstock to produce biofuel/biogas in line with circular economy principles?

- **Does the feedstock have non-energy (re)uses, which could extend its life or sequester carbon for longer?**

  Answer: No

  Rationale: All of the existing uses for which there is strong evidence that soapstock and derivatives is used would not extend the life of this material of sequester its carbon for longer. It is possible soapstock and derivatives could be used in long-lived oleochemical products, such as paint, but there is little evidence significant amounts are used in such uses at present.

- **Does its use as biofuel/biogas feedstock contribute to nutrient recovery?**

  Answer: Variable

  Rationale: It is possible that digestate from anaerobic digestion of soapstock and derivatives could be used as a fertilizer, although use of this feedstock for biogas production could possibly divert its use directly in fertilizer production.

- **Does its use as biofuel/biogas feedstock contribute to a more efficient use of resources by avoiding primary material extraction?**

  Answer: No

  Rationale: Soapstock and derivatives appears to be mostly or entirely used at present, either in livestock feed or in high-value material uses. The use of this material in biofuel or biogas would likely not be a more efficient use of resources.

- **Does its use as biofuel/biogas feedstock contribute to reducing waste generation, especially food waste?**

  Answer: Variable

  Rationale: Soapstock and derivatives reportedly was historically discarded, and it is not entirely clear that none of this material is discarded at present. It is possible that use as biofuel/biogas would contribute to reducing waste generation (although not food waste).

2.3. Is the use of this feedstock for biofuel/biogas production in line with the waste hierarchy?

Soapstock and derivatives is considered a residue for the purpose of this assessment and therefore assessment against the waste hierarchy is not necessary.

2.4. Conclusion

Contribution to circular economy

The use of soapstock and derivatives as biogas/biofuel feedstock is in line with circular economy principles. Soapstock and derivatives are used in oleochemicals and other products. There is no documented evidence of commercial implementation for use of soapstock and derivatives in long-lived products, although this is theoretically possible. Increasing the use of soapstock and derivatives for energy purposes would not contribute to a more efficient use of resources, and it will not prevent materials from going to waste disposal.

3. SUSTAINABILITY AND GREENHOUSE GASES

3.1. Union sustainability criteria

The Union sustainability criteria relate to agricultural field residues (Article 29(2)), agricultural biomass (Articles 29 (3) to (5)) and forestry biomass (Articles 29 (6) and (7)), and therefore do not apply to soapstock and derivatives, which is classified as a process residue.

3.2. GHG Savings Criteria

Soapstock and derivatives are essentially a type of residual oil, and so the GHG emissions for biofuel produced from this feedstock are likely similar to those of biodiesel produced from used cooking oil or animal fats. The REDII default values for GHG savings from used cooking oil and animal fats biodiesel are 84% and 78%, respectively. It is thus likely that biodiesel produced from soapstock and derivatives would meet the GHG savings criteria of the RED II.

3.3. Other environmental impacts

Soapstock and derivatives is a secondary process residue and therefore have no land management impact. The evaluation of risks of adverse effects on soil, water, air and biodiversity is not applicable.

4. MARKET EFFECTS AND 2030/2050 POTENTIAL

4.1. Market effects

From the available evidence, it appears that most or all soapstock and derivatives is already used in biofuel production, livestock feed, and oleochemicals, likely with little or none of this material discarded. Increased demand for soapstock and derivatives for use in biofuel production would thus very likely divert this material from other existing uses and thus cause market distortion.

Soapstock and derivatives appears to realise lower value than refined vegetable oil, although there is limited price evidence available. Piloto-Rodriguez et al., (2014) reports that acid oil sells for approximately half the cost of refined vegetable oils. Haas (2005) states that soapstock's "market value is approximately US$ 0.11 per kg on a dry weight basis, i.e., about one-fifth the price of crude soybean oil." The historical U.S. price of soybean oil in 2005 (USD 0.2341 per pound),[86] at the time of publication of Haas (2005), supports this statement. These two sources (Haas, 2005 and Piloto-Rodriguez et al., 2014) appear to be consistent. Soapstock is around 50% water, so the value of the lipids in it should in principle be around two-fifths the price of crude soybean oil,

[86] https://www.ers.usda.gov/data-products/oil-crops-yearbook/

which is roughly in line with Piloto-Rodriguez's report that acid oil (i.e. the separated lipids from soapstock) sells for approximately half the cost of refined vegetable oils.

The role that soapstock and derivatives plays in the livestock feed market is relevant to identifying the potential effect of its diversion to biofuel production on that market and for identifying substitute materials. Acid oil can be used in the production of rumen protected fats, which is a specialty product for dairy cattle production. However, it is likely a relatively niche use of soapstock and derivatives. FiorMarkets (2020) reports that the global market for 'rumen bypass fat' was USD 759 million in 2019. Using available information, we can very roughly estimate the size of the global soapstock and derivatives market. In 2019/2020, global production of vegetable oils was 207.26 million tons (Statistica, 2021). Assuming soapstock was 6% of this (following Haas, 2005) and using a value for soapstock of 20% that of U.S. soybean oil in 2019 (USD 0.3150 per pound), we estimate a global market value of approximately USD 1.7 billion. Processing is required to both a) convert soapstock to acid oil and b) convert acid oil to rumen protected fats, and so we may assume that the cost of soapstock used to produce rumen protected fats in 2019 was significantly less than USD 759. Rumen protected fats are likely also produced from materials other than soapstock and derivatives, such as palm fatty acid distillate (Malins, 2017). It is thus clear that far more soapstock is produced globally than is used in the production of rumen protected fats. However, it is still possible that increased demand for soapstock and derivatives in biofuel production could divert this material from use in the production of rumen protected fats. This would depend on the substitutability of this material with other types of oils and fats. If soapstock and derivatives is diverted from rumen protected fats production, its substitute would be virgin vegetable oils such as palm oil and soy oil, understanding that we must select a substitute with elastic supply.

It thus seems likely that some soapstock and derivatives are added to livestock feed, not as rumen-protected fats. Soapstock and derivatives appears to be a fairly low-quality feed ingredient; one study found the metabolizable energy of sunflower acid oil was 18% lower than that of refined sunflower oil when fed to broilers (Wiseman et al., 1992). It thus seems likely that soapstock and derivatives is added to livestock feed simply as inexpensive calories, rather than fulfilling any nutritional requirement for oils and fats in livestock diets. On an energy equivalent basis, acid oil sells for less than maize in the U.S. (which is generally the lowest cost livestock feed ingredient that is also a primary crop). The 5-year average U.S. maize price from 2015-2019 was USD 0.0025 per MJ,[87] and for soy oil was USD 0.0040 per MJ.[88] If acid oil is half the price of soybean oil, it would then sell for approximately USD 0.0020 per MJ, less than the price of maize. The fact that soapstock and derivatives is less expensive than maize supports the argument that its use in livestock feed is to supply inexpensive calories. Thus, its substitute in this use would be the least expensive primary crop used in livestock feed in the EU, which would likely be barley and maize.

Similar to the case of rumen protected fats, it is not clear how readily soapstock and derivatives would be displaced from use in oleochemicals. Again, it depends on how readily cost-competitive substitutes are available. If soapstock and derivatives is displaced from oleochemicals production, the likely substitute would be virgin vegetable oils such as palm oil and soybean oil, understanding that we must select a substitute material with elastic supply.

Final result for soapstock and derivatives: high risk of market distortion.

4.2. 2030/2050 Potential

The future potential production of soapstock and derivatives depends largely on the future production of refined vegetable oils. The Food and Agriculture Organization of the United Nations (2006) projects 215.5 and 293.2 million tons of oil content in oil crops in 2030 and 2050, respectively. Assuming that soapstock is produced at a rate of 6% of crude oil production, around 13 and 18 million tons of soapstock would be produced in 2030 and 2050, respectively. If all this soapstock were acidulated into acid oil, approximately 6 and 8 million tons of acid oil would be produced in 2030 and 2050, respectively. If this entire amount were converted to biofuel, it could amount to 6 million tonnes FAME or 5 million tonnes HVO in 2030 and 8 million tonnes FAME or 7

[87] https://data.ers.usda.gov/FEED-GRAINS-custom-query.aspx

[88] https://www.ers.usda.gov/data-products/oil-crops-yearbook/

million tonnes HVO in 2050. . Because not all oil crops are processed into oil and not all oil is refined, these are likely overestimates. Furthermore, not all soapstock and derivatives that are produced can be considered available for biofuel since there are other existing uses.

5. Additional demand for land

5.1. Assessment of additional demand for land

In the section on Market effects above, we identified vegetable oils such as palm oil and soybean oil as substitutes for soapstock and derivatives in its uses in rumen protected fats and oleochemicals. We identified barley and maize as substitutes for its use in livestock feed (not as rumen protected fats). In **Table 143**, we categorize the level of risk for additional demand for land for these substitute materials. This list includes high risk substitutes; combined with a high risk of market distortion, the overall risk of additional demand for land for soapstock and derivatives is high.

Table 143: Categorization of risk of additional demand for land for various materials

Substitute materials	Risk level
Palm oil	High
Soybean oil	
Maize	Medium
Barley	

Final result for soapstock and derivatives: high risk of additional demand for land

6. Processing technologies

6.1. Evaluation of processing technology (mature vs advanced)

Soapstock and derivatives can be converted to biodiesel using esterification and transesterification, which are mature technologies. It can also be converted to biogas using anaerobic digestion. Anaerobic digestion and subsequent biogas upgrading are mature technologies (TRL 9, CRL 5). If soapstock and derivatives were to be added to Annex IX, it would be suitable for part B.

7. Conclusions

Nomenclature:

- No concern = the evaluation did not reveal any significant concern about this feedstock.
- Some concern = the evaluation identified limited conditions under which some concerns may exist, i.e. using this feedstock for biofuel production could be in contradiction with this criterion.
- Significant concern = the evaluation reveals that using this feedstock for biofuel production would be in contradiction with this criterion in most circumstances.
- Not applicable = this criterion is not applicable to the feedstock.

Table 144: Summary of evaluation results

	Evaluation Result	Rationale
Circular economy and waste hierarchy	No concern	Using soapstock and derivatives for biogas/biofuel does neither contribute to, nor contravene circular economy principles or the waste hierarchy.
Union sustainability criteria	Not applicable	Sustainability Union criteria do not apply because soapstock and

		derivatives is a process residue.
Sustainability GHG	No concern	Biofuel and biogas produced from soapstock and derivatives would likely meet the GHG criteria of the RED II.
Sustainability Others	Not applicable	Other sustainability impacts do not apply because soapstock and derivatives is a process residue with no land management impact.
Market distortion	Significant concern	Soapstock and derivatives appear to be mostly or entirely used in existing uses in livestock feed and oleochemicals. Diverting this feedstock to biofuel production would likely cause high risk of market distortion. <u>How to mitigate this concern?</u> This feedstock has been assessed as potentially appropriate for inclusion in Annex IXB. The contribution of Annex IXB feedstocks to national RED transport targets is capped at 1.7% of transport energy. Inclusion under this cap would limit the amount of feedstock likely to be used for biofuel/biogas production and thus mitigate against the most market distortive outcomes, but would not fully prevent indirect impacts.
2030/2050 Potential	5-6 million tons FAME or HVO in 2030 7-8 million tons FAME or HVO in 2050	Soapstock and derivatives production will likely grow with the growing vegetable oil market.
Land demand	Significant concern	The diversion of soapstock and derivatives from existing uses to biofuel production would likely cause increased production of barley, maize, and vegetable oils such as palm oil and soy oil, with high risk of increased demand for land. <u>How to mitigate this concern?</u> This feedstock has been assessed as potentially appropriate for inclusion in Annex IXB. The contribution of Annex IXB feedstocks to national RED transport targets is capped at 1.7% of transport energy. Inclusion under this cap would limit the amount of feedstock likely to be used for biofuel/biogas production

		and thus mitigate against the most market distortive outcomes, but would not fully prevent indirect impacts.
Processing Technologies	Mature	Soapstock and derivatives can be processed into biodiesel and biogas using mature technologies.

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Brown grease

1. TECHNICAL DESCRIPTION

1.1. Feedstock description

Brown grease, also known as fat trap oil or trap grease, is the oily material collected from grease traps that are installed for separating insoluble and gelatinous greases from kitchen wastewater streams, which originate mainly from foodservice enterprises such as restaurants, before water enters the wastewater disposal system. . Grease traps can also be found in hotels, hospitals, schools, prisons, event halls or wastewater treatment facilities (Kolet et al., 2020; Universal Green Commodities, n.d.; US DoE, 2017). These traps allow water to continue flowing to the main sewer or through the water treatment operations. If brown grease is not collected in a grease trap, it may cause severe pipe fouling and even sewer blockages (Kolet et al., 2020).

Brown grease is a lower quality feedstock compared to used cooking oil (yellow grease) (Annex IX Task 1 report, stakeholder feedback). Brown grease is composed of fats, oils and greases (FOGs), water and biosolids (namely food waste) and high levels of non-oil contaminants such as detergents and cutlery (Guidehouse *pers comm.*; Tran et al., 2016; Gerpen and He, 2014). The composition can vary widely depending on the grease trap collection system (see section 1.2 for details), including its age and level of maintenance, as well as the source of origin. There is no industry standard. Kolet et al. (2020) indicate that brown grease typically consists of 50-60% FOGs, 25-30% water and 15-20% biosolids. However, according to an industry source brown grease currently collected in Europe typically consists of a much lower FOG content (5-15%) and a much higher water content (70-80%). Material with a FOG content as low as 2-3% has even been encountered. About 80% of the lipids are free fatty acids (FFAs), mostly oleic, linoleic and palmitic acids, obtained as a result of triglyceride decomposition in the course of frying and other cooking processes, and due to the presence of detergents and sanitizers which enhance the hydrolysis of triglycerides in brown grease (Kolet et al., 2020; Wallace et al., 2016), although this can reportedly range from 70-95%. Brown grease typically has a sulphur content of 500 ppm, although this can range between 350 to 1,000 ppm depending on the source.

In the US, dedicated brown grease collection companies, also called haulers, are contracted to collect the material from restaurants and other food-processing establishments[89], and dispose it at landfills, wastewater treatment plants (WWTPs), rendering plants, incinerators, or anaerobic digesters (Spiller et al., 2020; Winner, 2015). Rendering plants either collect brown grease themselves or receive it from haulers and/or WWTPs to further process the material into products and chemicals (Spiller et al., 2020). FOG (including brown grease) may pass through the sewer system and enter WWTPs where it can cause overloading of the system (Wallace et al., 2016). FOG is primarily separated at WWTPs in the skimming tanks, at the first stage of treatment (Wallace et al., 2016). The FOG that is not removed in the primary skimming tanks can cause blockages in the plant infrastructure causing impedance of treatment processes (Wallace et al., 2016). These issues lead to increased operational and maintenance costs (Wallace et al., 2016). The prevalence of FOGs in wastewaters entering WWTPs is becoming increasingly uncommon in countries where grease traps have been installed at food processing facilities, restaurants and households (Spiller et al., 2020). In some cases, the material is processed on-site via anaerobic digestion or incineration (Spiller et al., 2020).

[89] At the end of the month, the grease collection company/ hauler will either be paid by the restaurant for the gallons of grease hauled away that month; or receive the grease for free; or pay the restaurant per gallon of oil collected. It depends on market conditions and location (Winner, 2015). However, this is the case for yellow grease (also called UCO). Limited information is available for brown grease. It is assumed that no payment is made for collecting brown grease at this point in time.

As mentioned in the Task 1 report, **brown grease is partly covered (industrial fryers) in Annex IX Part A d)[90] but not for restaurants and households.** It could also fit under Annex IX B (along with UCO). FOGs (including brown grease) in wastewater are covered in a separate assessment.

The National Commission for Markets and Competences (CNMC) in Spain considers brown grease to be covered under point d) of Annex IX Part A. As a result, brown grease has been included in the official list of feedstocks for manufacturing doubled-counted advanced biofuels in Spain (stakeholder feedback; CNMC, 2019; USDA GAIN, 2020).

1.2. Production process

Brown grease is generated as kitchen waste in households, restaurants, and food-processing establishments including industrial fryers. The waste is recovered onsite when a grease trap is installed as a pretreatment device before wastewater enters the sewage network (Guidehouse, Personal Communication). Grease trapping systems (GTSs), also referred to as grease abatement systems, grease interceptors, grease separators or grease recovery units, separate FOG and fine food waste from wastewater through gravitational separation (Wallace et al., 2016). Wastewater entering the grease trapping equipment is slowed down long enough for FOG to float to the top surface and wastewater with a reduced FOG content flows out of the unit on the other side (Guidehouse, Personal Communication). The grease and settled solids separate from the kitchen wastewater and slowly accumulate in the interceptor (AquaCure, n.d.).

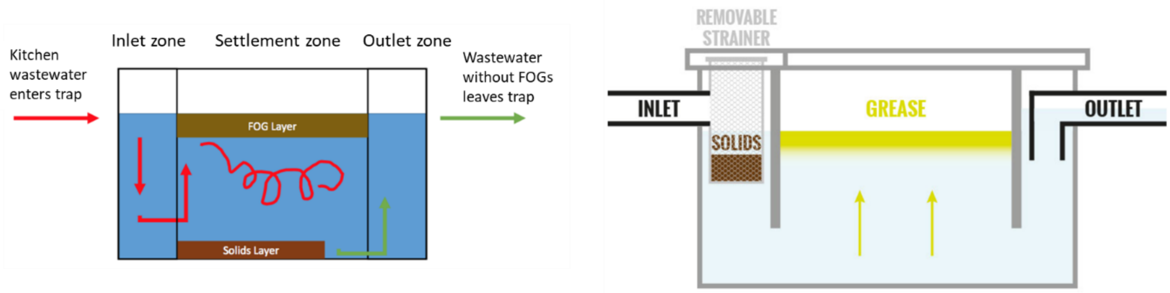

Figure 63: Basic principles of a grease trap with or without a removable strainer for collecting solid debris (Source: Guidehouse, Personal Communication; AquaCure, n.d.)

Grease traps vary in size, and can either be stored indoors (above ground) or outdoors (above ground). There are three main types of grease trap; passive hydromechanical (manual), automatic and gravity (AquaCure, n.d.).

- **Passive hydromechanical (manual) grease traps:** These are one of the most common systems used in smaller establishments. This is due to their low initial investment cost and the variety of sizes available, meaning they can be easily installed under most sinks. Passive systems need to be cleaned manually on a regular basis (e.g. once every one to four weeks), either by restaurant staff or by a specialist collection company. Passive systems can also be deployed at a large scale at wastewater treatment facilities (AquaCure, n.d.).
- **Automatic grease traps:** Automatic systems, also known as AGRU's (automatic grease removal units), use some of the same principals as a traditional passive trap but re-heat and skim out the FOG automatically on a programmed schedule. The skimmed FOG is then transferred into a collector bin for easy removal and recycling. Automatic systems have a higher investment cost, but lower operational costs (AquaCure, n.d.). This lipid-rich FOG layer is the most similar to UCO and has less impurities than the contents of passive grease trapping systems (Wallace et al., 2016).

[90] Biomass fraction of industrial waste not fit for use in the food or feed chain, including material from retail and wholesale and the agro-food and fish and aquaculture industry, and excluding feedstocks listed in part B of Annex IX

- **Gravity grease traps:** Gravity systems are usually large in-ground tanks constructed from concrete, fibreglass or steel. They work in a similar way to a passive hydromechanical trap but have a much larger capacity and are better suited for high-flow applications (AquaCure, n.d.).

1.3. Possible uses

Brown grease is generally removed by specialized grease collectors from various collection sites and **disposed of in landfills or combusted** with limited aggregation and trading (Spiller et al., 2020; Brown grease narrative T3.3.). However, the following uses have been documented.

- While the compounds necessary to produce FAME biodiesel are present, the high water and FFA content as well as high levels of contamination and low quality nature of brown grease leads to much higher than normal processing costs and limited commercial viability (Brown grease narrative T3.3; Farm Energy, 2019). However, processes have been developed to convert brown grease to **biodiesel**, that require a two-stage conversion process to allow both the triglycerides (the typical feedstock for biodiesel) and FFAs to be converted (Spiller et al., 2020). Alternatively, brown grease could potentially be blended with higher quality feedstock to reduce the need for pretreatment, although this would limit the amount of brown grease that could be processed.

  Brown grease is already **used in Spain and the UK[91] for the production of FAME biodiesel** (stakeholder feedback, UK Department for Transport, 2020). The majority of the biodiesel produced from brown grease used in the UK is sourced from the U.S. (typically 75-85%).

- Some brown grease is converted to **biogas** via anaerobic digestion, although it is reportedly not an ideal substrate with operational challenges including inhibition of complete conversion, sludge flotation, foaming and system blockages (Spiller et al., 2020). However, co-digestion of brown grease with other biodegradable wastes, such as organic fraction of municipal solid wastes, has been shown to be applicable (Wallace et al., 2016). The addition of brown grease to sewage sludge digesters has shown an increase of the methane yield of 9–27% when 10–30% of sludge from grease traps was added (Wallace et al., 2016).
- Some brown grease is used in electricity producing boilers in the US (Nelson and Searle, 2016).
- Some portion of brown grease is processed by rendering plants in the US for use in various industries, e.g. biofuels, **lubricants**, but the volume of material monetized in this way is not known, and not considered to be significant (Spiller et al., 2020). It should be noted that yellow grease is typically preferred over brown grease for biofuels, soap manufacturing, and other manufacturing uses (Zillah Municipal Code, 2018). The (European Council) **Animal By-products regulations 1774/2002 stops grease waste (collected in grease traps) being used in animal feed** (Fogtrap, 2015). Similarly, it is our understanding that brown grease, along with UCO, are no longer permitted for use as animal feed in the U.S. (EC, 2020).
- The FFA content of brown grease makes it a potential feedstock for production of biopolymer polyhydroxyalkanoates (PHAs) (Wallace et al., 2016; Guidehouse, Personal Communication). PHAs are a family of polyesters produced by bacterial fermentation with the potential to replace conventional hydrocarbon-based polymers and have been successfully recovered from many renewable feedstocks including fatty acids such as those derived from FOG (Wallace et al., 2016; Guidehouse, Personal Communication). However, for brown grease to be a viable feedstock for PHA production, removal of impurities and moisture reduction is essential (Wallace et al., 2016). This pretreatment increases the expense of the PHA manufacturing process (Wallace et al., 2016).

Possible uses of brown grease are summarised in **Table 146**.

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[91] Reported volumes since 2017/2018 are around 15 to 20 million litres per year.

Table 145 : Summary of possible uses of brown grease

Food use	Feed use	Other uses
None	None	Biogas: Documented evidence of commercial implementation. FAME biodiesel: Documented evidence of commercial implementation. Lubricants: Some evidence but use of brown grease for this application is not considered to be significant. Biopolymers: Documented evidence in the form of research articles. No evidence of commercial implementation.

2. Circular economy and waste hierarchy

2.1. Classification of the feedstock as a co-product, residue or waste

On the basis of the feedstock description provided in sub-section 0, its possible uses in sub-section 0, stakeholder feedback and additional references, brown grease can be classified as a residue or waste as described below.

Table 146 : Classification of brown grease

<table>
<tr><th>Evaluation question</th><th>Answer</th><th>Rationale</th></tr>
<tr><td>Is the feedstock the primary aim of the production process?</td><td>No</td><td>Production of brown grease is not the primary aim of facilities where food is prepared. It is a waste that is collected in grease traps following which the kitchen wastewater minus FOGs enters the sewer (see section 0).</td></tr>
<tr><td>Does the feedstock have any economic value, but is not the primary aim of the process, and therefore a residue?</td><td>Variable</td><td rowspan="2">In the US, brown grease can be collected for a small fee or free from households, restaurants and wastewater treatment plants (Mićić et al., 2019). Brown grease price typically trades at a discount to used cooking oil (UCO). For example, recently the brown grease price in Chicago was around 19-20 cents/lb or 42-44 cents/kg which was 50% of the FOB[92] Illinois Yellow Grease price (39-41 cents/lb or 87-91 cents/kg of yellow grease) (Source: The Jacobsen, 2021). Therefore, in the regions where it is being sold, but is not the primary aim of the process, it can be classified as a residue.

However, as mentioned in sections 0 and 0, a large percentage of brown grease collected globally is still being disposed of or incinerated, which would make it a waste.</td></tr>
<tr><td>Is the feedstock normally discarded, and therefore a waste?</td><td>Yes</td></tr>
</table>

[92] Free On Board (FOB) is a term used in shipping where the seller quotes a price including the cost of delivering goods to the nearest port.

2.2. Is the use of feedstock to produce biofuel/biogas in line with circular economy principles?

- **Does the feedstock have non-energy (re)uses, which could extend its life or sequester carbon for longer?**

  Answer: Variable.

  Rationale: There could be some use of the feedstock as a lubricant and as potential biopolymer feedstock (see section 0). These could qualify as extending the lifetime of the feedstock or sequestering carbon for a longer period of time. However, the use of brown grease for lubricants or biopolymer production has not been demonstrated at a commercial scale.

- **Does its use as biofuel/biogas feedstock contribute to nutrient recovery?**

  Answer: Variable.

  Rationale: Anaerobic digestion of brown grease can generate a digestate, which retains C, N, P and other important nutrients and can be used as fertiliser, thus contributing to decreasing the need for industrial fertiliser production (IEA Bioenergy, 2015; European Commission, 2019).

  Biodiesel derived from brown grease has no documented contribution to nutrient recovery.

- **Does its use as biofuel/biogas feedstock contribute to a more efficient use of resources by avoiding primary material extraction?**

  Answer: Yes.

  Rationale: As with all other biomass feedstocks, biofuels and biogas derived from brown grease can displace fossil fuels and natural gas, thus reducing the need for primary material extraction. Furthermore, if brown grease is collected and used for biofuel or biogas production then this will result in significant energy savings at the WWTP.

- **Does its use as biofuel/biogas feedstock contribute to reducing waste generation, especially food waste?**

  Answer: Variable.

  Rationale: Transforming brown grease into energy, which eventually displaces fossil fuels, has higher environmental benefits than if this waste was simply discarded. If brown grease (and other FOGs) are not collected onsite they can accumulate in sewers and cause blockages (Guidehouse, Personal Communication). In the UK alone there are 366,000 sewer blockages every year, 70% caused by FOG, with water companies estimating a total cost of £90 million to unblock (Guidehouse, Personal Communication).

  Industry stakeholders reported that brown grease was being converted into biodiesel and could be converted into biogas, thus generating additional revenues, which could constitute an incentive against trying to improve cooking facility efficiency to reduce the share of waste. However, this is anticipated to be more the case for UCO than for brown grease. If selling waste for energy recovery is the only alternative to discarding brown grease, then using it as biofuel/biogas feedstock does indeed contribute to reducing waste generation.

2.3. Is the use of this feedstock for biofuel/biogas production in line with the waste hierarchy?

- **Contribution to increasing waste?**

  Answer: Variable.

  Rationale. No evidence exists that using brown grease for biogas or biofuel production would generate more waste. However, there could be a broader risk to create an incentive against reducing waste generated in cooking facilities by offering an extra source of income to operators. There could be the dual risk of increase in the amount of oils or fats used for cooking, causing detrimental health impacts, as well as increase in the frequency with which oils or fats are discarded in order to generate more wastes. However, these risks are anticipated to be more the case for UCO than for brown grease. These risks are discussed further in Task 3 of the project.

- **Can this feedstock be potentially reused?**

  Answer: No.

  Rationale: Brown grease is a waste which is contaminated with cleaning agents (Gerpen and He, 2014). It cannot be reused in the facilities where it is generated. It therefore needs to be discarded or pretreated before it can be used for biodiesel production, which does not qualify as 'reuse'.

- **Can this feedstock be potentially recycled?**

  Answer: Variable.

  Rationale: The main documented use of brown grease is for production of biodiesel, some biogas, and as feedstock in electricity producing boilers (see section 0). As per the Waste Framework Directive, these do not qualify as recycling of brown grease[93]. However, there is a reference for the use of brown grease to produce lubricants and biopolymers (see section 0), which would qualify as recycling.

2.4. Conclusion

Contribution to circular economy

There is no demonstrated commercial use of brown grease for material/chemical purposes, which could ensure a significantly longer life time and/or carbon sequestration than energy uses (biogas and biodiesel), which can therefore be considered in line with circular economy principles. Using brown grease to produce lubricants or other types of chemicals, and as feedstock for the production of biopolymers (PHAs) could be in line with circular economy principles, but these are not at commercial scale.

With regards to contributing to waste reduction, it can be expected that further encouraging the use of brown grease for biogas or biofuel risks incentivising producers against improving processes and reducing the amount of kitchen facility waste being generated, should these be economically and technically feasible. However, this risk is anticipated to be more the case for UCO than for brown grease.

Alignment with the waste hierarchy

Using brown grease for biogas/biofuel is in line with the waste hierarchy under the following conditions:

- Waste do not meet food or feed quality standards.

  This is definitely the case for brown grease as it does not meet these standards and is prohibited from being used in food/feed applications.

- Waste, for which a food or feed use is not economically viable for the economic operator or the logistical chains to collect and/or process residues and waste into food or feed chains are not in place, and could not be readily put in place.

  This is also applicable to brown grease as it is too contaminated to be used for food/feed in the first place, let alone economical and logistical viability for its use in food/feed.

[93] As per the Waste Framework Directive, 'recycling' means any recovery operation by which waste materials are reprocessed into products, materials or substances whether for the original or other purposes. It includes the reprocessing of organic material but does not include energy recovery and the reprocessing into materials that are to be used as fuels or for backfilling operations (EC, 2008)

In summary, using brown grease as food or feed ingredient is not possible due to high contamination levels. Therefore, using these feedstocks for energy purposes (biodiesel, biogas, electricity) is in line with the waste hierarchy.

3. SUSTAINABILITY AND GREENHOUSE GASES

3.1. Union sustainability criteria

The Union sustainability criteria relate to agricultural field residues (Article 29(2)), agricultural biomass (Articles 29 (3) to (5)) and forestry biomass (Articles 29 (6) and (7)), and therefore do not apply to brown grease which is classified as a process residue/ waste.

3.2. GHG Savings Criteria

The conversion process considered is **biodiesel** production as there is evidence that brown grease is used for this (see section 0). According to the approach outlined for assessing this criterion, the first consideration is to look for a proxy in existing default values in REDII. No default value for biodiesel from brown grease is available. As an initial estimate, the default value provided in the REDII for waste cooking oil biodiesel is considered (84% savings). Rationale for selecting waste cooking oil biodiesel as a proxy is because of the common origins of the waste and the fact that as per the RTFO[94], brown grease, like UCO, may use the waste vegetable or animal oil default GHG value (RTFO, 2021). Furthermore, GHG emission savings reported under the RTFO since 2017 for FAME biodiesel based on waste/ residue feedstock are 83-88% (UK Department for Transport, 2020).

Considering GHG savings in the range of 84% to over 90%, biodiesel using brown grease would be in compliance with the GHG savings criteria for new installations i.e. at least 65% GHG savings.

Another conversion process considered is biogas production which provides **biomethane** for transport. According to the approach outlined for assessing this criterion, the first consideration is to look for a proxy in existing default values in REDII. Default values are provided for biomethane production in REDII Annex VI Part C for wet manure, maize and biowaste[95]. No default value for biomethane from brown grease is available. As an initial estimate, default values provided in the RED II for biowaste are considered which show based on the technological option a large variation in GHG emission savings is observed (20 – 80 %) depending on whether digestate is stored in an open or a closed tank and whether the off-gas is vented or combusted (see **Figure 64**). The GHG savings criteria for new installations require at least 65% GHG savings. This shows that to be eligible, the technology option of close digestate, off-gas combustion should be applied. Otherwise there is a high risk of non-compliance with GHG saving criteria.

[94] In 2008, the Department for Transport placed an obligation on suppliers of transport fuels to demonstrate that a proportion of the fuel they supply comes from renewable sources. This obligation, known as the Renewable Transport Fuel Obligation (RTFO), aims to reduce greenhouse gas emissions from vehicles, ultimately supporting the Government's target of net zero by 2050 (Action Renewables, 2020). Brown grease features in the RTFO's list of renewable fuel feedstocks including wastes and residues.

[95] As per Directive 2008/98/EC, 'biowaste' means biodegradable garden and park waste, food and kitchen waste from households, restaurants, caterers and retail premises and comparable waste from food processing plants.

BIOMETHANE FOR TRANSPORT (*)			
Biomethane production system	Technological options	Greenhouse gas emissions savings – typical value	Greenhouse gas emissions savings – default value
Biowaste	Open digestate, no off-gas combustion	43 %	20 %
	Open digestate, off-gas combustion	59 %	42 %
	Close digestate, no off-gas combustion	70 %	58 %
	Close digestate, off-gas combustion	86 %	80 %

(*) The greenhouse gas emissions savings for biomethane only refer to compressed biomethane relative to the fossil fuel comparator for transport of 94 g CO_2eq/MJ.

Figure 64. Default GHG emissions savings values provided in REDII for biomethane from biowaste

3.3. Other environmental impacts

Brown grease is a process residue/ waste and therefore has no land management impact. The evaluation of risks of adverse effects on soil, water, air and biodiversity is not applicable.

4. MARKET EFFECTS AND 2030/2050 POTENTIAL

4.1. Market effects

In the United States alone, between 1.5 and 1.7 million tonnes of brown grease is estimated to be produced annually (Spiller et al., 2020; US DoE, 2017). The estimate is based on per capita extrapolations, concentrating the resource close to urban areas with the greatest distribution located in the north east of the United States (US DoE, 2017). Availability of brown grease or 'grease separator contents' in Germany is estimated to be around 428,500 tonnes (Umweltbundesamt (Federal Environment Agency), 2019). European level data on brown grease production or collection is not available. Furthermore, the collection of brown grease using grease traps is currently not that widespread in Europe, with the possible exceptions of Austria, Germany, the Netherlands and Sweden.

Supply of brown grease depends on the volume of vegetable oil/animal fats consumed as well as the volumes collected in grease traps. Brown grease is a traded commodity (see section 2.1).

Brown grease can cause severe damage to wastewater systems, and therefore emphasis is being placed on collecting it from cooking facility wastewater before discharge to the sewage system. As mentioned in section 0, the main use of brown grease is for biodiesel and biogas production, although the biogas market is reportedly easier to target given larger number of plants compared to biodiesel plants. However, the brown grease supply chain is significantly underdeveloped, from the infrastructure for collection to aggregation and treatment. This is a major barrier to its use, alongside the limited installation of grease traps in the first instance.

Some brown grease can be used for production of lubricants and other chemicals, however, the volume of brown grease used for these applications is not considered to be significant (Spiller, 2020). **Therefore, given limited existing non-energy uses, adding brown grease to Annex IX should not have a distortive effect on any market.**

4.2. 2030/2050 Potential

We are not aware of studies that estimate the future potential supply of brown grease in the EU, or other regions. However, the future potential supply of brown grease will be dictated by future demand for vegetable oil and edible animal fat as well as the volume of brown grease collected in grease traps. Global oilseeds production is expected to increase by around 1.5% p.a. for the period 2018-2027 (FAO, 2018). Brazil and the United States will be the largest soybean producers, with similar volumes (FAO, 2018). Demand for vegetable oil is expected to grow more slowly due to slower growth in per capita food use in developing countries and the projected stagnation in demand as feedstock for biodiesel (FAO, 2018). Vegetable oil exports will continue to be dominated by Indonesia and Malaysia, while soybean, other oilseeds and protein meal exports are dominated by the Americas (FAO, 2018). In case of animal fats, global edible animal fats market has witnessed significant growth and is projected to reach over 26 million tonnes by the year 2023 with CAGR of 2.8% (Marketwatch, 2021). Growing demand for edible animal fats is due to increasing popularity of lard and tallow as main ingredient for bakery and confectionery products (Marketwatch, 2021). Focusing on the consumption of edible oils/fats, the average consumption of vegetable oils in the US and the EU between 2014 and 2016 was 15,181 kt and 24,064 kt respectively (OECD/FAO, 2017). Per capita consumption was calculated using population data (World Bank, 2021) and this is roughly 0.05 tonnes of vegetable oil consumption/ capita/ year in both the US and the EU.

The production of brown grease is expected to grow as the demand for vegetable oil and animal fat is expected to rise, as mentioned above. There are no references available that provide estimates of brown grease production in 2030 and 2050. However, using the brown grease production figures stated in section 4.1 (1.5 to 1.7 million tonnes in the US (theoretical potential); 428,500 tonnes in Germany), and population data, the per capita production figures for brown grease in the US and the EU[96] were calculated. These were used along with population growth projections (World Bank, 2021) to estimate brown grease potentials in the US and the EU in 2030 and 2050 (see **Table 147** and **Table 148**).

Table 147: Brown grease theoretical potential estimates for the US (Calculated using data from Spiller et al., 2020; World Bank, 2021)

Region	Brown grease production (tonnes/capita/ year)	Brown grease produced in 2030 (million tonnes)	Brown grease produced in 2050 (million tonnes)
US	0.005	1.6 to 1.8	1.7 to >1.9

In 2030, 1.6 million tonnes of brown grease can result in the generation of around 1.4 million tonnes of biodiesel or 0.3 million tonnes of biogas. While in 2050, 1.7 million tonnes of the feedstock can yield around 1.5 million tonnes of biodiesel or 0.33 million tonnes of biogas.

Table 148: Brown grease estimates for the EU (Calculated using data from Umweltbundesamt (Federal Environment Agency), 2019; World Bank, 2021)

Region	Brown grease technical potential (tonnes/capita/ year)	Brown grease technical potential in 2030 (tonnes)	Brown grease technical potential in 2050 (tonnes)
EU	0.01	2.3	2.2

[96] Per capita production figure of brown grease in Germany has been assumed to be the same for all of EU.

In 2030, 2.3 million tonnes of brown grease can result in the generation of around 2 million tonnes of biodiesel or 0.43 million tonnes of biogas. While in 2050, 2.2 million tonnes of the feedstock can yield around 1.9 million tonnes of biodiesel or 0.41 million tonnes of biogas.

Brown grease is and will be generated in other regions of the world as well. However, we are not aware of any references that indicate the current or future production potentials of brown grease in these regions.

In summary, the theoretical potential of brown grease production appears to be growing in the US while technical potential of brown grease is likely to decline in the EU. The brown grease production potential for remaining regions is uncertain. Furthermore, the collection potential of brown grease is uncertain as that is dictated by the number of grease traps installed as well as their maintenance.

Given limited use for brown grease in non-energy applications, this feedstock should be available in both 2030 and 2050 without causing any distortive market effects.

5. ADDITIONAL DEMAND FOR LAND

5.1. Assessment of additional demand for land

As discussed in section 4.1, brown grease is mainly used for the production of biodiesel and some biogas. It can be used for the production of lubricants and chemicals such as fatty acids, fatty alcohols, and polyol esters. However, exact quantities of brown grease used for these applications is not known and is considered to be relatively low. Taking this into account, it seems unlikely that the use of brown grease as a biofuel feedstock will have an impact on any other resource and is therefore considered a **low risk** (no land use change is expected). **Incentivising brown grease under the REDII could help boost the collection of the waste and its use in biofuel production rather than landfilling (where still permitted) or incineration.**

6. PROCESSING TECHNOLOGIES

6.1. Evaluation of processing technology (mature vs advanced)

Conversion of brown grease to **biogas/biomethane** via anaerobic digestion is the prevalent processing technology in use today. Anaerobic digestion is a mature technology (TRL 9, CRL 5) and so is biogas upgrading via CO_2 removal technologies (TRL 9, CRL 5)[97]. This makes the feedstock potentially suitable to be added to Part B of Annex IX.

Brown grease can be converted into **biodiesel** using a two-stage conversion process to allow both the triglycerides (the typical feedstock for biodiesel) and free fatty acids (FFAs) to be converted (Spiller et al., 2020). FFAs can be converted into biodiesel by an esterification reaction in which ethyl esters (biodiesel) are the main product and water is a side product. The alcohols that are frequently used in this process are methanol and ethanol. Methanol is cheaper than ethanol and is usually used in industry. Esterification can be accelerated by a catalyst that improves the reaction efficiency and the biodiesel yield. The main types of catalysts are base, acid or enzymatic catalysts that can be applied homogeneously or heterogeneously (Kolet et al., 2020). Homogeneous catalysts are more effective than heterogeneous ones, but it is difficult to separate them from the mixture after the reaction has ended. Therefore, the main focus is currently on the development and application of heterogeneous catalysts, since they are more environmentally friendly, and it is easier to separate them from the reaction mixture. Heterogeneous catalysts allow their re-use or continuous use (Kolet et al., 2020). However, all types of catalysts have their set of drawbacks

[97] It should be noted that while biogas upgrading via CO_2 removal technologies are mature technologies, new technologies for biogas upgrading via the utilisation and conversion of CO_2 are not yet mature (Adnan et al., 2019).

and R&D is underway to improve their performance as well as to reduce costs. Currently, the main method for activation of esterification reactions is thermal (Kolet et al., 2020).

Stakeholder feedback suggests that specialist/ advanced processing technology is required in order to handle feedstock with high FFA content. Compared to conventional biodiesel feedstocks, this material requires different and additional processing steps for biodiesel production due to its heterogeneous composition, high acidity, and high sulphur content (UGC, n.d.). Special processing and/or pretreatment of brown grease is required as it is contaminated with cleaning agents (Gerpen and He, 2014). However, since this feedstock conversion route has been implemented commercially in Spain and the UK (see section 0), we consider it to be a mature technology leading to FAME biodiesel production (TRL 9, CRL 5).

Although not currently applied, it is possible to process brown grease by pyrolysis to a **kerosene-like mixture of hydrocarbons** (Pratt et al., 2017). This processing option would qualify as an advanced technology. Similarly, Neste has listed brown grease as a 'future raw material option' for producing 'green diesel', which would be **HVO renewable diesel** given that is their flagship product (Biofuel Express, n.d.; Neste, n.d.). This processing option would qualify as a mature technology (TRL 9, CRL 3).

Finally, there is the option for **dual-fuel production** from brown grease which involves the transesterification process of the lipid rich FOG layer and anaerobic co-digestion of the dewatered food waste layer (Wallace et al., 2016). However, this option is still under investigation and therefore early stage in terms of TRL/ CRL.

7. Conclusions

Nomenclature:

- No concern = the evaluation did not reveal any significant concern about this feedstock.
- Some concern = the evaluation identified limited conditions under which some concerns may exist, i.e. using this feedstock for biofuel/biogas production could be in contradiction with this criterion.
- Problematic = the evaluation reveals that using this feedstock for biofuel/biogas production would be in contradiction with this criterion in most circumstances.
- Not applicable = this criterion is not applicable to the feedstock.

Table 149: Summary of evaluation results

	Evaluation Result	Rationale
Circular economy and waste hierarchy	No concern	No commercial uses exist, that can extend product life and sequester carbon for longer than energy uses. Therefore, using brown grease for biogas/biofuel does neither contribute to, nor contravene circular economy principles or the waste hierarchy. Production of lubricants, other chemicals, and biopolymers are alternatives to energy production which can extend the lifetime of the feedstock. However, feedstock pretreatment costs make the overall production process very expensive, and therefore commercially unattractive.
Union sustainability criteria	Not applicable	These criteria are **not applicable** to brown grease as this feedstock is

		neither primary agricultural biomass or agricultural field residue or forest biomass. Brown grease is a process residue or waste.
Sustainability GHG	No concern	Considering GHG savings in the range of 84% to over 90%, biodiesel using brown grease would be in compliance with the GHG savings criteria for new installations i.e. at least 65% GHG savings. <u>Under which circumstances could this feedstock be problematic?</u> To be eligible with the 65% minimum GHG saving threshold, operators producing **biogas/biomethane** from brown grease should ensure that the resulting digestate is maintained in a closed infrastructure and off-gas combustion is applied. <u>How to mitigate this concern?</u> Failure to meet the minimum GHG savings will be efficiently addressed throughout the certification process by an EU-approved voluntary or national scheme.
Sustainability Others	Not applicable	Brown grease is a residue or waste. These criteria are **not applicable** as this feedstock has no land impact.
Market distortion	No concern	Given limited existing non-energy uses, adding brown grease to Annex IX should not have a distortive effect on any market.
2030/2050 Potential	2030: EU: 2.3 million tonnes (i.e. 2 million tonnes of biodiesel or 0.43 million tonnes of biogas); US: 1.6 million tonnes (theoretical potential) (i.e. 1.4 million tonnes of biodiesel or 0.3 million tonnes of biogas) 2050: EU: 2.2 million tonnes (i.e. 1.9 million tonnes of biodiesel or 0.41 million tonnes of biogas); US: 1.7 million tonnes (theoretical	Additional supply potential will exist in other global regions.

	potential) (i.e. 1.5 million tonnes of biodiesel or 0.33 million tonnes of biogas)	
Land demand	No concern	It seems unlikely that the use of brown grease as a biofuel feedstock will have an impact on any other resource and is therefore considered a **low risk**, that is, no land use change is expected.
Processing Technologies	Mature (biogas/ biomethane) Mature (biodiesel)	The conversion technologies of brown grease into biogas or biodiesel are considered to be mature, due to high TRL (9) and CRL (5).

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Fatty acid distillates

1. TECHNICAL DESCRIPTION

1.1. Feedstock description

Fatty acid distillates (FAD) are one of the resulting products from the deodorization step in vegetable oil refining, They can be produced from a wide range of oilseed crops and are comprised of FFA (80%, primarily palmitic acid and oleic acid), triglycerides (5-15%) and to a lesser extent components such as vitamin E, sterols, squalene and volatiles (Golden Agri-Resources, 2020).

Since FAD from physical refining is of greatest interest for bioenergy applications, palm fatty acid distillate (PFAD) is the most relevant feedstock and will remain the focus of this analysis.

1.2. Production process

FADs are produced in both chemical and physical refining of vegetable oils (see **Figure 65**). In chemical refining, sodium hydroxide is generally used and soapstock, acid oil, and FAD are generated as by-products. (Soapstock and acid oil are separately assessed) With physical refining, free fatty acids (FFA) are removed in the deodorizer through steam under high vacuum and temperature which generates FAD as a by-product. However, FAD from these two methods differ in that FAD from chemical refining typically contain lower FFAs (30-50% compared to >70% for physical refining). FADs from physical refining are thus more attractive for bioenergy applications (Sherazi et al., 2016).

The refining of tropical oils such as palm and soy yield approximately 3.5-5% FAD, while oilseeds such as rapeseed and sunflower have a slightly lower yield of ~3%. Palm, which is high in FFA[98] compared to other oilseeds (>3%) is typically refined physically[99], while soy and rapeseed are typically refined chemically (Sherazi et al., 2016).

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[98] The fat in oil palm fruit starts to degrade during harvest and transportation, producing FFA. The longer the transportation time, the more the fats in the oil palm fruits degrade. The FFA level also increases as the palm oil plantation gets older.

[99] We understand that around 95% of palm oil is refined physically globally. Chemical refining is typically only applied at older refineries.

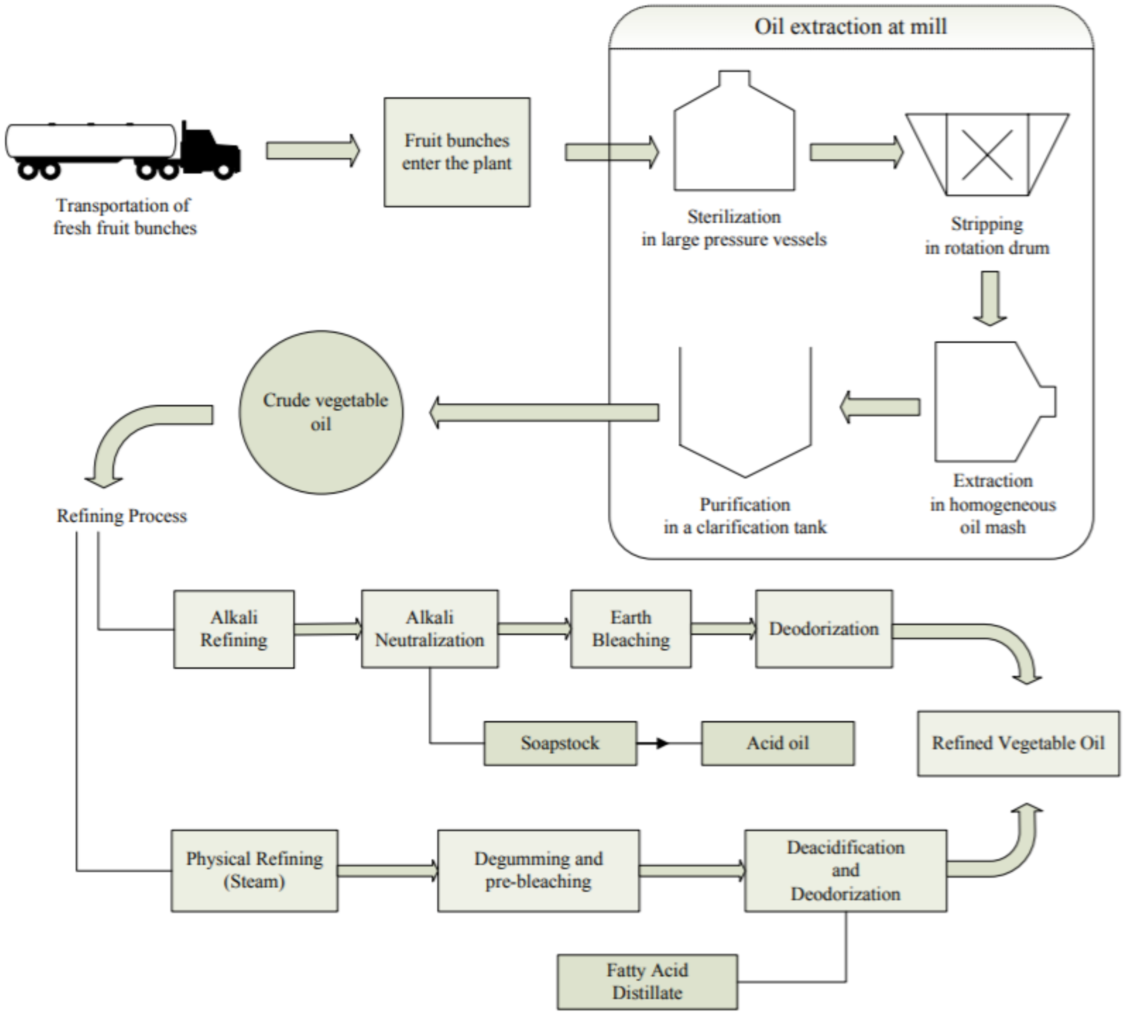

Figure 65: Process flow diagram of palm oil refining. FAD is generated in the physical refining route (bottom) (Piloto-Rodriguez et al., 2014).

1.3. Possible uses

PFAD are primarily utilised as an animal feed ingredient, for soap production and other uses in the oleochemical industry (see **Table 150**). It is also used at a lesser extent for biofuel production[100] (in particular HVO) as well as a process fuel for industrial boilers. Additional markets for PFAD utilisation, including vitamin E production, are currently emerging (Malins, 2017). Data on the relevant shares of PFAD use per application could not be readily identified.

[100] ISCC certified 173 kt of PFAD based biofuels in 2018 (ISCC, 2018).

Table 150 : Summary of possible uses for PFAD.

	Food use	Feed use	Other uses
PFAD		Documented evidence of commercial implementation.	Documented evidence of commercial implementation in oleochemical industry. Documented evidence of commercial implementation for biofuel production. Emerging use in vitamin E production

2. Circular economy and waste hierarchy

2.1. Classification of the feedstock as a co-product, residue or waste

Refined, Bleached and Deodorised Palm Oil (RBDO) is the primary aim of the oil extraction and refining process, but PFAD does have a comparable economic value on a mass basis to palm oil (605 vs 663.5 USD/MT). This could suggest that PFAD could be categorised as a co-product. However, PFAD only represents 4.9% of the total output by mass, thus its economic value is only 4.5% that of palm oil on an output weighted basis (see Table 151 and

Table 152). This low value rather suggests that PFAD could be categorised as a residue. A firm determination of PFAD as a co-product or residue would require further interpretation of the RED II and additional research beyond the scope of this project.

Table 151 : Economic value of PFAD to palm oil.

Product	Average Price 2020 (USD/MT)[101]	Output by volume (%)[102]	Economic Ratio PFAD: Palm oil (%)[103]
PFAD	605	4.9	**4.5%**

[101] Malaysian Palm Oil Board (2020).
[102] ZERO and Rainforest Foundation Norway (2016).
[103] Economic ratio is considered as ratio of prices multiplied by the output share by volume.

Palm oil[104]	663.5	100	

Table 152 : Classification of PFAD.

Evaluation question	Answer	Rationale
Is the feedstock the primary aim of the production process?	No	Refined palm oil (RPO) is the primary aim of the production process.
Does the feedstock have any economic value, but is not the primary aim of the process, and therefore a residue?	Yes	PFAD does have an economic value and is sold to the market.
Is the feedstock normally discarded, and therefore a waste?	No	PFAD is not normally discarded and is typically used for animal feed, for soap production and other uses in the oleochemical industry.

2.2. Is the use of feedstock to produce biofuel/biogas in line with circular economy principles?

- **Does the feedstock have non-energy (re)uses, which could extend its life or sequester carbon for longer?**
  Answer: Yes.

  Rationale: PFAD can be used for soap production and has other uses in the oleochemical industry which could extend its life.

  Does its use as biofuel/biogas feedstock contribute to nutrient recovery?

  Answer: No.

  Rationale: PFAD is typically converted to biodiesel, which does not contribute to nutrient recovery.

[104] Refined, Bleached and Deodorised Palm Oil.

- **Does its use as biofuel/biogas feedstock contribute to a more efficient use of resources by avoiding primary material extraction?**

  Answer: Variable.

  Rationale: As with all other biomass feedstocks, biofuel derived from PFAD displaces liquid fossil fuels, thus reducing the need for primary material extraction.

  Does its use as biofuel/biogas feedstock contribute to reducing waste generation, especially food waste?

  Answer: No.

  Rationale: PFAD is not typically disposed of, so it does not reduce waste generation to use it as a biofuel. Food waste is not applicable to PFAD.

2.3. Is the use of this feedstock for biofuel/biogas production in line with the waste hierarchy?

PFAD is considered a residue for the purpose of this assessment and therefore assessment against the waste hierarchy is not necessary.

2.4. Conclusion

The use of PFAD for biofuels is not completely aligned with the circular economy principles, as the PFAD can have non-energy uses, such as a feedstock for the oleochemical industry. This use would extend the life of this product and sequester carbon for longer compared to biodiesel derived from PFAD.

3. Sustainability and Greenhouse gases

3.1. Union sustainability criteria

The Union sustainability criteria relate to agricultural field residues (Article 29(2)), agricultural biomass (Articles 29 (3) to (5)) and forestry biomass (Articles 29 (6) and (7)), and therefore do not apply to PFAD which is classified as residue.

3.2. GHG Savings Criteria

The potential GHG savings are analysed for the pathway of PFAD to HVO biodiesel. Default values for processing and transport and distribution for hydrotreated vegetable oil from palm oil from REDII are used as a conservative proxy. Since PFAD is categorised as a residue, cultivation emissions are considered zero. GHG emissions from land use change, soil carbon accumulation, use, carbon capture and storage, and carbon capture and replacement are considered to be zero in this example.

The emissions from processing and transport would result in a GHG savings range of 51-78% depending on the processing (51% for open effluent pond and 78% for methane capture at oil mill). This demonstrates that open effluent ponds would likely not meet the GHG savings criteria of 65% reduction for new installations, but that mills with methane capture could meet the criteria.

Table 153 : Estimation of GHG emissions by lifecycle stage and GHG savings of HVO from PFAD.

Lifecycle stage	GHG Emissions Low[105] (g CO_2eq/MJ)	GHG Emission High[106] (g CO_2eq/MJ)
E_{ec} – Cultivation of raw	0	0

[105] Low considers process with methane capture at mill.
[106] High considers open effluent pond.

materials		
E_p – Processing	13.6	38.9
E_{td} – Transport and Distribution	7	7
Total	**20.6**	**45.9**
GHG Savings[107]	***78%***	***51%***

3.3. Other environmental impacts

PFAD is a process residue and therefore has no land management impact. The evaluation of risks of adverse effects on soil, water, air and biodiversity is not applicable.

4. MARKET EFFECTS AND 2030/2050 POTENTIAL

4.1. Market effects

Globally, an estimated 2.5-3.6 million tonnes[108] of PFAD are produced.[109] Most palm refining is undertaken in the country of origin. Since Indonesia and Malaysia represent the largest share of global palm cultivation (80-85%), these countries correspondingly produce the largest volumes of PFAD (IISD, 2019). PFAD is a highly traded commodity and Malaysia exported 208 kt of PFAD and palm acid oil to Europe in 2018, around a third of the total PFAD export globally (Malaysian Palm Oil Council, 2018). Some palm oil refining also takes place in Europe, where 4 million tonnes of crude palm oil was refined in 2018, which would correspond to approximately 160 kt PFAD (T&E, 2019). This indicates that PFAD is both produced domestically within Europe and imported.

PFAD only represents approximately 4.5% of the economic value compared to palm oil, as described in Section 2.1. Thus, PFAD is considered to have a **rigid supply** since supply is unlikely to increase if demand for PFAD increases. It is rather the demand for palm oil that ultimately dictates PFAD supply.

The current demand for PFAD across several industries already matches its supply. Given that this supply is rigid, diverting PFAD away from these industries to biofuel production has a **high risk of having distortive effect on these industries**. The use of PFAD for biofuel production would further increase demand of this rigid supply. The newly introduced competition from biofuel could thus lead to the substitution of PFAD with other materials in the sectors where it is currently being used. This substitution could subsequently lead to potential **negative environmental effects**.

Malins (2017) studied the potential GHG emission effects if PFAD were substituted with alternative materials and concluded that in its application in the oleochemical and soap industries, PFAD would likely be replaced by animal or other vegetable oils, most likely crude or refined, bleached and deodorized (RBD) palm oil. In its application as animal feed, it was concluded that PFAD may likely be substituted with palm or soy oil, despite their slightly higher price. This would result in additional palm or soy cultivated to fill the market demand which would subsequently have several negative environmental effects. Most notably, the additional cultivation of soy and palm would result in overall higher GHG emissions compared to PFAD, primarily due to land use change (Malins, 2017). Other potential negative environmental effects could include biodiversity loss, declining water quality, soil erosion, and air quality, amongst others (Boerma et al., 2016; Turner et al., 2011; Obidzinski et al., 2012).

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[107] Compared to the fossil fuel comparator or 94 gCO_2/MJ.

[108] An additional 0.3-0.4 kt of palm kernel fatty acid distillate (PKFAD) is produced globally, but is negligible in comparison to PFAD and therefore excluded in this analysis.

[109] Assuming 3.5-5% of palm oil refining raw material input (Neste, no date) and total palm production of 77 million tonnes in 2017-2019 (OECD, 2020).

4.2. 2030/2050 Potential

The future potential for PFAD will be dictated by future demand for palm oil. The OECD-FAO Agricultural Outlook predicts that from 2019-2029, palm oil production will grow at an annual rate of 1.5%, from 77 to 92 million tonnes. Although a slowing expansion of palm in Malaysia and Indonesia is expected due to more stringent environmental criteria of importers, growth is projected as a result of improved productivity, particularly the acceleration of replanting. In other producing countries such as Thailand, Colombia and Nigeria, expansion is expected which will also contribute to this growth (OECD, 2020). Assuming the same continued growth from 2029 to 2030, this results in estimated global palm oil production of 93.6 million tonnes. This would result in a **potential production of approximately 4.4 million tonnes PFAD in 2030[110].** Some stakeholders estimate that by 2050, the production of palm oil will nearly double. For example, the Roundtable on Sustainable Palm Oil (RSPO) estimate that global palm oil demand could increase to 120-156 million tonnes by 2050 (RSPO, 2015). This would imply a **potential production of 5.7-7.4 million tonnes of PFAD in 2050[110,111].**

As discussed above, PFAD is already widely used by other industries, and this demand is expected to remain strong until 2050. These estimated volumes, therefore, do not necessarily represent the volumes of PFAD that will be available for biofuel production, but rather provide a sense of the maximum theoretical volumes that may be available in 2030 and 2050 for all uses. **The availability of PFAD for biofuel production, without having distortive market effects, would be extremely limited in both 2030 and 2050.**

5. ADDITIONAL DEMAND FOR LAND

5.1. Assessment of additional demand for land

As identified in section 4.1, the supply of PFAD is rigid. Since PFAD is already fully used in non-biofuel commercial applications, primarily oleochemical production and livestock rearing, the increased use of PFAD in biofuel would lead to those other uses increasing consumption of substitute materials. Section 4.1 furthermore identified palm and soy oils as the most likely substitutes for PFAD diverted from these industries. Palm and soy oils both correspond with the high risk category for additional demand for land. **We thus select the high risk category for PFAD overall.**

6. PROCESSING TECHNOLOGIES

6.1. Evaluation of processing technology (mature vs advanced)

PFAD can be converted to FAME biodiesel through esterification and transesterification but proves to be more technically challenging as it requires an additional preliminary esterification step. Therefore, PFAD is of more interest for HVO production. Both transesterification and hydrotreating are considered mature technologies and biodiesel production from PFAD is already commercially practised (Neste, no date). **Therefore, both conventional biodiesel and HVO from PFAD could be considered a mature technology.** Accordingly, this feedstock would be suitable to be added to Part B of Annex IX.

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110 Assuming upper limit of 5% content of crude palm oil by mass and that 95% of palm oil is refined by physical refining

111 This could be an overestimate as this publication is from before the introduction of the phase out of high LUC risk palm oil in EU policy.

7. Conclusions

Table 154 : Summary of evaluation results.

	Evaluation Result	Rationale
Circular economy	Some concern	Under which circumstances could this feedstock be problematic? PFAD does have possible non-energy uses (e.g. feedstock for oleochemical industry) which would extend the life of PFAD and sequester the carbon for longer compared to its use as a biofuel. How to mitigate this concern? Concerns could potentially be mitigated if feedstock is used in a biorefinery setup where both biofuels and feedstocks for the oleochemical industry could be produced.
Union sustainability criteria	Not applicable	Not relevant if PFAD is considered to be a residue from processing.
Sustainability GHG	No concern	The GHG savings criteria for new installations require at least 65% GHG savings might not be met if the oil mill has open effluent ponds. In the case that there is methane capture at the mill, the GHG criteria will likely be met. How to mitigate this concern? Failure to meet the minimum GHG savings will be efficiently addressed throughout the certification process by an EU-approved voluntary or national scheme.
Sustainability Others	Not applicable	If this feedstock is categorised as a process residue, these criteria are **not applicable**.
Market distortion	Significant concern	Given that Palm Fatty Acid Distillates (PFAD) has current uses in several industries and has a rigid supply, diverting PFAD from these industries to biofuel production has a **high risk** of having distortive effect on these industries. How to mitigate this concern? This feedstock has been assessed as potentially appropriate for inclusion in Annex IXB. The contribution of Annex IXB feedstocks to national RED transport targets is capped at 1.7% of transport energy. Inclusion under this cap would limit the amount of feedstock likely to be used for biofuel

		production and thus mitigate against the most market distortive outcomes, but would not fully prevent indirect impacts.
2030/2050 Potential	2030: 4.4 million tonnes 2050: 5.7-7.4 million tonnes	The evaluation concluded that there is a potential of approximately **4.4 million tonnes** of **PFAD** in **2030**. This could increase to a potential of **5.7-7.4 million tonnes of PFAD in 2050**.
Land demand	Significant concern	The use of PFAD for biofuel will divert this material from other existing uses, and the operators of those uses may then seek substitute materials such as palm or soy oil. The risk of additional demand for land for substitute materials has been assessed in previous studies and on that basis, the majority of PFAD substitutes (palm and soy) would fall in the **high risk category**. How to mitigate this concern? See market distortion.
Processing Technologies	Mature	Biodiesel production from PFAD is already commercially practised and both transesterification and hydrotreating are considered **mature technologies**.

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Technical corn oil

1. TECHNICAL DESCRIPTION

1.1. Feedstock description

Technical corn oil is defined here as oil extracted from corn (maize) after fermentation. It is also sometimes referred to as distillers' corn oil. Oil extracted from corn prior to fermentation is here referred to as 'crude corn oil'. Unlike crude corn oil, technical corn oil is not considered fit for human consumption and only has non-food applications. In the United States the Association of American Feed Control Officials defines technical corn oil (and other similar technical oils) as follows:

> *Distillers Oil, Feed Grade, is obtained after the removal of ethyl alcohol by distillation from the yeast fermentation of a grain or a grain mixture and mechanical or solvent extraction of oil by methods employed in the ethanol production industry. It consists predominantly of glyceride esters of fatty acids and contains no additions of free fatty acids or other materials from fats. It must contain, and be guaranteed for, not less than 85 percent total fatty acids, not more than 2.5 percent unsaponifiable matter, and not more than one percent insoluble impurities. Maximum free fatty acids and moisture must be guaranteed. If an antioxidant(s) is used, the common or usual name must be indicated, followed by the words "used as a preservative." If the product bears a name descriptive of its kind of origin, i.e. "corn, sorghum, barley, rye," it must correspond thereto with the predominating grain declared as the first word in the name."* (see chapter 4 of U.S. Grains Council, 2018).

1.2. Production process

Following fermentation at an ethanol plant, ethanol is separated out from the 'beer' produced by fermentation, the remnant material being referred to as whole stillage. Whole stillage is further separated into a solid (distillers' grains) and liquid (thin stillage) fraction. This liquid fraction, thin stillage, contains most of the oily/fatty content of the corn grain. In the past the standard practice would be to condense the thin stillage (into condensed distillers' solubles) and mix this material back into the solid fraction to produce the distillers' grains and solubles (DGS) that are marketed as animal feed. It is also possible to extract the oily/fatty content from the thin stillage prior to recombination. That extracted oily content is technical corn oil, and the feed produced by mixing distillers' grains with reduced-fat condensed distillers' solubles is sometimes referred to as 'reduced-fat' or 'de-oiled' distillers' grains and solubles (see chapter 3 of U.S. Grains Council, 2018).

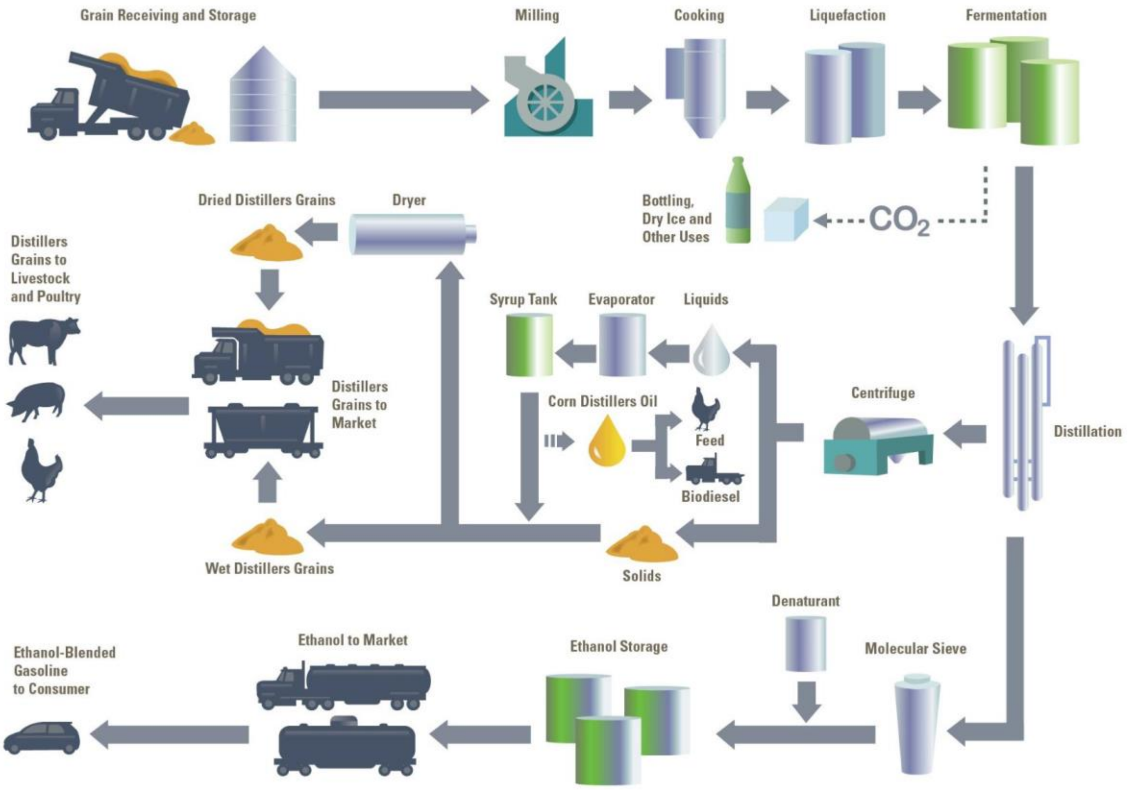

Figure 66: Process for TCO extraction (source: Renewable Fuels Association via E4tech, 2019)

1.3. Possible uses

Technical corn oil is currently used as an animal feed ingredient and as a biodiesel/HVO feedstock. The consultation produced no evidence of technical corn oil being used for cosmetics applications or processed to meet requirements for human consumption.

Respondents to the consultation indicated that technical corn oil is marketed in the EU animal feed market under designation 2.20.1 (vegetable oil and fat) of the EU Catalogue of feed materials (European Commission, 2017).

Technical corn oil extraction is more widespread in the United States, and its use in livestock diets is better documented in the U.S. context. U.S. Grains Council (2018) identifies technical corn oil as an ingredient primarily used in poultry and swine diets (primarily for younger animals in the case of swine).

If technical corn oil is not extracted from thin stillage, the fat content will remain in the solubles and be mixed back into the distillers' grains and solubles and generally provided to the feed market.

Table 155: Summary of possible uses of technical corn oil

	Food use	Feed use	Other uses
Technical corn oil	None	Animal feed supplement	Biodiesel and HVO production

2. Circular economy and waste hierarchy

2.1. Classification of the product as a co-product, residue or waste

There was some disagreement among consultation respondents about whether technical corn oil should be characterised as a residue or as a co-product, though all agreed it is not a waste. Respondents who consider it a residue noted that technical corn oil extraction is not uniformly practiced and argue that its production is not a primary aim of the industry. Respondents who consider it a co-product noted that the process has to be modified to allow technical corn oil extraction and that it has a relatively high unit value (higher value per unit mass than corn itself, for example). Having considered these arguments, the consortium considers that in the sense of the RED II technical corn oil may be classed as a residue. The modifications to the process required to extract technical corn oil are relatively minor and do not affect the core ethanol production processes. The contribution of corn oil sales to overall ethanol plant revenue is modest (expected to be of the order of 2-4% based on responses to the consultation).

Table 156: Classification of technical corn oil

Evaluation question	Answer	Rationale
Is the feedstock a primary aim of the production process?	No	The ethanol production process existed and was widely used before the introduction of processes to extract oil from thin stillage. While the value of technical corn oil per unit mass is significant compared to the value of distillers' grains, the quantities produced are low compared to ethanol and DGS. The process does have to be modified to extract technical corn oil, but only after the main process step (fermentation) has already occurred.
Does the feedstock have any economic value, but is not a primary aim of the process, and therefore a residue?	Yes	Technical corn oil has economic value as a standalone or else it would not be extracted. In the United States where technical corn oil extraction is now practiced in over 90% of ethanol plants, the development of the market was led by animal feed use, and more than 50% of technical corn oil in the U.S. is still supplied to animal feed, i.e. the value is not solely predicated on the biodiesel market.
Is the feedstock normally discarded, and therefore a waste?	No	Technical corn oil will not be extracted unless there is a market for it.

2.2. Is the use of feedstock to produce biofuel/biogas in line with circular economy principles?

- **Does the feedstock have other material (re)uses, which could further extend its life or sequester carbon for longer?**

  Answer: No.

  Rationale: The primary alternative use for technical corn oil is animal feed, which is comparable to energy recovery as a short-term material use. There may in principle be applications in oleochemicals[112] in which technical corn oil could substitute other oils or

[112] This is also suggested as a current use in online material from Neste published by Neste: https://www.neste.com/products/all-products/raw-materials/waste-and-residues

fats and which would generate more persistent output products, but we have not received evidence of commercial implementation of such technologies.

- **Does its use as biofuel/biogas feedstock contribute to nutrient recovery?**

  Answer: No.

  Rationale: Oils are fully consumed when used as biodiesel/HVO feedstock.

- **Does its use as biofuel/biogas feedstock contribute to a more efficient use of resources by avoiding primary material extraction?**

  Answer: Not substantially.

  Rationale: Technical corn oil would be entirely utilised in animal feed if it was not supplied to the biofuel/biogas market, either through sale of the extracted oil into the feed market, or by inclusion of the fatty constituents in DGS. This existing use of the resource limits the potential to deliver net reductions in primary material extraction. To the extent that demand from the biofuel/biogas market supports increased rates of technical corn oil extraction (rather than displacement of material already being extracted), it may allow these fatty materials to be put to a more efficient use than is achieved as a DGS constituent. There is some evidence from livestock studies that the loss of fatty content from reduced-fat DGS may be substituted on an energy basis by corn feed (e.g. Anderson, Kalscheur, Garcia, et al., 2015a). As the price per unit of energy of corn feed is below that of vegetable oils/diesel fuel, this could be seen as a marginally more efficient use of resources.

- **Does its use as biofuel/biogas feedstock contribute to reducing waste generation, especially food waste?**

  Answer: No.

  Rationale: No impact on waste generation is expected.

2.3. Is the use of this feedstock for biofuel/biogas production in line with the waste hierarchy?

TCO is considered a residue for the purpose of this assessment and therefore assessment against the waste hierarchy is not necessary.

2.4. Conclusion

Contribution to the circular economy

The use of technical corn oil as biofuel/biogas feedstock does not actively contribute to development of a circular economy, but it does not contradict circular economy principles.

Alignment with the waste hierarchy

Technical corn oil is considered a residue for the purpose of this assessment and therefore assessment against the waste hierarchy is not necessary.

3. SUSTAINABILITY AND GREENHOUSE GASES

3.1. Union sustainability criteria

TCO is a process residue therefore the mandatory REDII sustainability criteria do not apply.

3.2. GHG savings criteria

Technical corn oil does not have a default GHG emission value provided in the RED II. If considered a process residue technical corn oil according to REDII TCO would be considered to have zero life cycle emissions until the point of collection. Technical corn oil is somewhat comparable in terms of properties to use cooking oil (e.g. higher free fatty acid content than virgin oils) and the default GHG emissions values for used cooking oil biodiesel and HVO (84% and 83% GHG savings respectively) may therefore be taken as indicative of potential values for technical corn oil. Approved pathways for TCO biodiesel assessed under the California Low Carbon Fuel Standard methodology (California Air Resources Board, 2021) generally have GHG emission values in the range from 25 to 35 gCO2e/MJ.

Biodiesel and HVO from TCO are therefore likely to meet the GHG savings criteria.

3.3. Other environmental impacts

Technical corn ethanol is a process residue and therefore has no land management impact. No other negative environmental impact is anticipated from increased use of TCO for biofuel/biogas.

4. MARKET EFFECTS AND 2030/2050 POTENTIAL

4.1. Market effects

The production of TCO may be considered semi-elastic. The total potential is determined by the rates of corn ethanol production from dry milling, but there is some potential to increase implementation of extraction technology.

The largest corn ethanol producer in the world is the United States. Since 2005 technical corn oil extraction has become a normative technology in the U.S. industry, utilised by over 90% of plants, and annual production of technical corn oil had reached about 1.5 million tonnes by 2017 and more than half of that material is currently supplied as animal feed (U.S. Grains Council, 2018). Less information is readily available regarding extraction and disposition of technical corn oil in the EU. Flach et al. (2019) suggests around 150 million litres of annual corn oil production by the EU ethanol industry and that this production has been more or less stable since at least 2013. This would be consistent with corn oil extraction being implemented for less than half of EU corn ethanol capacity. It was suggested in response to the stakeholder consultation that there is currently no significant use of technical corn oil as a biodiesel feedstock in the EU and therefore that all EU extracted material is used for animal feed. That assessment is consistent with conclusions drawn by some previous studies (E4tech, 2019; Malins, 2017). Technical corn oil is identified as a potential HVO feedstock by Neste but they report only the use of material from the U.S.[113] The EU and U.S. are the main regions in which corn ethanol Is produced. Allowing for a limited continued increase in corn oil extraction in the U.S. since 2017 we therefore estimate about 1.7 million tonnes of current annual global technical corn oil production. This could be increased by implementing corn oil extraction at the remaining facilities where it is not current practice and potentially through increasing the efficiency of extraction systems. Doubling extraction in the EU and increasing U.S. extraction by a further 5-10% would bring the total potential resource to about 2 million tonnes.

Scaling up the use of technical corn oil as an EU biofuel/biogas feedstock could be achieved either by displacing currently extracted material from existing feed applications, or by increasing rates of extraction and thereby slightly reducing production and changing the nutritional profile of DGS form corn ethanol plants. However the material is removed from the feed market, the metabolisable energy content of the oil would need to be replaced.

Chapter 4 of U.S. Grains Council (2018) discusses the characteristics of technical corn oil as animal feed. It is reported that technical corn oil is primarily added to swine and poultry feed rations as a high-metabolisable-energy feed supplement. Technical corn oil is identified in particular as an alternative to animal fats allowing meat to be marketed as plant fed. Technical corn oil has a higher fatty acid content than virgin vegetable oils such as palm or soy, more comparable to used cooking oils or animal fats such as ‘white grease’ (a grade of pork fat). The metabolisable energy per unit mass is significantly higher than that of cereal feeds, comparable to that for other fats and oils. If technical corn oil is diverted to the biofuel/biogas market, the obvious choices for alternative energy feeds would be cereals or vegetable oils (we assume that total supply of animal fats is rigid to demand).

[113] https://www.neste.com/products/all-products/raw-materials/waste-and-residues

There is some disagreement in the literature regarding whether cereals or vegetable oils are indeed the more likely alternatives. Searle (2019) argues in the U.S. context that diversion of technical corn oil to the biodiesel industry has been largely compensated by increased use of corn feed, and states that there is very little direct use of vegetable oils in animal feed rations in the U.S. An alternative view is presented by Malins (2017), which notes that the reported price per unit of metabolisable energy of oils and fats including technical corn oil is systematically higher than that of cereal feeds. This implies that livestock producers see added value from the use of fatty feeds beyond simply the metabolisable energy content, and therefore may consider alternative fatty feeds rather than increased use of cereal feed if the availability of technical corn oil changes.

Several sources discuss the specific benefits of including liquid fats in animal rations. For example, Vine (2016) identifies soybean, palm, rapeseed and sunflower oils as possible components of high-density poultry feed, Shoen (2014) discusses technical corn oil as a soybean oil alternative for swine and Tomkins & Drackley (2010) discuss the opportunities for use of palm oil in animal diets. Numerous studies detail the nutritional performance of vegetable oils in animal diets (e.g. Cao & Adeola, 2016; Kamran et al., 2020; Smink et al., 2008) and it has been demonstrated that fatty feed supplements can improve animal growth performance when used at appropriate levels at appropriate growth stages (Nwoche et al., 2004). Soffe & Lobley (2021) identifies soya, sunflower, corn and rapeseed oils as all being routinely used by the feed industry in feed blends. It notes that fatty feeds may be marketed by linoleic acid content and that preferred applications differ between these soft fats and harder fats based on palm oil or animal fats – harder fats may be preferred for ruminant animals, while soft fats including technical corn oil are better suited for monogastrics.

The picture may be somewhat different for the impact of increasing the rate of technical oil extraction. Oil extraction reduces the total output mass of DGS and changes their nutritional profile, in particular reducing the energy content per dry tonne (reduced-fat DGS). As with the removal from the feed market of extracted oils, this lost material would need to be compensated with other feeds. Garcia (2012) argues that reduced-fat DGS should be priced at a systematic discount compared to conventional DGS due to reduced energy density – under the market conditions assessed, going from 10.6% fat to 4% fat in DGS should reduce price per unit mass by 9.3%. This study also notes however that reducing fatty content in DDGS may allow higher rates of dietary inclusion for ruminants.

One series of papers (Anderson, Kalscheur, Clapper, et al., 2015; Anderson, Kalscheur, Garcia, et al., 2015a, 2015b) looked at the relative performance of dairy heifers on feed mixes including a 'standard' higher fat DGS and a mix with reduced-fat DGS complemented with corn feed. This series of studies found no significant difference in growth performance for these two feed mixes and comparable lactation performance in heifers fed on the two types of DGS while developing, but that heifers on the higher-fat diet had higher cholesterol and may reach puberty more quickly. Some studies have suggested that reducing fat content in DGS does not strongly predict actual metabolisable energy in DGS fed to swine, has limited impact on laying performance for poultry and may be associated with marginal improvements in milk production for dairy animals (Shurson, 2012; Shurson & Kerr, 2012). Overall these studies suggest that the missing fat content in reduced-fat DGS may be successfully compensated on an energy basis with cereal feed, especially in the case of dairy heifers where there may be advantages from a reduced-fat diet.

Considering the two cases, the evidence suggests that if existing supplies of technical corn oil are displaced from animal feed markets they would be primarily replaced by other non-palm vegetable oils, but that if additional technical corn oil is supplied by increasing extraction rates then that material may be primarily replaced by cereal feeds.

4.2. 2030/2050 potential

The potential for technical corn oil production is dependent on rates of corn ethanol production. If the maximum corn oil yields suggested by Flach et al. (2019) could be achieved on all current EU corn ethanol production the annual supply could reach 320 thousand tonnes (potential to produce 320 thousand tonnes biodiesel).

Looking forward to 2030, the supply of food-based biofuels in the EU is constrained under the RED II and the European Commission has indicated that expansion in biofuel supply should come from advanced biofuels. We therefore do not anticipate significant growth in corn ethanol production in the period to 2030, and take 320 thousand tonnes as our estimate of 2030 EU production. Ethanol production in the U.S. is limited by the current blend wall (10% ethanol in gasoline in most of the country) and there is limited potential to increase extraction rates from DGS. The current phase of the Renewable Fuel Standard ends in 2022 and it is not yet clear what level of ethanol supply may be mandated in the U.S. for 2030. In the absence of clear evidence for the trajectory of ethanol production to 2030 we estimate that up to 1.7 million tonnes could be available in principle for export to the EU in 2030. Production of corn ethanol is limited outside the U.S. and EU. As the U.S. already has a mature market in biofuels from technical corn oil, we might expect that consumption in the EU would largely rely on mobilisation of local resources.

As the electric vehicle fleet grows the capacity to blend ethanol in the petrol pool will start to shrink. This will affect the potential for ethanol supply in 2030, and by 2050 the petrol pool will have been dramatically reduced in both the EU and U.S. First generation ethanol consumption may be expected to be significantly reduced if not eliminated by 2050, and there is therefore limited potential for technical corn oil use in the EU by 2050.

5. ADDITIONAL DEMAND FOR LAND

5.1. Assessment of additional demand for land

As discussed in the previous sections, technical corn oil is currently a fully utilised resource. Diverting existing supplies from animal feed is likely to primarily create increased demand for virgin vegetable oils (soy, rapeseed and/or sunflower) while increasing extraction of technical corn oil is likely to primarily create additional demand for cereals. Vegetable oils are considered high land use risk while cereals are considered medium land use risk. Technical corn oil is therefore considered to represent a medium to high risk of additional land demand.

6. PROCESSING TECHNOLOGIES

6.1. Evaluation of processing technology (mature vs advanced)

Technical corn oil could be used as a feedstock for biodiesel and for HVO – both pathways are already in use in the U.S. and are mature technologies. If added to Annex IX technical corn oil would therefore most appropriately be placed in Part B.

7. CONCLUSIONS

Table 157: Summary of evaluation results

	Evaluation Result	Rationale
Circular economy	No concern	Increased extraction and use of Technical corn oil (TCO) for bioenergy purposes does not contradict circular economy principles, nor does it actively contribute to them.
Union sustainability criteria	Not applicable	These criteria are not applicable to TCO as this feedstock is neither primary agricultural biomass or agricultural field residue or forest biomass.
Sustainability GHG	No concern	Default GHG emissions values for similar feedstocks meet the criteria.
Sustainability Others	No concern	No other significant environmental impact anticipated.
Market distortion	Significant concern	TCO is a resource that would otherwise be fully utilised, primarily in animal feed either directly or as a constituent of DGS. The feed value of TCO would need to be replaced if diverted to biofuel/biogas use.
2030/2050 Potential	2030: 320 thousand tonnes [320 thousand tonnes biodiesel] (EU); 1.7 million tonnes [1.7 million tonnes biodiesel] (U.S.) 2050: limited	Assumes corn ethanol production rates more or less constant to 2030 and then reduced significantly by 2050.
Land demand	Significant concern	TCO displaced from existing markets is likely to be replaced with vegetable oils, while additional extraction of TCO from distillers' grains is likely to be compensated by additional cereals. These are materials with a high and medium land use change risk respectively. The overall risk of additional demand for land is therefore considered high.
Processing Technologies	Mature	TCO may be processed with mature biodiesel and renewable diesel production technologies.

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Distillers' dried grain with solubles

1. TECHNICAL DESCRIPTION

1.1. Feedstock description

Distillers' dried grain with solubles (DDGS) is a material that arises from bioethanol production. It represents the non-fermented fraction of grains and is composed of crude proteins (26-33%), fat (9-14%), fibre, vitamins and minerals, and ins some cases, very small quantities of residual starch. The composition of DDGS varies depending on the process of ethanol production, the batch of production and more importantly the grain it is derived from. DDGS can be produced from maize[114], wheat and barley ethanol fermentation (Iram et al., 2020). Corn is the most abundantly used feedstock for bioethanol production globally, and therefore corn DDGS will be the specific focus of this analysis.

1.2. Production process

DDGS is produced during bioethanol production from grains using the dry milling process, as shown in **Figure 67.** (Chatzifragkou et al., 2015). After the starch fraction of the grain is fermented, the alcohol is removed by distillation. The resulting water and solids that remain after the distillation, called whole stillage, is then centrifuged to separate the coarse solids from the liquid. The liquid, also known as thin stillage, has the moisture removed by passing through an evaporator. This results in a syrup called condensed distillers solubles and a coarse solids fraction, also called wet cake. The wet cake can be dried to produce dried distillers' grains (DDG) or mixed with the condensed distillers solubles and dried to produce DDGS (U.S. Grains Council, 2012).

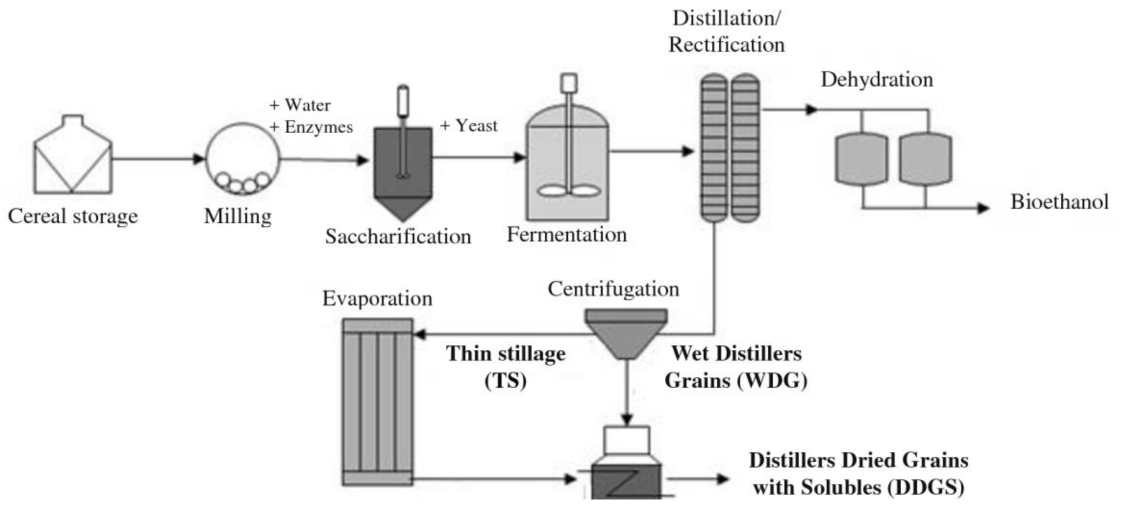

Figure 67. Process diagram of dry mill bioethanol production.

1.3. Possible Uses

Currently, DDGS is primarily used as animal feed due to its nutritional properties; it contains crude protein, fat, fibre and smaller amounts of other nutrients such as vitamins. DDGS is thus a partial

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114 Note that maize is typically referred to as corn in the United States. We have applied the term maize in this report throughout.

replacement for typical energy, protein and phosphorous ingredients in animal feed such as maize, soybean meal or dicalcium phosphate (U.S. Grains Council, 2012).

Although the health benefits have been explored for human consumption (Gallaher, 2013) there is no documented evidence that this has been implemented at commercial scale.

Many other applications have also been explored, such as the production of organic acids, biogas, biodiesel, biohydrogen hydrolytic enzymes, and most notably acetone, butanol, and ethanol (ABE). ABE can be produced through fermentation in two stages, anaerobic acidogenesis and solventogenesis while biodiesel can be produced through pyrolysis. Biogas can also be produced through anaerobic digestion (Iram et al., 2020). However, these are all lab scale studies, and the only current application at commercial scale is for animal feed.

Table 158 : Summary of possible uses of DDGS.

	Food use	Feed use	Other uses
Distillers' dried grain with solubles (DDGS)	No documented evidence of commercial implementation.	Documented evidence of commercial implementation.	Biogas, biodiesel, biohydrogen, organic acids and hydrolytic enzymes possible in theory but no evidence of commercial implementation.

2. Circular economy and waste hierarchy

2.1. Classification of the feedstock as a co-product, residue or waste

DDGS is a widely traded commodity, and in 2018, DDGS exported by the U.S. was valued at approximately 1.6 billion EUR. The price of ethanol and DDGS are also interconnected; from 2017 to 2018, for example, low ethanol prices were compensated by higher prices for ethanol co-products such as DDGS, and the DDGS price increased more than 40% during this period (ABF Economics, 2019). Although the economic value of ethanol and DDGS fluctuate, the economic value of DDGS compared to ethanol is estimated to be significant, at approximately 30% based on 2019 prices (as detailed in **Table 159**).

Table 159 : Economic value of ethanol and DDGS.

Product	Revenue (EUR/tonne maize)
Ethanol	149.59[115]
DDGS	44.05[116]
Economic value DDGS to Ethanol	**29.4%**

[115] Assuming a price of 443 USD/tonne and yield of 10.0 kg ethanol/bushel corn (Progressive Farmer, 2020; Penn State, n.d.). 1 bushel of corn is equivalent to 25.4 kg corn.

[116] Assuming a price of 170 USD/tonne and yield of 7.7 kg DDGS/bushel corn (Progressive Farmer, 2020; Penn State, n.d.). 1 bushel of corn is equivalent to 25.4 kg corn.

Both the high economic value and important traded volumes as animal feed suggest that DDGS should be classified as a co-product. However, the primary aim of dry corn processing is ethanol production via soaking and fermentation, which generate DDGS as a side stream; this would suggest that DDGS should be classified as a residue, as per RED II definition. A firm determination of DDGS as a co-product or residue would require further interpretation of the RED II and additional research beyond the scope of this project.

Table 160 : Classification of DDGS.

Evaluation question	Answer	Rationale
Is the feedstock the primary aim of the production process?	Yes	Ethanol is the primary aim of the production process.
Does the feedstock have any economic value, but is not the primary aim of the process, and therefore a residue?	No	DDGS has a high economic value of around 30% compared to ethanol.
Is the feedstock normally discarded, and therefore a waste?	No	DDGS is not normally discarded, it is widely used for animal feed.

2.2. Is the use of feedstock to produce biofuel/biogas in line with circular economy principles?

- **Does the feedstock have non-energy (re)uses, which could extend its life or sequester carbon for longer?**
  Answer: No.

  Rationale: DDGS is typically used for animal feed. Nevertheless, this use would not significantly extend its life or sequester carbon for longer than energy uses.

- **Does its use as biofuel/biogas feedstock contribute to nutrient recovery?**

  Answer: Variable.

  Rationale: Biogas production via digestion generates a digestate, which retains C, N, P and other important nutrients. The digestate can be used as fertiliser, thus contributing to decreasing the need for industrial fertiliser production (IEA Bioenergy, 2015 and EC, 2019). If DDGS were used for biogas production, this could contribute to nutrient recovery. However, if DDGS were used for other biofuel production such as ethanol or butanol, this would not contribute to nutrient recovery.

- **Does its use as biofuel/biogas feedstock contribute to a more efficient use of resources by avoiding primary material extraction?**

  Answer: No.

  Rationale: Using DDGS for biofuel or biogas production displaces liquid fossil fuels and natural gas, but this is not feedstock specific. On the contrary, using DDGS for biofuel or biogas production would prevent reuse of material for animal feed, thus leading to additional primary production of this animal feed.

- **Does its use as biofuel/biogas feedstock contribute to reducing waste generation, especially food waste?**

  Answer: No.

Rationale: DDGS is not currently disposed of, rather is used as animal feed. Thus, using this feedstock for biofuel or biogas production would not contribute to reducing waste generation.

2.3. Is the use of this feedstock for biofuel/biogas production in line with the waste hierarchy?

DDGS is considered a co-product for the purpose of this assessment and therefore assessment against the waste hierarchy is not necessary.

2.4. Conclusion

Contribution to circular economy

Using DDGS for biogas or biofuel production does not contribute to a circular economy as this feedstock is already used for animal feed, thus the nutrients are already used or recovered.

3. Sustainability and Greenhouse gases

Maize is generally cultivated on land that has been in agricultural production since before 2008, thus the Union sustainability criteria are of low concern. In addition, evidence needs to be provided as part of the biomass certification process to demonstrate that land use change has not occurred. A high risk of non-compliance is not foreseen for maize DDGS.

3.1. Union sustainability criteria

Table 161 : Assessment of DDGS.

Criterion (all land status assessed in 2008)	Assessment
(2) for wastes and residues derived from agricultural land operators or national authorities have monitoring or management plans in place in order to address the impacts on soil quality and soil carbon	Not relevant, DDGS is attained from processing not derived from agricultural land.
(3) bioenergy from agricultural biomass shall not be made from raw material obtained from land with a high biodiversity value	Maize is generally cultivated on land that has been in agricultural production since before 2008 and agricultural land is not highly biodiverse. A high risk of non-compliance is not foreseen for this criterion.
(4) bioenergy from agricultural biomass shall not be made from raw material obtained from land with high-carbon stock in January 2008 if the status of the land has changed	Maize is generally cultivated on land that has been in agricultural production since before 2008 and agricultural land is not high-carbon stock.. A high risk of non-compliance is not foreseen for this criterion.
(5) bioenergy from agricultural biomass shall not be made from raw material obtained from land that was peatland in January 2008, unless evidence is provided that the cultivation and harvesting of that raw material does not involve drainage of previously undrained soil.	Maize is generally not cultivated on land that was peatland. A high risk of non-compliance is not foreseen for this criterion.

3.2. Potential GHG savings

The potential GHG savings are assessed for the production of bioethanol from DDGS. Due to a lack of available data, we have applied the REDII default values of corn (maize) bioethanol as a proxy and allocated emissions to DDGS where applicable.[117] GHG emissions from land use change, soil carbon accumulation, carbon capture and storage, and carbon capture and replacement are considered to be zero.

DDGS is categorised as a co-product and energy allocation is applied (allocation factor 0.35 for DDGS and 0.65 maize) GHG savings range from 61-83% depending on the process fuel used in the CHP plant in the processing step, as detailed in Table 162 (forestry residues, natural gas and lignite respectively).

Table 162 : Estimation of GHG emissions by lifecycle stage and GHG savings of bioethanol production from DDGS.

Lifecycle stage	GHG Emissions Low[118] (gCO_2e/MJ)	GHG Emission Mid[119] (gCO_2e/MJ)	GHG Emission High[120] (gCO_2e/MJ)
E_{ec} – Cultivation of raw materials	13.7	13.7	13.7
E_p - Processing	1.4	11.2	21.6
E_{td} – Transport and Distribution	1.2	1.2	1.2
Total	**16.3**	**26.1**	**536.**
GHG Savings[121]	***83%***	***72%***	***61%***

If natural gas is used as a process fuel, as is most representative, the GHG savings would be 72%. If forestry residues are used for processing, the GHG savings will also very likely be met. Use of lignite, however, is not likely to meet the 65% savings criteria for installations starting operation from 1 January 2021.

3.3. Other environmental impacts

An overview of the potential negative environmental impacts from maize production (from which maize DDGS is derived) are highlighted in Table 167. The environmental impacts with high risk that should be minimised are soil erosion and risk and adverse impacts on biodiversity. Other impacts of medium risk are soil compaction from machinery, water quality and quality, and air pollution through application of herbicides and pesticides.

[117] Cultivation of raw materials default value of 25.5 gCO_2/MJ multiplied by allocation factor of 0.46, which is the allocation factor of DDGS to ethanol used for corn (maize) ethanol in the BioGrace-I Tool, v4.
[118] Low considers forest residues as process fuel in CHP plant.
[119] Mid considers natural gas as process fuel in CHP plant.
[120] High considers lignite as process fuel in CHP plant.
[121] Compared to the fossil fuel comparator or 94 gCO_2/MJ.

Table 163 : Overview of evaluation of risks for adverse effects on soil, water, air and biodiversity for maize.

Type of risk to be reviewed	Risk indicator	Risk level	Rationale and sources
Adverse impacts on soil quality	2.1 Soil Organic Matter: decline should be avoided	Low risk	Maize, as a row crop, is a high-risk crop with regard to soil erosion. The basic erosion risk comes from relatively wide rows, due to high demands for direct sunlight exposure, and from late sowing, leaving the soil bare for long periods (Diaz-Chavez et al., 2013). The use of fertiliser in maize is high and soil is bare for a long period, thus nutrient loss through leaching is considerable. Maize production leads to more soil erosion than any other crop gown in the U.S. (Altieri, 2009). Maize cultivation is also associated with moderate soil compaction risk from the use of harvesting machinery (Diaz-Chavez et al., 2013). The effect of maize production on soil organic carbon levels depends on the amount of stover residues left on the soil. The incorporation of stover into the soil can increase soil organic carbon and overall soil quality (Urra et al., 2018).
	2.2 Nutrient and phosphate balance: a disturbance of the balance leading to strong leaching of nutrients should be avoided	Medium risk	
	2.3 Soil erosion: should be minimised	High risk	
	2.4 Soil structure: soil compaction and waterlogging should be avoided	Medium risk	
	2.5 Soil biodiversity: contamination of soils with metals and other toxic component, disturbance of soil structure and decline in soil organic carbon may all lead to a decline in biodiversity and this should be avoided	Low risk	
Adverse impacts on water quality	3.1 Water quality: ground and surface water quality should not decline through increased leaching and run off of N, P from fertilization and of other contaminants from fertilization and weed and pest control.	Medium risk	In the EU, water pollution from nitrogen and sediment run-off in maize cultivation systems have been underlined as key risks from maize cultivation (Diaz-Chavez et al., 2013). Maize applies high rates N—from 100 to >200 kg N ha^{-1} yr^{-1} in the US Midwest, and often two to three times more than this in China (Hussain et al., 2019). Weed control, due to the large size of the crop, relies on pesticide use beyond the early stages of cultivation (Diaz-Chavez et al., 2013).
Adverse impacts on	4.1 Water quantity: excessive water consumption in	High risk	Maize irrigated systems are very frequent across the EU and characterised by high intensity

Type of risk to be reviewed	Risk indicator	Risk level	Rationale and sources
water quantity	agriculture should not lead to depletion of sweet water resources and salinization.		water requirements. In the Mediterranean region, 80% of maize croplands are under irrigated systems, whilst in the Atlantic region, the share is 40% of total maize croplands (Diaz-Chavez et al., 2013).
Adverse effects on air quality	5.1 GHG emissions: GHG emissions from cropping should be minimized	Low risk	Potential emissions of VOCs, SOx, CO and NOx during processing of maize into biofuels (Diaz-Chavez et al., 2013). Weed control, due to the large size of the crop, relies on pesticide use beyond the early stages of cultivation (Diaz-Chavez et al., 2013).
	5.2 Ammonia and NOx emissions: should be minimized	Low risk	
	5.3 Air pollution through spreading of herbicides and pesticides should be minimized	Medium risk	
Adverse effects on biodiversity	6.1 Crop diversity: large scale monocultures decreasing crop diversity strongly in a region should be avoided	High risk	In most EU countries, 30% or more of maize area is under monoculture (Diaz-Chavez, 2013). Maize production expansion in the U.S. leads to lower landscape diversity and decreases biocontrol services (Joley et al., 2015).
	6.2 Biodiversity: Direct adverse impacts on flora and fauna should be avoided	Low risk	
	6.3 Pollination: Direct adverse impacts on pollinators and their habitats should be avoided	Low risk	
	6.4 Invasive species: use of biomass crops that are invasive should be banned	Low risk	

4. Market effects and 2030/2050 potential

4.1. Market effects

As a co-product of bioethanol production, the market for DDG has grown in tandem with the growing demand for bioethanol. The U.S., as the major producer of bioethanol (estimated to represent 90% of global DDG production), saw a dramatic increase in bioethanol production after the Renewable Fuel Standard was passed. Consequently, from 2005/2006 to 2017/2018, DDGS production increased more than four-fold from 9 to 38.5 million tonnes. An additional 1 million tonnes was generated from beverage distilleries in the US (USDA, 2019). The European ethanol industry produced 3.8 million tonnes of DDGS in 2019 for comparison (Feed Navigator, 2020).

DDGS is currently used as animal feed for livestock and poultry due to its nutritional properties. In 2017/2018, the majority of DDGS produced in the U.S. was consumed domestically, while 12 million tonnes were exported to Mexico and Southeast Asia, due to their growing livestock industries (USDA, 2019). The aquaculture industry in Southeast Asia is also emerging as an additional growth opportunity for U.S. DDGS. Consumption could reach around 1 million tonnes depending on the inclusion rate (U.S. Grains Council, 2020). DDGS in Europe is also used for GMO-free animal feed and reduces the need for imported soybean meal (Feed Navigator, 2020).

Considering the current use of DDGS, there is high risk of distortion of the animal feed market if this feedstock were to be added to Annex IX.

There is also the risk of substitution of DDGS as an animal feed with other materials that could lead to negative environmental effects. DDGS substitutes protein sources in animal feed such as maize meal and soybean meal, meaning if there were a reduction in availability of DDGS due to its diversion to the biofuel market, additional corn and soybean meal would be needed to fulfill the animal feed demand (Hoffman et al., 2011).

4.2. 2030/2050 Potential

Since DDGS is a co-product of bioethanol production from grain, the potential supply is largely driven by ethanol demand. The International Energy Agency (2019) forecasts that global ethanol production will increase from 110 to 130 billion litres from 2019 to 2024, and if this growth is extrapolated to 2030, ethanol production would be approximately 154 billion litres. This also roughly aligns with the OECD Agricultural Outlook (2019) which projects 143 billion litres in 2028. This would imply a potential supply of DDGS of approximately 92 million tonnes in 2030.[122] However, the availability for the biofuel market would be near zero, as DDGS has an existing use as animal feed.

The U.S. EIA Annual Energy Outlook models a 1% annual growth in ethanol to 2050 in the reference scenario (Biomass Magazine, 2021). Assuming this same rate globally, this would translate to a maize DDGS potential of 127 million tonnes in 2050. However, the animal feed market will remain strong for the coming decades which uses this feedstock. FAO projects that production of animal proteins is expected to grow by around 1.7% per year, with meat production projected to rise by nearly 70% from 2010-2050 (International Feed Industry Federation, n.d.). Availability for the biofuel market, without distorting the animal feed market, would be negligible.

5. ADDITIONAL DEMAND FOR LAND

5.1. Assessment of additional demand for land

The potential for additional demand for land is dictated by the feedstock that would likely substitute DDGS if diverted from the animal feed to biofuel market. As indicated in Section 4, this would likely be maize meal or soybean meal. The global land use change of soy and maize are medium risk (< 0.02 ha/t). Considering the high risk of market distortion, **substituting DDGS would pose a medium-high risk for additional demand for land**

[122] Assuming a ratio of 0.6 million tonne DGS to 1 billion litres ethanol calculated from 2017/2018 USDA figures.

6. Processing technologies

6.1. Evaluation of processing technology (mature vs advanced)

DDGS has been studied for the production of different biofuels, ranging from bioethanol to biomethane to biodiesel to biohydrogen. However, these are all relatively new applications and have therefore not yet been demonstrated at commercial scale. For alcohol-based biofuels, the technical complexity lies in the pre-treatment of the feedstock before fermentation to transform DDGS into fermentable sugars. Both chemical and physicochemical pre-treatments have been tested at lab-scale. Similarly, biogas production via anaerobic digestion has been tested. Although anaerobic digestion is a mature technology, the specific use of DDGS as a substrate has only been demonstrated at lab-scale. Potential for biodiesel production has also been investigated with the pyrolysis of DDGS followed by the extraction of bio-oils. Biohydrogen production is perhaps the least mature, with only one notable study which investigated the use of DDGS as a feedstock for a photosynthetic purple non-sulphur bacterium to produce hydrogen (Iram et al., 2020). All applications are evidently at an experimental phase, **and therefore would all be considered as advanced technologies** which would mean this feedstock to be suitable to be added to Part A of Annex IX**.**

7. Conclusions

Table 164 : Summary of evaluation results.

	Evaluation Result	Rationale
Circular economy	No concern	No commercial uses exist, which can extend product life and sequester carbon for longer than energy uses. Therefore, using DDGS for biofuel/biogas production does neither contribute to, nor contravene circular economy principles.
Union sustainability criteria	No concern	Maize is generally cultivated on land that has been in agricultural production since before 2008.
Sustainability GHG	Some concern	Under which circumstances could this feedstock be problematic? The GHG savings depends on the fuel used in processing. Natural gas would likely meet the criteria whereas lignite may not. How to mitigate this concern? Failure to meet the minimum GHG savings will be efficiently addressed throughout the certification process by an EU-approved voluntary or national scheme.
Sustainability Others	Some concern	Under which circumstances could this feedstock be problematic? Several risks exist, including high risk for biodiversity and soil erosion. How to mitigate this concern? Whereas some EU-approved Voluntary

		Schemes have additional environmental requirements, which could potentially mitigate the identified concerns, new policy instruments would be required to address these consistently and systematically.
Market distortion	Significant concern	Use of DDGS as animal feed is very well-established globally (North America, Europe, South East Asia). This market is likely to be significantly distorted if the feedstock was instead diverted to biofuel/biogas production. <u>How to mitigate this concern?</u> Feedstock would fall under the food/feed crop cap, which would limit the amount of feedstock being used for biofuel/biogas production.
2030/2050 Potential	2030: 92 million tonnes 2050: 127 million tonnes	The evaluation concluded that there is a potential supply of approximately **92 million tonnes** of DDGS in **2030 and 127 million tonnes in 2050.**
Land demand	Significant concern	<u>Under which circumstances could this feedstock be problematic?</u> Substituting DDGS by soy meal and maize meal would pose a **medium-high risk** for additional demand for land. <u>How to mitigate this concern?</u> See market distortion.
Processing Technologies	Advanced	The conversion of DDGS to any biofuel has not been demonstrated at commercial scale.

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High oleic sunflower oil extraction residues

Important note: Publicly available literature and sources of information on high oleic sunflower oil extraction residues are very limited. This assessment is primarily based on direct inputs from industries participating in the stakeholder consultation organised in Task 1 of this project. The validity of some of the technical descriptions and data provided by these stakeholders and used in this assessment could not be cross-checked with other sources.

1. TECHNICAL DESCRIPTION

1.1. Feedstock description

The high oleic sunflower oil extraction residues considered in this study are:

- Fatty acids and Keto-Fatty acids (PSK-Keto)
- High Boiling Vegetable Fraction (FAV)

Both types of residues are generated during the oxidative reaction (using hydrogen peroxide and air) and hydrolysis of high oleic sunflower oil (HOSO) to produce pelargonic and azelaic acids, which are used a chemical ingredients for the production of pesticides, cosmetics, bio-lubricants and plasticizers. According to the National Sunflower Association (NSA)[123], HOSO is higher in oleic (mono-unsaturated) acid than regular sunflower oil.

PSK-Keto are a mixture of free carboxylic and keto-carboxylic acids. FAV is a mixture of di- and tri-glycerides of C4-C18 fatty acids and of C6-C11 dicarboxylic acid (Matrica, 2020).

PSK-Keto and FAV can be converted into biodiesel (fatty acid methyl ester - FAME) or renewable diesel (hydrogenated vegetable oil - HVO), respectively via a transesterification or a hydrogenation (in a dedicated HVO unit or via co-processing in a refinery) process.

1.2. Production process

Based on stakeholder inputs (Matrica, 2020), we understand that high oleic sunflower oil undergoes the following stages to extract pelargonic acid, azelaic acid, C5-C9 acids and glycerin:

- Hydroxylation
- Oxidative cleavage
- Hydrolysis

As illustrated in **Figure 68**, Keto-acids are generated during the purification of pelargonic acid, whereas PSK come from the purification of azelaic acid. FAV are generated at the glycerin purification and azelaic acid purification stages. According to the stakeholders consulted for this project (Matrica, 2020), 15-20% of the incoming vegetable oil is converted into PSK-Keto and 25-30% of the incoming vegetable oil is converted into FAV, but research and development is ongoing to further increase the yields of main products.

[123] https://www.sunflowernsa.com/oil/

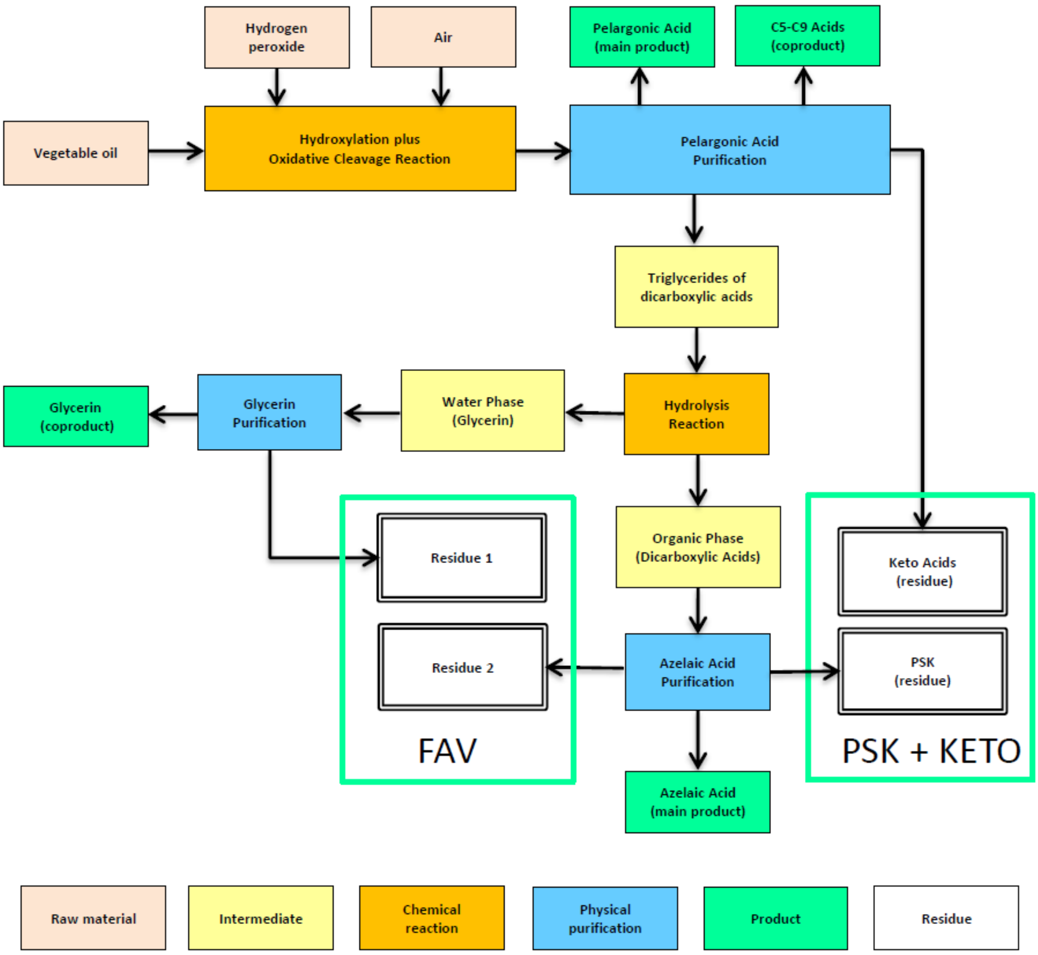

Figure 68: Flowchart of the pelargonic acid and azelaic acid production process (Source: Matrica)

1.3. Possible uses

- PSK-Keto and FAV are already being used for energy purpose in Italy, namely:
  - On-site combined heat and power production.
  - Renewable Diesel (HVO) via hydrogenation in a dedicated unit or via co-processing.

  No ongoing conversion of PSK-Keto and FAV as FAME feedstocks were reported.
- There are no reported non-energy uses for PSK-Keto as of today, although some possibilities are currently under investigation (Matrica, 2020).
- FAV can be used to produce butanol ester, which is applied in tyres and rubber as extensor oil. This application is reported to be limited, due to lower prices for fossil alternatives. A commercial trial is being conducted in Italy the production of oil extended Styrene-Butadiene Rubber grades)
- FAV-derived butanol ester can also be used as plasticizer in bitumen.

Possible uses of high oleic sunflower oil residues are summarised in **Table 169**.

Table 165 : Summary of possible uses of high oleic sunflower oil residues

	Food use	Feed use	Other uses

PSK-Keto	No reported use	No reported use	Combined Heat and Power HVO production
FAV	No reported use	No reported use	Combined Heat and Power HVO production Butanol ester production (plasticizer and extensor oil for rubber and tyres)

2. Circular economy and waste hierarchy

Result from the Circular economy and waste hierarchy assessment.

2.1. Classification of the feedstock as a co-product, residue or waste

On the basis of the feedstock description provided in sub-section 0, its possible uses in sub-section 0, stakeholder feedback and additional references, high oleic sunflower oil extraction residues can be classified as **residues,** as described below.

Table 166 : Classification of high oleic sunflower oil extraction residues

Evaluation question	Answer	Rationale
Is the feedstock the primary aim of the production process?	No	The primary aim of the process is to produce pelargonic and azelaic acids, as well as glycerine.
Does the feedstock have any economic value, but is not the primary aim of the process, and therefore a residue?	Yes	No information exists regarding selling price for PSK-Keto or FAV, but given their potential use as process energy, HVO feedstock or chemical ingredient, we assume that they carry an economic value.
Is the feedstock normally discarded, and therefore a waste?	No	Feedstock is either used on-site to produce heat and power or converted into HVO.

2.2. Is the use of feedstock to produce biofuel/biogas in line with circular economy principles?

The following questions apply to high oleic sunflower oil extraction residues.

- **Does the feedstock have non-energy (re)uses, which could extend its life or sequester carbon for longer?**

Answer: Variable.

Rationale: Limited evidence exists that PSK-Keto can be used for other purposes than energy production. FAV can be used to produce biobutanol esters, which can serve as plasticizer or extender oil for rubber and tyres; production at commercial scale is being reported.

- **Does its use as biofuel/biogas feedstock contribute to nutrient recovery?**

Answer: No

Rationale: HVO produced out of high oleic sunflower oil extraction residues have no documented contribution to nutrient recovery.

- **Does its use as biofuel/biogas feedstock contribute to a more efficient use of resources by avoiding primary material extraction?**

Answer: Variable.

Rationale: As with all other biomass feedstocks, HVO derived from high oleic sunflower oil extraction residues displaces fossil fuels and natural gas, thus reducing the need for primary material extraction. When economically feasible, using high oleic sunflower oil extraction residues for the production of chemicals could also displace fossil products.

It should be noted that the reported business model of pelargonic and azelaic acids based on high oleic sunflower oil extraction residues generate a large amount of PSK-Keto and FAV (up to 50% of the incoming sunflower oil), which can be considered an inefficient use of high oleic sunflower oil, compared to food uses.

- **Does its use as biofuel/biogas feedstock contribute to reducing waste generation, especially food waste?**

Answer: No

Rationale: Although the use of PSK-Keto and FAV for energy purposes can be considered as a contribution to reducing waste, the initial transformation of edible high oleic sunflower oil into pelargonic and azelaic acids, which are exclusively used in non-food products can be seen as problematic vis-à-vis food security considerations.

2.3. Is the use of this feedstock for biofuel/biogas production in line with the waste hierarchy?

High oleic sunflower oil extraction residues are considered as residues for the purpose of this assessment and therefore assessment against the waste hierarchy is not necessary.

2.4. Conclusion

Contribution to circular economy

There is no demonstrated commercial use of high oleic sunflower oil extraction residues for material/chemical purposes, which could ensure a significantly longer life time and/or carbon sequestration than energy uses (combined heat/power or biodiesel), which can therefore be considered in line with circular economy principles.

However, the business model of converting edible high oleic sunflower oil into non-food chemicals can be considered as problematic vis-à-vis food security considerations.

3. Sustainability and Greenhouse gases

3.1. Union sustainability criteria

None of the union sustainability criteria are applicable to high oleic sunflower oil extraction residues.

3.2. GHG Savings Criteria

The main conversion processes of high oleic sunflower oil extraction residues considered in this section are hydrogenation (either in a dedicated facility or in a refinery via co-processing) and transesterification, which respectively produce hydrotreated vegetable oil (HVO) and Fatty Acid Methyl Esters (FAME).

No default value exists in REDII for HVO or FAME from high oleic sunflower oil extraction residues. Nevertheless, these can be considered as a type of residual oil, and so the GHG emissions for HVO/FAME produced from this feedstock are likely similar to those of biodiesel produced from used cooking oil or animal fats. The REDII default values for GHG savings from used cooking oil and animal fats HVO/FAME range between 77% and 84%, which is above the GHG saving threshold for installations starting operations after January 1, 2021 i.e. 65%. It is thus likely that HVO or FAME produced from high oleic sunflower oil extraction residues would meet the GHG savings criteria of the RED II.

3.3. Other environmental impacts

High oleic sunflower oil extraction residues do not require dedicated land cultivation and therefore have no land management impact. The evaluation of risks of adverse effects on soil, water, air and biodiversity is not applicable.

4. MARKET EFFECTS AND 2030/2050 POTENTIAL

4.1. Market effects

According to Matrica (2020), about 4,500 tons of PSK-Keto and 7,000 tons of FAV are produced at the Porto Torres (Sardinia) facility, as residues from pelargonic (10,000 tons) and azelaic (14,000 tons) acids production (MCT, 2018). Production of PSK-Keto and FAV in the rest of the world is not documented; therefore global pelargonic acid production is used as a proxy. Market Watch (2021) identifies 6 companies representing most of the global pelargonic acid production:

- Matrica S.p.A
- OXEA
- Emery
- Croda Sipo
- Zhenghou Yibang
- Chongqing Yuanda

To provide an estimate of global supply of PSK-Keto and FAV, we assume that all six companies use high oleic sunflower oil, although pelargonic acid can also be produced out of brassicacea and cardoons, which are also rich in oleic acid. Should all six companies use similar conversion processes as Matrica, up to 27,000 tons of PSK-Keto and 42,000 tons of FAV would be globally produced every year as of now.

On the basis of the documentation received during the stakeholder consultation and additional research during this study, the demand for PSK-Keto and FAV derived from high oleic sunflower oil remains limited to date and a limited amount is currently used for non-energy purposes. The business model described by Matrica (2020), whereby PSK-Keto and FAV are used locally by industrial partners tend to show that PSK-Keto and FAV are not being traded in an open market, which would further reduce the risk of market distortions.

In light of the above, the risk of market distortion from using PSK-Keto and FAV for HVO production appears limited.

4.2. 2030/2050 Potential

No market reports could be found regarding PSK-Keto and FAV derived from high oleic sunflower oil. Market Watch (2021) anticipates a 5.3% growth rate of the pelargonic acid global market between 2021 and 2026. Applying a similar rate to the estimated max volumes of PSK-Keto and FAV calculated in the previous section, the available feedstock could be up to approx. 28,400 tons of PSK-Keto and 44,200 tons of FAV produced annually.

It should be noted that more than 40% of the total pelargonic acid produced is used in pesticides (incl. glyphosate), which tend to be increasingly constrained by health and environmental policies. Therefore, the evolution of agricultural policies and consumers' behaviour may reduce the size of the pelargonic market over the coming decades, which would de facto reduce the amounts of available high oleic sunflower oil extraction residues.

The increasing use of bio-based chemicals in other industrial sectors may nevertheless compensate for this effect.

Based on the limited evidence gathered in this study, the availability of high oleic sunflower extraction residues for biofuel production would likely increase through 2030 but the 2050 potential cannot be precisely estimated due to limited market information and uncertainty over the evolution of health and environmental policies.

5. Additional demand for land

5.1. Assessment of additional demand for land

4Only a limited fraction of this feedstock is currently being used for non-energy purposes, and the non-energy use identified (FAV as a butanol ester feedstock) is in competition with petroleum based alternatives. Use of these materials for bioenergy is therefore expected to pose a low risk of creating additional land demand.

Final result for high oleic sunflower oil extraction residues: Low risk for additional demand for land.

6. Processing technologies

6.1. Evaluation of processing technology (mature vs advanced)

Stakeholder consultation (Matrica, 2020) reveals that high oleic sunflower oil extraction residues are converted without pre-treatment into HVO via hydrogenation in a dedicated unit or via co-processing, or could theoretically be turned into FAME via transesterification, which can all be considered a **mature technology** (TRL 9, CRL 3).

7. Conclusions

Nomenclature:

- No concern = the evaluation did not reveal any significant concern about this feedstock.
- Some concern = the evaluation identified limited conditions under which some concerns may exist, i.e. using this feedstock for biofuel production could be in contradiction with this criterion.
- Problematic = the evaluation reveals that using this feedstock for biofuel production would be in contradiction with this criterion in most circumstances.
- Not applicable = this criterion is not applicable to the feedstock.

Table 167: Summary of evaluation results

	Evaluation Result	Rationale
Circular economy	Some concern	No commercial uses exist that can extend product life and sequester carbon for longer than energy uses. Using high oleic sunflower oil extraction residues for HVO production is in line with circular economy principles. <u>Under which circumstances could this feedstock be problematic?</u> PSK-Keto and FAV are processing

		residues generated in large volumes through the conversion of high oleic sunflower oil into pelargonic and azelaic acids, which are used as chemical precursors. The use of a food crop (high oleic sunflower) for non-food purposes can be seen as problematic from a food security perspective. <u>How to mitigate this concern?</u> This concern relates to the business model of pelargonic and azelaic production out of biomass. EU bio-based economy policies should ensure that the use of biomass does not present any risk to food security.
Union sustainability criteria	Not applicable	These criteria are **not applicable** to high oleic sunflower oil extraction residues, as this feedstock is neither primary agricultural biomass or agricultural field residue or forest biomass. This feedstock is a process residue.
Sustainability GHG	No concern	GHG savings estimates are largely above the most stringent minimum GHG saving threshold (65%) applied to installations starting operations after January 1, 2021.
Sustainability Others	Not applicable	High oleic sunflower oil extraction residues do not require dedicated land cultivation and therefore have no land management impact.
Market distortion	No concern	High oleic sunflower oil extraction residues (PSK-Keto and FAV) are currently not distributed via an established market, rather among business partners. Non-energy uses are currently very limited.
2030/2050 Potential	2030 (Global): 28,400 tonnes (PSK-Keto), i.e. 24,200 tonnes of HVO; 44,200 tonnes (FAV), i.e. 37,200 tonnes of HVO. 2050 (Global): undetermined	No specific data could be found for the 2030 and 2050 production of high oleic sunflower oil extraction residues. 2030 are based on 2021-2026 growth estimates for pelargonic acid markets, assuming that all operators use similar processes as Matrica.
Land demand	No concern	Competition with non-energy uses appears unlikely. Therefore, the risk for additional demand for land is **low**.

Processing Technologies	Mature (HVO)	The conversion technologies of high oleic sunflower oil extraction residues into HVO or FAME are considered to be **mature**, due to high TRL (9) and CRL (3).

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Other biowaste

1. TECHNICAL DESCRIPTION

1.1. Feedstock description

Biowaste is defined in point (4) of Article 3 of Directive 2008/98/EC (European Union, 2008) as biodegradable garden and park waste, food and kitchen waste from households, restaurants, caterers and retail premises and comparable waste from food processing plants. Biowaste can be described as organic matter in waste which can be decomposed into carbon dioxide, water, methane or simple organic molecules by micro-organisms and other living things under aerobic conditions (in the presence of oxygen) and anaerobic conditions (in the absence of oxygen).

Municipal waste includes waste originating from households, commerce and trade, small businesses, office buildings and institutions (schools, hospitals, government buildings. It also includes waste from selected municipal services i.e. waste from park and garden maintenance, waste from street cleaning services. It consists of fractions collected separately and mixed waste (mixed municipal waste). Municipal waste is covered in chapter 20 of European List of Wastes (LoW) (European Union, 2001) which has a heading of 'Municipal waste (household waste and similar commercial, industrial and institutional wastes) including separately collected wastes'. This implies that if a waste type is generated by households and the same waste type is also generated by commercial, industrial and institutional companies, this waste will be allocated to the same code. For example, when a household generates kitchen waste or when a canteen belonging to an office or manufacturing activity generates kitchen waste, and the waste is separately collected, this waste has the same code according to the LoW (Biodegradable kitchen and canteen waste - code *20 01 08*). It will also have the same code if the generated kitchen waste is not separately collected but is a part of the mixed waste (Mixed municipal waste - code *20 03 01*). However, if a company generates waste as a part of processing meat and other foods, this waste is not similar in its nature to household waste and will be allocated a code belonging to chapter 2 of the LoW (Wastes from agriculture, horticulture, horticulture, aquaculture, forestry, hunting and fishing, food preparation and processing).

According to waste types defined in the European LoW (European Union, 2001) biowaste include the following:

- biodegradable garden and park waste – code *20 02 01*
- food and kitchen waste from households, restaurants, caterers and retail premises and comparable waste from food processing plants – *20 01 08* (separately collected) and *20 03 01* (part of mixed municipal waste)

Following the preliminary assessment conducted in Task 1 of this project, garden and park waste is considered to be covered in Annex IX part p) other non-food cellulosic material. Moreover, the "bio-waste as defined in Article 3(4) of Directive 2008/98/EC from private households subject to separate collection", is included in Annex IX part c), and "biomass fraction of mixed municipal waste, but not separated household waste subject to recycling targets" is covered in Annex IX part b). Therefore, this assessment focuses specifically on **biowaste (food and kitchen waste) from restaurants, caterers and retail premises and comparable waste from food processing plants that are separately collected**, which is not currently covered in Annex IX.

As illustrated in Table 168, biowaste (food and kitchen waste) from restaurants, caterers and retail premises and comparable waste from food processing plants is included in the code *20 01 08* in and are generated by economic operators involved in retail/distribution and by restaurants/food services:

- *Retail and other distribution* covers the handling of food and its storage at the point of sale or delivery to the final consumer, and includes distribution terminals, shops, supermarket distribution centres and wholesale outlets;
- *Restaurant and food services* covers the preparation of food at the point of sale or delivery to the final consumer, and includes catering operations, factory canteens, institutional catering, restaurants and other similar food service operations

Table 168. Waste codes included in the European List of Wastes which include food waste (European Commission, 2020)

LoW Sub-chapter		LoW entry						
Code	Description	Code	Description	Primary production	Processing, manufacturing	Retail / distribution	Restaurants, food services	Households
02 01	wastes from agriculture, horticulture, aquaculture, forestry, hunting and fishing	02 01 02	animal-tissue waste	X				
		02 01 03	plant-tissue waste	X				
02 02	wastes from the preparation and processing of meat, fish and other foods of animal origin				X			
02 03	wastes from fruit, vegetables, cereals, edible oils, cocoa, coffee, tea and tabacco preparation and processing; conserve production; yeast and yeast extract production, molasses preparation and fermentation				X			
02 04	wastes from sugar processing				X			
02 05	wastes from the dairy products industry				X			
02 06	wastes from the baking and confectionery industry				X			
02 07	wastes from the production of alcoholic and non-alcoholic beverages (except coffee, tea and cocoa)				X			
16 03	off-specification batches and unused products	16 03 06	organic wastes other than those mentioned in 16 03 05			X		
20 01	separately collected fractions (except 15 01)	20 01 08	biodegradable kitchen and canteen waste			X	X	X
		20 01 25	edible oil and fat			X	X	X
20 03	other municipal wastes	20 03 01	mixed municipal waste			X	X	X
		20 03 02	waste from markets			X		

1.2. Production process

Figure 69 describes the food supply chains, which generate biowaste (food and kitchen waste) from restaurants, caterers and retail premises and comparable waste from food processing plants. Many European countries implement separate biowaste collection systems in place, but some do not have such systems in place. As a result, about 50 % of the biowaste (food and kitchen waste) in the EU is collected separately, with the remaining 50 % collected with mixed municipal waste (European Environment Agency, 2020). However, there is great variation in the proportion of at country level.

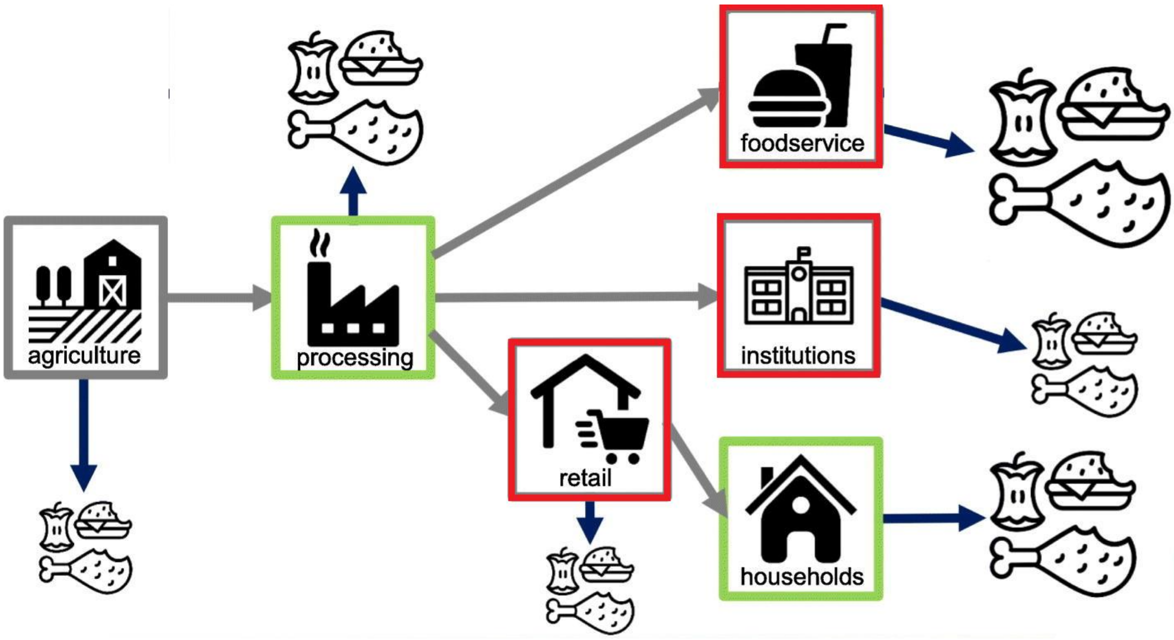

Figure 69. Food loss and waste along the food supply chain (Read et al., 2020)

1.3. Possible uses

Treatment of separately collected biowaste is done by composting or anaerobic digestion with biogas production.

The **compost** produced from composting can be used as **fertiliser and soil improver**. Separate collection at source minimises contamination which is important to attain high-quality fertilizer and soil improver. Composting is usually carried out in industrial composting plants where biowaste from separate collection and also biowaste stream sorted from mixed municipal waste are handled together.

In anaerobic digestion, biowaste is turned into **biogas** and a **digestate**. Biogas can be used to generate **electricity or heat**, or upgraded into a **fuel**. Digestate can be fed to composting also to use as **fertiliser or soil improver**. Best results for material and energy recovery were achieved by combination of composting and anaerobic digestion as pre-treatment since both energy and materials are recovered (Odegard et al., 2015).

Research and innovation increasingly explore the opportunities for using biowaste as a source of fuel and materials e.g. ethanol, hydrochar and volatile fatty acids (European Environment Agency, 2020).

Ethanol production from biowaste is also in development (Matsakas et al., 2017). The Finnish energy company St1 has developed Etanolix and Bionolix processes for production of ethanol from municipal and commercial biowaste to test feasibility (St1, 2018). The heterogeneous nature of biowaste creates challenges for industrial-scale bioethanol production.

Additionally hydrothermal carbonisation (HTC) is an attractive option for producing energy from bio-waste with high water content (Li et al., 2013). HTC produces **hydrochar** which is an energy rich resource that is easy to store and transport, Hydrochar can be used as a solid fuel or soil improver or be further processed into activated carbon (Heidenreich et al., 2016).Further technical development is needed for industrial-scale applications.

Volatile fatty acids (VFAs) can be produced from anaerobic digestion of biowaste (Atasoy et al., 2018; Strazzera et al., 2018; Tampio et al., 2019). Further developments are required to enable sustainable and economically feasible production and recovery of VFAs from biowaste at commercial scale (European Environment Agency, 2020). VFAs find use in the production of biofuels and biobased plastics.

Direct use as animal feed, or biowaste treatment methods to turn biowaste into protein and lipids are currently being studied. However, EU food safety regulations create obstacle for valorising biowaste as **animal feed** (European Environment Agency, 2020).

Possible uses of other biowaste are summarised in **Table 173**.

Table 169 : Summary of possible uses of other biowaste

Food use	Feed use	Other uses
Not applicable.	Not applicable. EU food safety regulations hinder valorising biowaste as animal feed.	Biogas/biomethane: Documented evidence of commercial implementation. Bioethanol: Testing feasibility at industrial scale. Further technical development is needed for commercial implementation. Hydrochar: Tested in lab scale. No documented evidence of commercial implementation. Volatile fatty acids: Tested in lab scale. No documented evidence of commercial implementation.

2. CIRCULAR ECONOMY AND WASTE HIERARCHY

2.1. Classification of the feedstock as a co-product, residue or waste

Biowaste can be classified as waste, as described below.

Table 170 : Classification of other biowaste

Evaluation question	Answer	Rationale
Is the feedstock the primary aim of the production process?	No	This is food and kitchen waste attained from retail premises and food services.
Does the feedstock have any economic value, but is not the primary aim of the process, and therefore a residue?	No	It does not have an economic value.
Is the feedstock normally discarded, and therefore a waste?	Yes	Biowaste is discarded, it is part of municipal waste.

2.2. Is the use of feedstock to produce biofuel/biogas in line with circular economy principles?

- **Does the feedstock have non-energy (re)uses, which could extend its life or sequester carbon for longer?**

  Answer: No

  Rationale: Use of biowaste for biobased chemicals and materials could theoretically be possible, but there is currently no commercial applications.

- **Does its use as biofuel/biogas feedstock contribute to nutrient recovery?**

  Answer: Yes (for biogas production)

  Rationale: Anaerobic digestion of biowaste for biogas production generates a by-product digestate, which retains nutrients. The European Compost Network calculated that the amount of nitrogen in the digestate and compost produced is equivalent to 1.5 % of the total inorganic nitrogen and 4.3 % of inorganic phosphate consumed which is possible to be recycled (ECN, 2019).

- **Does its use as biofuel/biogas feedstock contribute to a more efficient use of resources by avoiding primary material extraction?**

  Answer: Yes

  Rationale: As with all other biomass feedstocks, biofuels and biogas derived from biowaste displaces fossil fuels, thus reducing the need for primary material extraction. Increasing the use of biowaste for biogas production will contribute to a more efficient use of resources and will prevent it from going to landfilling and incineration. Furthermore, the use of digestate as fertiliser contribute to decreasing the need for artificial fertiliser production.

- **Does its use as biofuel/biogas feedstock contribute to reducing waste generation, especially food waste?**

  Answer: Not applicable

  Rationale: Since biowaste is already waste that is generated, this is not applicable. However, the use of biowaste as biofuel/biogas feedstock allow reducing waste going to landfilling and incineration. Thereby also the methane emissions associated with landfilling can be avoided. Valorisation of biowaste contributes to circular economy.

2.3. Is the use of this feedstock for biofuel/biogas production in line with the waste hierarchy?

- **Contribution to increasing waste?**

  Answer: No.

  Rationale. The use of this feedstock for biofuel/biogas production allows valorisation of waste.

- **Can this feedstock be potentially reused?**

  Answer: Not applicable

  Rationale: Reuse of biowaste is not applicable.

- **Can this feedstock be potentially recycled?**

  Answer: Yes.

  Rationale: Anaerobic digestion allows the production of both digestate and biogas where the digestate can be used for organic recycling. EC considers composting and anaerobic digestion as options for (organic) recycling of biowaste. Waste framework directive (European Union, 2018a) describes that "the amount of municipal biodegradable waste that enters aerobic or anaerobic treatment may be counted as recycled where that treatment generates compost, digestate, or other output with a similar quantity of recycled content in relation to input, which is to be used as a recycled product, material or substance. Where the output is used on land, Member States may count it as recycled only if this use results in benefits to agriculture or ecological improvement."

2.4. Conclusion

Contribution to circular economy

The use of biowaste as biogas/biofuel feedstock is in line with circular economy principles. There is no documented evidence of commercial implementation for use of biowaste for biobased chemicals and materials. Increasing the use of biowaste for biogas/biofuel purposes will contribute to resource efficiency and will prevent it from going to landfilling or incineration.

Alignment with the waste hierarchy

Using biowaste for biogas/biofuel is in line with the waste hierarchy. According to the waste hierarchy, waste prevention has the highest priority, followed by recovery, and disposal is the least desirable option. In the context of waste prevention, food waste is recognised as comprising both avoidable (edible) and unavoidable (inedible) components. Only the avoidable fraction can be considered for prevention. It is important to collect large quantities of unpreventable biowaste separately and treat it to provide the highest environmental benefits. Currently, anaerobic digestion which allows recovering material (digestate as fertilizer) and energy (biogas) is preferred option. Recycling of nutrients can be achieved by using digestate as fertilizer. Anaerobic digestion is preferable to incineration and landfilling following the waste hierarchy.

3. Sustainability and Greenhouse gases

3.1. Union sustainability criteria

Biowaste is waste and therefore the Union sustainability criteria are not applicable.

3.2. GHG Savings Criteria

The most typical conversion process considered for biowaste is biogas production which provides biomethane for transport. Biowaste, according to REDII, is considered to have zero life cycle emissions until the point of collection. Default values are provided for biomethane production in REDII Annex VI Part C for biowaste. A large variation in GHG emission savings (20 – 80 %) is seen depending on whether digestate is stored in an open or a closed tank and whether the off-gas is vented or combusted (see **Figure 70**). The GHG savings criteria for new installations require at least 65% GHG savings. This shows that to be eligible, the technology option of close digestate, off-gas combustion should be applied. Failure to meet the minimum GHG savings will be efficiently addressed throughout the certification process by an EU-approved voluntary or national scheme.

BIOMETHANE FOR TRANSPORT (*)			
Biomethane production system	Technological options	Greenhouse gas emissions savings – typical value	Greenhouse gas emissions savings – default value
Biowaste	Open digestate, no off-gas combustion	43 %	20 %
	Open digestate, off-gas combustion	59 %	42 %
	Close digestate, no off-gas combustion	70 %	58 %
	Close digestate, off-gas combustion	86 %	80 %

(*) The greenhouse gas emissions savings for biomethane only refer to compressed biomethane relative to the fossil fuel comparator for transport of 94 g CO_2eq/MJ.

Figure 70. Default GHG emissions savings values provided in REDII for biomethane from biowaste

3.3. Other environmental impacts

Biowaste does not require dedicated land cultivation and therefore have no land management impact. The evaluation of risks of adverse effects on soil, water, air and biodiversity is not applicable.

4. Market effects and 2030/2050 potential

4.1. Market effects

Eurostat estimates that about 11 million tonnes of animal and vegetal waste is produced in the services industry (retail, accommodation, food and beverage service, institutions). Of this about 5 million tonnes correspond to animal and mixed food waste which is mostly made up of biowaste (food and kitchen waste) from restaurants, caterers and retail premises and comparable waste from food processing plants, which are collected separately (Eurostat, 2018).

There is additionally about 20 million tonnes of mixed municipal waste produced in the services industry(Eurostat, 2018). This includes biowaste (food and kitchen waste) from restaurants, caterers and retail premises and comparable waste from food processing plants which are not separately collected. This could provide an additional estimated 3.5 million tonnes food and kitchen waste that could be directed to separate collection and provide a higher quality feedstock for anaerobic digestion.

Biowaste has a **rigid supply**. Biowaste is currently used in composting, anaerobic digestion or a combination of both. Redirecting biowaste from composting to anaerobic digestion is **not expected to create a distortive effect on market**. Because the digestate formed from anaerobic digestion can be also composted and composted digestate can serve the same purpose. The digestate is suited for agricultural usage, while a post-treatment composting stage is needed for use in other sectors (e.g. horticulture) (European Environment Agency, 2002). As no substitution effect is expected, **no negative environmental impacts** from the increased use of biowaste for anaerobic digestion instead of direct use in composting is considered. On the contrary, anaerobic digestion is expected to deliver higher environmental benefits than composting since it allows recovering energy in addition to source of organic fertilizer (European Environment Agency, 2018).

4.2. 2030/2050 Potential

Generation of municipal waste has been increasing over time. With a share of 34 %, biowaste is the largest single component of municipal waste in the EU. Share of municipal waste composted and digested was 17 % in 2018 up from 11 % in 2004. Currently, in total about 39 million tonnes biowaste is recycled (Eurostat, 2018). However, it is estimated that about 75 million tonnes of biowaste from municipal waste is created every year across Europe (EU 27). A high proportion of biowaste (about 50%) still ends up in the mixed waste that is landfilled or incinerated.

In 2018, the revised Waste Framework Directive (WFD) (European Union, 2018a) introduced new targets regarding municipal waste recycling and preparation for reuse (by weight, at least 55 % by 2025, 60 % by 2030 and 65 % by 2035). In addition, as from 2027, compost derived from mixed municipal waste will no longer count towards achieving compliance with the recycling targets for municipal waste. Furthermore, Landfill Directive (European Union, 2018b) introduces new landfill reduction targets for municipal waste (target to reduce landfill to a maximum of 10 % by 2035).

These legal obligations are expected to push more biowaste being separately collected and treated in anaerobic digestion and composting. Furthermore, the uptake of biowaste in anaerobic digestion is expected to increase with the support from RED II.

On the other hand, according to the EU waste hierarchy, decreasing waste generation is a priority. The EU and its Member States are committed to meeting Sustainable Development Goal (SDG) 12.3, adopted in 2015, which aims to halve food waste per person at the retail and consumer levels by 2030. Most recently, an EU 'Farm to fork' strategy is intended to address all stages of the food chain, including food waste (European Commission, 2019). Furthermore, reducing food waste in the catering sector not only saves environmental impacts but also offers considerable potential for making financial savings. These ambitions on the other hand may result in decrease in food waste and thereby reduce production of biowaste.

It can be considered that the increased amount of biowaste that is separately collected and sent to anaerobic digestion in services industry could be balanced with the decreased availability of biowaste due to reduction of food waste. As described above the current production of biowaste (food and kitchen waste) from restaurants, caterers and retail premises and comparable waste from food processing plants is about 5 million tonnes. Diverting biowaste (food and kitchen waste) from restaurants, caterers and retail premises and comparable waste from food processing plants from mixed municipal waste to separate collection could bring this potential up to 9 million tonnes. Considering also the pressure to reduce food waste, a potential production of approximately **5-9 million tonnes "other biowaste" in 2030 and 2050** is estimated. Any additional availability of biowaste can be expected to be used in the future for energy **without having distortive market effects.**

5. Additional demand for land

5.1. Assessment of additional demand for land

The use of biowaste for biogas/biofuel pose no risk of additional demand for land (either directly or indirectly). There is no substituted material and no market distortion.

Final result for biowaste: low/no risk for additional demand for land

6. Processing technologies

6.1. Evaluation of processing technology (mature vs advanced)

Currently most developed conversion process for biowaste is biogas production which provides biomethane for transport. Anaerobic digestion and subsequent biogas upgrading are mature technologies (TRL 9, CRL 5).

Although not currently commercially applied, it is tested to process biowaste through fermentation to produce ethanol. This processing option would qualify as an advanced technology.

7. CONCLUSIONS

Nomenclature:

- No concern = the evaluation did not reveal any significant concern about this feedstock.
- Some concern = the evaluation identified limited conditions under which some concerns may exist, i.e. using this feedstock for biofuel production could be in contradiction with this criterion.
- Significant concern = the evaluation reveals that using this feedstock for biofuel production would be in contradiction with this criterion in most circumstances.
- Not applicable = this criterion is not applicable to the feedstock.

Table 171: Summary of evaluation results

The feedstock "other biowaste" studied in this report concern biowaste that is not already covered in Annex IX and refer to food and kitchen waste from restaurants, caterers and retail premises that are similar in nature to household waste and are separately collected.

	Evaluation Result	Rationale
Circular economy and waste hierarchy	No concern	Using biowaste for biogas/biofuel does neither contribute to, nor contravene circular economy principles or the waste hierarchy.
Union sustainability criteria	Not applicable	Biowaste is waste. These criteria are **not applicable** as this feedstock is neither primary agricultural biomass nor agricultural field residue nor forest biomass.
Sustainability GHG	No concern	<u>Under which circumstances could this feedstock be problematic?</u> To be eligible, the technology option of close digestate, off-gas combustion should be applied for producing biogas. <u>How to mitigate this concern?</u> Failure to meet the minimum GHG savings will be efficiently addressed throughout the certification process by an EU-approved voluntary or national scheme.
Sustainability Others	Not applicable	Biowaste is waste. These criteria are **not applicable** as this feedstock has no land impact.
Market distortion	No concern	Biowaste has a rigid supply. Redirecting biowaste from composting to anaerobic digestion is **not expected to create a distortive effect on market**.
2030/2050 Potential	2030 & 2050: 5-9 million tonnes (i.e. 1-1.7 million tonnes	The evaluation concluded that there is a potential of approximately **5-9 million tonnes** of "other biowaste" available in **2030 and**

	biogas)	**2050**.
Land demand	No concern	The use of biowaste for biogas/biofuel pose no risk of additional demand for land.
Processing Technologies	Mature (biogas)	Conversion of biowaste into biomethane can be done using anaerobic digestion technology and biogas upgrading technology. These are **mature processing technologies**.

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Sea algae

1. Technical description

1.1. Feedstock description

Sea algae, or marine algae, can be divided into two main categories – macroalgae and microalgae. Macroalgae are macroscopic plants, typically referred to as seaweed, while microalgae are microscopic photosynthetic plant-like organisms such as phytoplankton. The cultivation of these types differs in that macroalgae are typically cultured in natural environments while microalgae are typically cultivated on land in photobioreactors or ponds (Oilgae, 2010). Seaweed can also be cultivated with land-based techniques in ponds or tanks, however, *sea algae* in this report only refers to macroalgae grown in the sea, as microalgae and macroalgae grown on land are already included in Annex IX, point (a) as "Algae if cultivated on land in ponds or photobioreactors".

Seaweed can be categorised into red, green and brown algae, each of which have slightly different characteristics relevant for biofuel and biogas production, such as sugar content or ideal climatic conditions for growth. Green algae for example have a higher level of cellulose and accessible sugars for fermentation than brown algae, thus is potentially more attractive as a biofuel feedstock (SEI, 2009).

1.2. Production process

Sea algae can either be harvested from natural stocks along coastal areas or cultivated in aquaculture facilities (see **Figure 71**). Sustainable volumes of natural stocks are however limited, and only represent about 3% of total seaweed cultivation (FAO, 2018). The remainder are grown in aquaculture facilities, where structures such as ropes or nets are seeded with spores in nurseries and then grown to maturity out at sea along coastal areas (Oilgae, 2010).

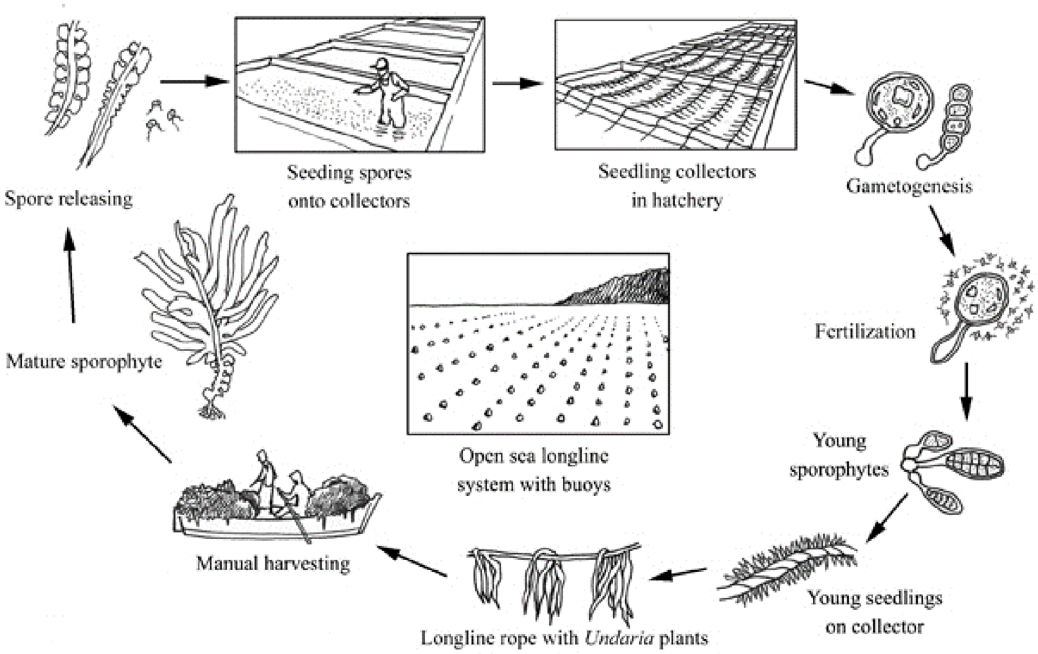

Figure 71: Production cycle of sea algae (Undaria pinnatifida).[124]

[124] Adapted from: https://thefishsite.com/articles/how-to-farm-wakame-undaria-pinnatifida-seaweed

1.3. Possible uses

Macroalgae have a broad range of current uses (see **Table 172**), including human food consumption, food additives, fertilisers, animal feed, pharmaceuticals and other uses (Van den Burg et al., 2019). Human consumption is the largest share, representing approximately 85% of production in 2015 (FAO, 2018).

Table 172 : Summary of possible uses of sea algae.

	Food use	Feed use	Other uses
Sea algae	Human consumption	Animal feed	Pharmaceuticals, food additive, fertiliser, etc.

Many biorefinery concepts have been explored and sea algae can be processed into a broad spectrum of products. Alginates extracted from seaweed can be used in food and paper products or in biomedical applications while carrageenanas from red algae can be used for food products, cosmetics or pharmaceutical products (Suganya et al., 2015).

Sea algae has also been explored as a feedstock for biofuel and biogas production. It has the potential to be converted to many different types of fuels via thermochemical or biochemical conversion (Suganya et al., 2015). Some studies have looked at acetone, butanol and ethanol production from sea algae (van der Wal et al., 2013) while others have explored an integrated biorefinery approach, producing both bioethanol and biogas (Yahmed et al., 2016). The potential for sea algae for bioenergy applications is clearly versatile as illustrated in **Figure 72** below.

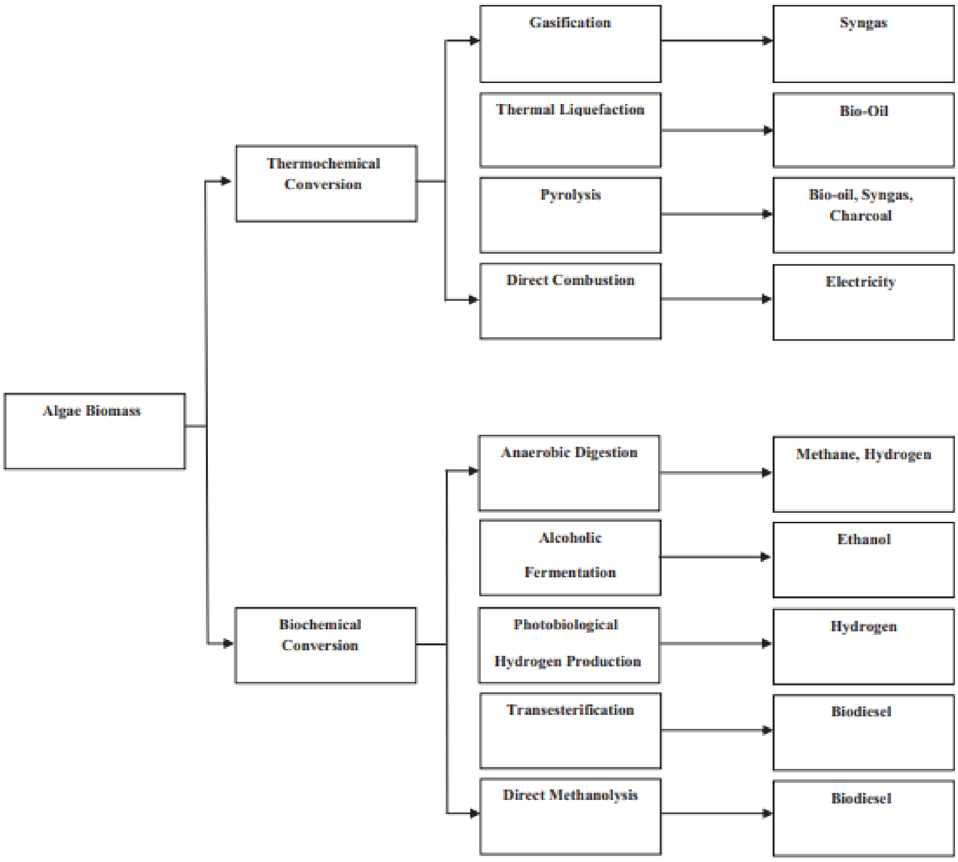

Figure 72 : Possible routes for biofuel and biogas production from algae biomass (Suganya et al., 2015).

2. CIRCULAR ECONOMY AND WASTE HIERARCHY

2.1. Classification of the feedstock as a co-product, residue or waste

Sea algae that is deliberately cultivated for biofuel or biogas production is considered a main product. It is not a co-product, residue or waste from a process.

Table 173 : Classification of sea algae.

Evaluation question	Answer	Rationale
Is the feedstock the primary aim of the production process?	Yes	**Sea algae** is not a waste or residue of a process, rather it is a **main product** that is deliberately cultivated.
Does the feedstock have any economic value, but is not the primary aim of the process, and therefore a residue?	No	
Is the feedstock normally discarded, and therefore a waste?	No	

2.2. Is the use of feedstock to produce biofuel/biogas in line with circular economy principles?

- **Does the feedstock have non-energy (re)uses, which could further extend its life?**

  Answer: Yes.

  Rationale: Sea algae is used for human food consumption, hydrocolloids (gel forming agent), fertilisers, animal feed and other uses.

- **Does its use as biofuel/biogas feedstock contribute to nutrient recovery?**

  Answer: No.

  Rationale: If sea algae were used for biofuel production, there is no contribution to nutrient recovery. If used for biogas production through anaerobic digestion, sea algae generates a digestate, which retains C, N, P and other important nutrients and can be used as fertiliser, thus contributing to decreasing the need for industrial fertiliser production (IEA, 2015; EC, 2019).

  However, sea algae used for human consumption, animal feed, or for fertilisers would be direct use of nutrients.

- **Does its use as biofuel/biogas feedstock contribute to a more efficient use of resources by avoiding primary material extraction?**

  Answer: No

  Rationale: Using sea algae for biofuel or biogas production displaces fossil fuels and natural gas, but this is not feedstock specific.

- **Does its use as biofuel/biogas feedstock contribute to reducing waste generation, especially food waste?**

  Answer: No.

Rationale: Since sea algae is a main product and not a waste or residue, it does not contribute to reducing waste generation.

2.3. Is the use of this feedstock for biofuel/biogas production in line with the waste hierarchy?

Sea algae are considered a product for the purpose of this assessment and therefore assessment against the waste hierarchy is not necessary.

2.4. Conclusion

Contribution to circular economy

Sea algae for biogas or biofuel production could contribute to a circular economy if it is additional to the supply of sea algae currently used for human consumption, fertilisers or for animal feed. These applications are a direct use of nutrients and should be prioritised above energy use. Sea algae cultivation additional to this demand would be in line with the circular economy as it would not interfere with these applications and would displace fossil fuels. In addition, a macroalgae biorefinery approach, where sea algae can be processed into a broad range of products such as bioethanol, biogas, and fertiliser, adheres to many pillars of the circular economy such as the cascading principle.

3. Sustainability and Greenhouse gases

3.1. Union sustainability criteria

The Union sustainability criteria laid down in Articles 29 (2) to (7) relate to land-based biomass, thus do not apply to sea algae.

3.2. Potential GHG savings

To calculate the potential GHG savings for macroalgae biofuels or biogas is challenging, as LCA studies using primary data in literature are scarce and do not directly follow the REDII GHG methodology. The species of sea algae, cultivation methods, harvesting yields, methane or bioethanol yield, and other parameters in an LCA study can also highly vary the outcome (Rocca et al., 2015). The choice of cultivation method for example can result in GHG emissions that have a multifold difference (Ecofys, 2008). In addition, the setup of a biorefinery producing fuel as well as co-product(s) could also have a significant bearing on the final outcome since GHG emissions would need to be allocated to these co-products (Rocca et al., 2015).

For a high-level comparison, one study by JRC investigated the GHG emissions of an integrated biorefinery approach in which bioethanol, biogas from the stillage, and fertiliser from the digestate production from sea algae harvested in Denmark were studied. The resulting emissions were ~450 g CO_2eq/kg dry weight macroalgae which corresponds to ~87 g CO_2eq/MJ ethanol and ~136 g CO_2eq/MJ biogas (Rocca et al., 2015).[125] Compared to a fossil comparator of 94 g CO_2eq/MJ, both of these fuels would not come close to reaching the GHG reduction threshold of the REDII (at least 65% for installations starting operation from 1 January 2021) and in the case of bioethanol even exceed GHG emissions of the fossil fuel comparator. However, it is merely speculative whether biofuels or biogas from sea algae would or would not meet the GHG threshold as this study did explicitly follow REDII methodology. Based on recent GHG assessment studies, there is a high risk of non-compliance with the GHG savings criteria of REDII. Though as technologies scale and move up the learning curve, these GHG savings could possibly increase.

[125] Assuming allocation on an energy basis and a bioethanol yield of 75 g/kg dry wt macroalgae and 160 m^3 biogas/tonne dry wt. macroalgae.

3.3. Other environmental impacts

Although sea algae is not land-based biomass, there are still other important marine environmental impacts to consider. In a recent study assessing the potential negative environmental impact of industrial seaweed harvesting in Europe, the factors of greatest concern were facilitation of disease, alteration of population genetics and wider alterations to the local physiochemical environment (Campbell et al., 2019). Seaweed cultivation is primarily harvested from aquaculture rather than from natural stocks, but the over harvesting of natural stocks of sea algae would also have to be monitored and safeguarded (Oilgae, 2010).

4. MARKET EFFECTS AND 2030/2050 POTENTIAL

4.1. Market effects

FAO (2018) estimates that in 2015, 30 million tonnes of sea algae was produced (1 million tonnes from natural stock, remainder from aquaculture). China and Indonesia are the largest producers in the market, representing 47% and 38% by weight respectively in 2015. Although data is limited, Europe (including Norway, Russia and Iceland) is an extremely small player in the global market and it is estimated that in 2015 only 230 kt (presumably wet weight) was produced. The majority of this is harvested from the wild (estimated 99%) and aquaculture is limited, although growing.

Sea algae for biofuel production has a very limited use, and this market is still in its infancy. Although there is active research and development in this area, there are only a limited number of small-scale demonstrations to date (ETIP Bioenergy, 2019). Sea algae, however, has an elastic supply that could increase with growing demand for biofuels. Therefore, the risk for market distortion of the current uses is likely to be low.

4.2. 2030/2050 Potential

Some forecasts project that the seaweed market will grow 9% annually to 2027, driven primarily by growth in demand for human consumption and use as a thickening or gelling agent in cosmetics and food (Grandview Research, 2020). However, this supply is elastic, and production could be increased by a demand from the biofuel sector.

Studies on the global estimates of technical seaweed cultivation potential are limited. One mathematical model from Lehahn et al. (2016) estimated that the technical potential of offshore seaweed cultivation (400 km from shore, 100 m deep) could amount to 1 billion tonnes per year over an area of 10 billion hectares. Since this is a technical potential, the volumes that could be economically produced in reality are likely much lower. However, in addition to the expansion of aquaculture in coastal areas, other options have also been explored, such as integrating seaweed cultivation with offshore wind parks which could add to this potential (Reith et al, 2009). Despite uncertainties in modelling potential, it is clear that the technical potential for sea algae is high.

Nonetheless, several environmental effects need to be taken into consideration when discussing the large-scale cultivation of sea algae. These environmental effects dictate the sustainable potential available from technical potentials.

To directly translate these environmental constraints into qualitative implications of seaweed potentials is challenging. Though it does make clear that these concerns need to be further researched before scaling and expanding sea algae production. In the same way that the REDII sustainability criteria require land-based feedstocks to safeguard environmental aspects such as protecting high biodiversity and high carbon stock land, and soil carbon and quality, the same would need to be considered for marine ecosystems.

5. Additional demand for land

5.1. Assessment of additional demand for land

Since sea algae by definition is algae grown at sea, there is no additional demand for land to cultivate this feedstock. Nonetheless, it is recommended that consideration should be made to the placement of any projects to ensure that environmentally sensitive coastal areas are not specifically targeted.

6. Processing technologies

6.1. Evaluation of processing technology (mature vs advanced)

The most well studied biofuel or biogas products from sea algae are alcohol-based fuels such as ethanol or butanol and biogas via anaerobic digestion. For alcohol-based fuels, conventional sugar fermentation technologies can be used. It is only the pre-treatment and sugar extraction that differ from conventional bioethanol production from feedstocks such as corn or sugar beet, since sea algae have a more diverse range of sugars. Various techniques for pre-treatment and sugar extraction have been demonstrated. van der Wal et al. (2013) demonstrated successful pre-treatment with hot-water treatment followed by hydrolysis while Obata et al. (2016) pre-treated the sea algae with sulfuric acid and demonstrated hydrolysation with commercially available enzymes.

While the pre-treatment and hydrolysation might not be technically challenging, the application for sea algae cannot be considered a mature technology as the application of these at commercial scale is limited. The few companies, such as Solazyme, who have performed biofuel production from algae at commercial scale have since shifted their focus to the production of higher value products in the food and personal care industries. Some would categorise alcohol-based biofuel production at TRL of 3, and projects such as the Horizon 2020 MacroFuel project aimed to raise this TRL to 4/5 (EU CORDIS, 2019). Biofuel production from sea algae should thus be categorised as an advanced technology.

Biogas production from seaweed has been studied by several researchers and a limited number of trials have been performed (Biomass Magazine, 2015; EU CORDIS, 2015), but few examples of large-scale production exist (ETIP Bioenergy, 2019). It could thus also be considered as an advanced technology, and would be suitable to be placed in Annex IX Part A.

7. Conclusions

Sea algae has limited concern for being added as a feedstock to Part A of Annex IX in that it has an elastic supply with low risk of distorting existing markets. There is a high technical potential for cultivation, but broader sustainability aspects would need to be considered compared to other feedstocks, as marine ecosystems, rather than the typical land-based ecosystems considered under the REDII, would be affected by large scale cultivation of this feedstock. It is also unclear whether the GHG savings would meet the GHG reduction threshold as this would highly vary case by case. As a new feedstock with only limited commercial demonstration to date, the processing technologies would qualify as advanced.

Table 174 : Summary of evaluation results.

	Evaluation Result	Rationale
Circular economy	No concern	Sea algae could help contribute to a more circular economy with a biorefinery approach in which energy, fertiliser, and other products can displace fossil equivalents and use the primary material of sea algae

		efficiently.
Union sustainability criteria	Not applicable	These criteria are **not applicable** to sea algae as this feedstock is neither primary agricultural biomass or agricultural field residue or forest biomass.
Sustainability GHG	Some concern	Under which circumstances could this feedstock be problematic? Very high level GHG estimates for sea algae fuels suggest that the threshold may not be met. However, these estimates are based on experimental data and are not robust enough upon which to draw conclusions. How to mitigate this concern? Failure to meet the minimum GHG savings will be efficiently addressed throughout the certification process by an EU-approved voluntary or national scheme.
Sustainability Others	Some concern	Under which circumstances could this feedstock be problematic? Several sustainability impacts on marine ecosystems would need to be investigated for large scale production. The main concerns are facilitation of disease, alteration of population genetics and wider alterations to the local physiochemical environment. How to mitigate this concern? Whereas some EU-approved Voluntary Schemes have additional environmental requirements, which could potentially mitigate the identified concerns, new policy instruments would be required to address these consistently and systematically.
Market distortion	No concern	Sea algae is considered to have an elastic supply thus will have little interference with the markets of existing applications such as for human food consumption.
2030/2050 Potential	Variable	The potential for sea algae depends on the demand and economics of producing biofuels and biogas that drive this demand. Technical potentials are very high (1 billion tonnes per year over an area of 10 billion hectares),

		but the economic and sustainable potentials would be lower.
Land demand	Not applicable	By definition, sea algae is not land based so does not cause concern for increased land demand.
Processing Technologies	Advanced (biofuels and biogas)	Although some parts of biofuel and biogas production use conventional technologies, there are few examples of large-scale production specifically with sea algae. Biofuel or biogas production from sea algae should thus be categorised as an advanced technology.

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Cyanobacteria

1. TECHNICAL DESCRIPTION

1.1. Feedstock description

Cyanobacteria are photosynthetic bacteria. They are the only type of bacteria containing chlorophyll a. They are sometimes called "blue-green algae" because of their colour as well as their similarities with microalgae. Cyanobacteria differ from microalgae in that they do not have nuclei or other membrane-bound organelles such as chloroplasts (Nguyen et al., 2016). Cyanobacteria are highly prevalent in the natural world. In fact, they are thought to be responsible for increasing the Earth's atmospheric oxygen concentration from 1% to 21% around 2 billion years ago through photosynthesis (Raven et al., 2005). Commercial farming of cyanobacteria appears to be uncommon with the exception of spirulina production.

Cyanobacteria can be genetically engineered relatively easily to produce a variety of lipids and other compounds. It is also possible to genetically modify cyanobacteria to excrete compounds such as alkanes or free fatty acids, which could then be made into biofuel or other product.

1.2. Production process

Cyanobacteria can be commercially produced in much the same was as microalgae. An overview of the production process is shown in Figure 73.

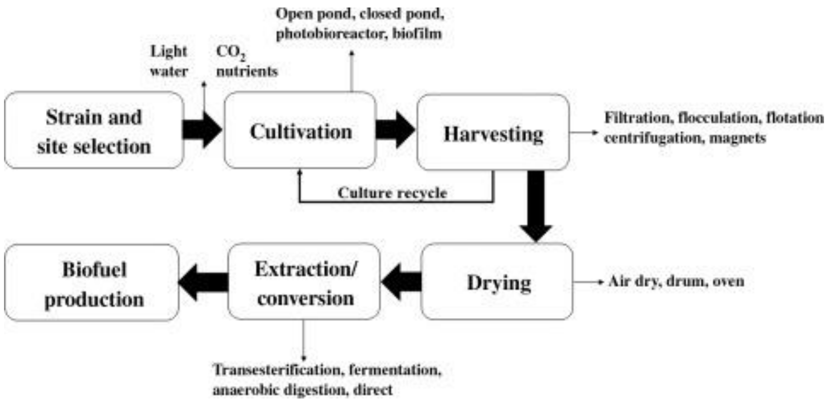

Figure 73 : Schematic of a typical production process for biofuel or biogas from cyanobacteria. Source: Sitther et al., (2020).

The first production step is cultivating the cyanobacteria. This can be done in a) open systems, b) closed systems using natural sunlight, and c) closed systems using artificial light. Open systems are generally artificial raceway or circular-shaped shallow ponds open to the water. These systems rely on natural sunlight and air. Closed systems using sunlight are typically vessels constructed from a transparent material such as plastic or glass. The cost of constructing these systems is higher than open ponds, but the clear barrier excludes grazers (e.g. pests that consume the cyanobacteria) and competitors (e.g. natural strains of algae that may contaminate and grow in the ponds) and eliminate evaporation of water. Closed systems using artificial light are similar, but use artificial light sources. These light sources can produce higher growth than natural sunlight because they can operate during the night (Ngyuen et al., 2016).

The next production step is harvesting the cyanobacteria from the ponds or vessels. This mainly involves concentrating the cyanobacteria so as to remove most of the water from the growing medium. Typically cyanbacteria are first separated from most of the water through flotation or flocculation. In flotation, air or gas is bubbled through the cyanobacteria suspension, and the cyanobacteria particles attach to the bubbles and are levitated by them. The cyanobacteria floating on the surface can then be skimmed off. In flocculation, chemical additives are placed in the water that encourage cell aggregation (Ngyuen et al., 2016; Parmar et al., 2011). The clusters of cells then sink to the bottom of the growing medium. After flotation or flocculation, the mixture is typically further concentrated through filtration, centrifugation, or ultrasonic aggregation. Filtration is carried out with membranes and a suction pump. Ultrasonic aggregation uses acoustic force to concentrate the cells and cause them to sink to the bottom; but this technique has only been found to be suitable in laboratory settings. Centrifugation uses centrifugal force to settle cells to the bottom of containers (Ngyuen et al., 2016). The cyanobacteria can then be further dewatered through drying, but the costs are high (Parmar et al., 2011). The water separated from the cyanobacteria can be recycled to grow the next batch of cyanobacteria (Markou et al., 2014).

The last production step is the extraction of desired compounds from the cyanobacteria, if applicable. This can be achieved through grinding, ultrasonication, homogenizing, using solvents, using subcritical water, using osmotic shock to rupture the cell walls, and using enzymes for extraction (Parmar et al., 2011). If cyanobacteria are genetically engineered to excrete desired substances such as free fatty acids, there may be no need for harvesting the cyanobacteria (Sarsekeyeva et al., 2015).

While cyanobacteria are widely occurring in the natural world, we could not find evidence of commercial interest in extracting naturally growing cyanobacteria, presumably because identification and extraction of naturally growing cyanobacteria would be inefficient and thus expensive.

Cyanobacteria can be produced using wastewater (Markou et al., 2014). Because cyanobacteria would presumably be produced either in artificial ponds or vessels, it is unlikely this feedstock would be produced on agricultural land or any other high-value land.

1.3. Possible uses

The largest current market for farmed cyanobacteria for which information is readily available is spirulina. Spirulina is a nutritional supplement (Riley, 2014). The global spirulina market has been estimated to be worth 348 million USD in 2018 and is projected by market research agencies to reach 651-779 million USD by 2025-2026 (Kunsel & Sumant, 2019; KBV Research, 2019). Cyanobacteria can also be used to produce biofertilizer, food coloring, livestock feed, cosmetics and other personal care products, and medicines. It can also be used for bioremediation to remove heavy metals and other contaminants from soils (Pathak et al., 2018; Newsome et al., 2014; Parmar et al., 2011).

While there has been industry interest in producing biofuel from cyanobacteria, there do not appear to be any currently operating commercial-size facilities producing biofuel as the main product from cyanobacteria. For example, Joule Unlimited developed a process to generate hydrocarbon-based fuel from cyanobacteria, but the company shut down in 2017 (Wikipedia, n.d.) The company claimed to be able to produce fuel using waste CO_2 from industrial processes and on desert land. As another example, Algenol produces, or at least used to produce, both cyanobacteria and algae (Algenol, n.d.a). The company originally targeted production of ethanol as its main product (Sandru, 2013). Now, the company advertises personal care ingredients, foods (protein and natural colorants), and biofertilizers, as well as biofuel production (Algenol, n.d.b). However, it is not clear from its website whether Algenol specifically uses cyanobacteria in biofuel production. The experience of Algenol is similar to that of many companies that originally sought to produce algal biofuels and either stopped production or shifted to primarily targeting higher-value products such as personal care products and nutritional supplements or have moved to producing entirely different products. Algal biofuels are generally thought to be too expensive for commercial viability (Wesoff, 2017).

Table 175 : Summary of possible uses of cyanobacteria

Food use	Feed use	Other uses
Documented evidence of use in food	Possible use in livestock feed	Possible use in biofuel

2. Circular economy and waste hierarchy

2.1. Classification of the feedstock as a co-product, residue or waste

Cyanobacteria is classified as a main product, following the classification below:

Table 176 : Classification of cyanobacteria

Evaluation question	Answer	Rationale
Is the feedstock the primary aim of the production process?	Yes	Cyanobacteria is the main product.
Does the feedstock have any economic value, but is not the primary aim of the process, and therefore a residue?	No	Cyanobacteria is the main product.
Is the feedstock normally discarded, and therefore a waste?	No	Cyanobacteria is not discarded.

2.2. Is the use of feedstock to produce biofuel/biogas in line with circular economy principles?

- **Does the feedstock have non-energy (re)uses, which could extend its life or sequester carbon for longer?**

  Answer: No

  Rationale: All the identified current and likely uses of cyanobacteria would not extend its life or sequester carbon for significantly longer than use in energy.

- **Does its use as biofuel/biogas feedstock contribute to nutrient recovery?**

  Answer: Variable

  Rationale: It is possible that digestate from anaerobic digestion of cyanobacteria could be used as a fertilizer.

- **Does its use as biofuel/biogas feedstock contribute to a more efficient use of resources by avoiding primary material extraction?**

  Answer: No

  Rationale: The production of cyanobacteria constitutes additional primary material extraction.

- **Does its use as biofuel/biogas feedstock contribute to reducing waste generation, especially food waste?**

  Answer: No

  Rationale: Cyanobacteria is not typically discarded to waste.

2.3. Is the use of this feedstock for biofuel/biogas production in line with the waste hierarchy?

Cyanobacteria is considered a main product for the purpose of this assessment and therefore assessment against the waste hierarchy is not necessary.

2.4. Conclusion

Contribution to circular economy

The use of cyanobacteria as biogas/biofuel feedstock is in line with circular economy principles. There is no documented evidence of commercial implementation for use of cyanobacteria in long-lived products, although this is theoretically possible. Increasing the use of cyanobacteria for energy purposes would not contribute to a more efficient use of resources, and it will not prevent materials from going to waste disposal.

3. Sustainability and Greenhouse gases

3.1. Union sustainability criteria

Cyanobacteria is not produced on agricultural land and therefore these criteria are not applicable.

Table 177: Assessment of cyanobacteria

Criterion (all land status assessed in 2008)	Assessment
(2) for wastes and residues derived from agricultural land operators or national authorities have monitoring or management plans in place in order to address the impacts on soil quality and soil carbon	Cyanobacteria is not produced on agricultural land and therefore this criteria is not applicable.
(3) bioenergy from agricultural biomass shall not be made from raw material obtained from land with a high biodiversity value	Cyanobacteria is not produced on agricultural land and therefore this criteria is not applicable.
(4) bioenergy from agricultural biomass shall not be made from raw material obtained from land with high-carbon stock in January 2008 if the status of the land has changed	Cyanobacteria is not produced on agricultural land and therefore this criteria is not applicable.
(5) bioenergy from agricultural biomass shall not be made from raw material obtained from land that was peatland in January 2008, unless evidence is provided that the cultivation and harvesting of that raw material does not involve drainage of previously undrained soil.	Cyanobacteria is not produced on agricultural land and therefore this criteria is not applicable.

Criterion (6) and (7) lay down criteria for bioenergy from forest biomass which are not applicable.

3.2. GHG Savings Criteria

There is a large range in estimates of the lifecycle GHG intensity of biofuels produced from cyanobacteria. Published estimates in the literature include values from 12-234 gCO_2eq/MJ for ethanol (Luo et al., 2010; Quiroz-Anita et al., 2017), although this literature search was not exhaustive. Quiroz-Anita et al., (2017) present a literature review of lifecycle GHG studies on algal biofuels and report that the values from these papers are similar to the range the authors calculate for cyanobacteria biofuels: 89-234 gCO2e/MJ for ethanol. Since the fossil fuel comparator for biomass fuels used for transport is 94 g CO2eq/MJ, there is a significant risk that the GHG emissions from this feedstock would be too high and this feedstock would not comply with the GHG savings criteria.

3.3. Other environmental impacts

For the risk assessment we score the risks for adverse effects on soil, water, air and biodiversity in a qualitative way as follows:

- Not applicable (in case of secondary residue with no land management impact)
- Low risk
- Medium risk
- High risk

The example assessment results for cyanobacteria are presented in **Table 178** below.

Table 178: Overview of evaluation of risks for adverse effects on soil, water, air and biodiversity for cyanobacteria

Type of risk to be reviewed according REDII Art. 29	Aspects to be reviewed in relation to environment and biodiversity	Risk level	Rationale and sources
2. Ban on biomass coming from certain types of land (Art 29, par 3, 4 and 5)	• Land with high biodiversity value, including primary forest and natural wooded land; • Protected areas; • Highly biodiverse grasslands (natural and non-natural); • Wetlands; • Continuously forested areas; • Peatlands.	Not applicable	Cyanobacteria would not be produced on agricultural land
3. Adverse impacts on soil quality	2.1 Soil Organic Matter: decline should be avoided 2.2 Nutrient balance: a disturbance of the balance should be avoided 2.3 Soil erosion: should be minimised 2.4: Soil structure: soil compaction and waterlogging should be avoided 2.5: Soil biodiversity: contamination of soils with metals and other toxic component, disturbance of soil structure and decline in soil organic carbon may all lead to a decline in biodiversity and this should be avoided	Not applicable	Cyanobacteria would not be produced on agricultural land
4. Adverse impacts on water quality	3.1 Water quality: ground and surface water quality should not decline through increased leaching and run off of N, P from fertilization and of other contaminants from fertilization	Low risk	Cyanobacteria can utilize wastewater and could thus in principle reduce wastewater discharge to natural water bodies,

	and weed and pest control.		improving water quality.
5. Adverse impacts on water quantity	4.1 Water quantity: excessive water consumption in agriculture should not lead to depletion of sweet water resources and salinization.	Low risk	There is no evidence that cyanobacteria would result in excessive water consumption. And cyanobactaria can use waste water.
6. Adverse impacts on air quality	5.1 GHG emissions: GHG emissions from cropping should be minimized 5.2 Ammonia and NOx emissions: should be minimized	Medium risk	Some species of cyanobacteria can emit NOx (Lenhart et al., 2015), but it is not clear whether the species likely to be grown for biofuel production would emit significant amounts of NOx. The cultivation and use of cyanobacteria for biofuel production could emit large amounts of GHGs.
7. Adverse impacts on biodiversity	6.1 Crop diversity: large scale monocultures decreasing crop diversity strongly in a region should be avoided	Low risk	Cyanobacteria would not likely impact biodiversity. Any particular species of cyanobacteria could potentially be invasive in its non-native habitats, but it is unclear how significant this risk is relating to commercial cultivation.
	6.2 Biodiversity: Direct adverse impacts on flora and fauna should be avoided	Unclear	Direct impact on flora and fauna could be present, depends on where the commercial cultivation is established
	6.3 Pollination: Direct adverse impacts on pollinators and their habitats should be avoided	low risk	
	6.4 Invasive species: use of biomass crops that are invasive should be banned	Medium risk	

4. Market effects and 2030/2050 potential

4.1. Market effects

Use of cyanobacteria in biofuel is unlikely to significantly affect existing markets. The largest existing commercial use of cyanobacteria that we could identify is spirulina, which is used as a nutritional supplement. While no data is available on the wholesale price of spirulina, Google Shopping results give prices of around 10-60 euros per kilogram for spirulina.[126] Other potential current uses of cyanobacteria, such as personal care products, are also high value. It is thus unlikely that, even with policy incentives for the use of cyanobacteria in biofuel, this feedstock will be diverted from its existing high-value uses to biofuel or biogas production.

In conclusion, there is **low risk of negative market impacts** from the use of cyanobacteria for biofuel or biogas production.

4.2. 2030/2050 Potential

The existing market of cyanobacteria for biofuel production is essentially zero, and absent major technological changes that would fundamentally alter the economics of production, it seems likely that this market outlook will not change in future years. Thus, the 2030/2050 potential of cyanobacteria availability for biofuel production is likely low.

5. Additional demand for land

5.1. Assessment of additional demand for land

Cyanobacteria cultivation requires very little land for the amount of biomass it produces. Because it does not use soil, it is unlikely to compete for agricultural land. The demand for cyanobacteria for biofuel production is unlikely to divert this material from other uses and thus is not likely to have significant indirect impacts on land demand.

Final result for cyanobacteria: low risk for additional demand for land.

6. Processing technologies

6.1. Evaluation of processing technology (mature vs advanced)

Cyanobacteria can be processed using a number of mature as well as advanced technologies. Cyanobacteria can be engineered to secrete glucose and sucrose, which can be fermented into ethanol (mature technology; Parmar et al., 2011). Cyanobacteria can be converted to biomethane via anaerobic digestion (mature technology; Nguyen et al., 2016). Lipids extracted from cyanobacteria can be used to produce biodiesel using transesterification (mature technology; Parmar et al., 2011). Cyanobacteria can be used to directly make bio-hydrogen (advanced technology; Nguyen et al., 2016). Another advanced technology that can be applied is hydrothermal liquefaction (advanced; Baldino et al., 2019). In some cases, cyanobacteria could be processed into biofuel and biogas using a combination of an advanced processing technology and a mature biofuel production technology. However, it is possible to convert cyanobacteria into biofuel and biogas using only mature technologies.

Because mature technologies can be used to convert cyanobacteria to biofuel and biogas, it would be appropriate to add cyanobacteria to Annex IX list B.

7. Conclusions

Nomenclature:

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[126] https://shopping.google.com/?nord=1

- No concern = the evaluation did not reveal any significant concern about this feedstock.
- Some concern = the evaluation identified limited conditions under which some concerns may exist, i.e. using this feedstock for biofuel production could be in contradiction with this criterion.
- Significant concern = the evaluation reveals that using this feedstock for biofuel production would be in contradiction with this criterion in most circumstances.
- Not applicable = this criterion is not applicable to the feedstock.

Table 179: Summary of evaluation results

	Evaluation Result	Rationale
Circular economy and waste hierarchy	No concern	Using cyanobacteria for biogas/biofuel does neither contribute to, nor contravene circular economy principles or the waste hierarchy.
Union sustainability criteria	No concern	Sustainability Union criteria do not apply because cyanobacteria is aquatic and unlikely to be produced on agricultural land.
Sustainability GHG	No concern	Biofuel and biogas produced from cyanobacteria could have high GHG emissions. <u>How to mitigate this concern?</u> Failure to meet the minimum GHG savings will be efficiently addressed throughout the certification process by an EU-approved voluntary or national scheme.
Sustainability Others	No concern	Cyanobacteria cultivation is not very likely to cause negative sustainability impacts. <u>Under which circumstances could this feedstock be problematic?</u> Cyanobacteria could potentially be invasive, depending on what species are grown in what locations, and could potentially worsen air quality by emitting NO_x.
Market distortion	No concern	It is unlikely that biofuel and biogas demand would divert cyanobacteria from its existing high-value uses or otherwise impact existing markets.
2030/2050 Potential	Very low	At present, there does not appear to be any cyanobacteria available for economically viable biofuel or biogas production, and this status does not seem likely to change.
Land demand	No concern	Cyanobacteria are aquatic and not likely to be grown on agricultural or other high-value land. Because the risk of market distortion is low, there is no concern of an indirect increase on land

		demand.
Processing Technologies	Mature	Cyanobacteria can be processed into ethanol, biogas, and biodiesel using mature technologies.

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ANNEX F – SUBTASK 3.4 – FEEDSTOCK FRAUD RISK ASSESSMENT MATRICES (TASK 3)

F.1. Agriculture

F.1.1. Intermediate and Cover Crops

	Category	Indicator (Pointing to High Risk)	Low Risk	Medium Risk	High Risk
Elements incentivising fraud (Primary risk indicators)	Physical Characteristics	1. The physico-chemical properties of the feedstock and its derivatives are difficult to distinguish from other feedstocks			While the crop type (wheat, corn, soy etc) can easily be determined, it cannot be clearly known whether a crop was grown as a primary crop or intermediate crop by any physico-chemical analysis
		2. The feedstock can be grown on lands with different properties (e.g. prime farmland vs degraded land) and carries a claim of being grown on incentivized land			Impossible to tell whether given crop was grown on prime farmland vs degraded land, but N/A if there is no benefit to "stacking" (i.e. cover crop + degraded land = higher incentive than either alone)
		3. A different material could be altered to appear as this feedstock	Crops or materials cannot easily be altered to appear as a cover crop, mislabelling is the greater concern		
	Feedstock Definition Characteristics	1. The feedstock is not uniformly defined across all regions that it is traded			Currently there is no cohesive definition for intermediate and cover crops, especially in RED II. Will be difficult to find definition that does not encourage displacement of food crops, e.g. in China and Brazil
		2. The classification of a feedstock as a waste, residue or coproduct, varies by country, making it difficult to characterize with certainty		There is some chance cover crops could be considered a "residue" since the primary role is soil improvement, and the lack of EU RED definition adds to the confusion and risk	
		3. The cellulose to non-cellulose ratio and/or combined yield factor is not known or defined for the feedstock		Some crops have embedded cellulosic component, and co-processing conversions are not always clear	

Elements enabling fraud (Amplifiers)	Supply Chain Characteristics	1. The feedstock is traded between a large number of intermediaries and/or globally	Niche or primarily soil-improving cover crops are more likely to be traded among a smaller number of intermediaries	Commodity crops (corn, soy, wheat) will be traded among a large number of entities	
		2. The feedstock is typically produced in a country or region with weak rule of law.	Niche or primarily soil-improving cover crops tend to be grown in North America and EU, as does winter wheat		Corn, soy, and rice grown as intermediate crops tend to be produced in China, Brazil, and other tropical/ subtropical countries which often have weak rule of law
	Assurance	1. Feedstocks are not typically segregated in supply chain or are not easily tied to a particular origin.		Widely traded crops of the same type are very likely to be mixed, whether they are considered "intermediate/ cover"or not. This is less of a concern for crops that are not widely traded	
		2. Conversion technology is not well understood or transparent, and/or does not have typical values for yield/conversion	Majority of crops processed with very mature tech with exception of cellulosic co-processing		
		3. Assurance providers lack specific knowledge/ experience of this feedstock and derivatives		While assurance providers may be familiar with crops as biofuel feedstocks, they likely lack the expertise to differentiate between primary and intermediate/ cover crops	

F.2. Forestry

F.2.1. Other ligno-cellulosic material except saw logs and veneer logs

	Category	Indicator (Pointing to High Risk)	Low Risk	Medium Risk	High Risk	Not Applicable
Elements incentivising fraud (Primary risk indicators)	**Physical Characteristics**	1. The physico-chemical properties of the feedstock and its derivatives are difficult to distinguish from other feedstocks		Other ligno cellulosic material may be difficult or impossible to distinguish from saw/veneer logs once chipped or pelletised, but the higher value of saw and veneer logs should limit the incentive for fraud.		
		2. The feedstock can be grown on lands with different properties (e.g. prime farmland vs degraded land) and carries a claim of being grown on incentivized land.				Not applicable
		3. Production process may be modified to generate more residue/waste; OR a different material could be altered to appear as this feedstock.				Not applicable
	Feedstock Definition Characteristics	1. The feedstock is not uniformly defined across all regions that it is traded		Some of the materials included in other ligno-cellulosic biomass are not uniformly defined, such as the distinction between "pulplogs," "sawlogs," and "veneer logs," as well as "fuelwood," "logging residues," "forestry residues," and "pre-commercial thinnings"		
		2. The classification of a feedstock as a waste, residue or coproduct, varies by country, making it difficult to characterize with certainty		The classification of other ligno-cellulosic material varies by the particular type of material and likely also varies by classifiers, e.g. pre-commercial thinnings		
		3. The cellulose to non-cellulose		There is variability in these ratios across		

		ratio and/or combined yield factor is not known or defined for the feedstock		materials and no official threshold is established but fraction of cellulose is typically within the range of 40-60% and of hemicellulose 20-35%		
Elements enhancing fraud (Amplifiers)	**Supply Chain Characteristics**	1. The feedstock is traded between a large number of intermediaries and/or globally			Feedstocks could be traded among a large number of intermediaries, potentially internationally, before reaching end-point	
		2. The feedstock is typically produced in a country or region with weak rule of law.		Feedstock is produced in nearly every country, including many with middling rule of law, but around half of countries have traceability schemes		
	Assurance	1. Feedstocks are not typically segregated in supply chain or are not easily tied to a particular origin.		Qualifying other ligno-cellulosic material is sometimes segregated (e.g. pulplogs) but not always (e.g. woodchips from pulplogs could be mixed with woodchips from sawlogs)		
		2. Conversion technology is not well understood or transparent, and/or does not have typical values for yield/conversion		At least one conversion technology is fairly well understood with others less well so, and yields are not standardized or typical.		
		3. Assurance providers lack specific knowledge/ experience of this feedstock and derivatives	Assurance providers have experience with this feedstock			

E.3. Algae/microbes

F.3.1. Algae cultivated on land in ponds or photobioreactors

	Category	Indicator (Pointing to High Risk)	Low Risk	Medium Risk	High Risk	Not Applicable
Elements incentivising fraud (Primary risk indicators)	Physical Characteristics	1. The physico-chemical properties of the feedstock and its derivatives are difficult to distinguish from other feedstocks		Algae if cultivated on land in ponds or photobioreactors (microalgae) has physical properties distinctly different than most land based biomass feedstocks. Sea algae is macroalgae and would also be physically distinct from land-based microalgae. The physical characteristics once processed to oils, however, could be similar to other processed oil feedstocks		
		2. The feedstock can be grown on lands with different properties (e.g. prime farmland vs degraded land) and carries a claim of being grown on incentivized land				Not applicable as microalgae is not agricultural biomass grown on land, it is grown in ponds or photobioreactors.
		3. Production process may be modified to generate more residue/waste; OR a different material could be altered to appear as this feedstock.	The production process is geared towards the production of algae only as so there is no risk of modifiying the process to generate (more) residue/waste. There are no other materials similar to microalgae that would be altered to appear as microalgae. Microalgae can also be DNA sequenced to identify the feedstock.			
	Feedstock Definition Characteristics	1. The feedstock is not uniformly defined across all regions that it is traded				Not applicable as it is not yet traded across regions
		2. The classification of a feedstock as a waste, residue or coproduct, varies by country, making it difficult to characterize with certainty				Not applicable as it is not a waste, residue, or co-product.

		3. The cellulose to non-cellulose ratio and/or combined yield factor is not known or defined for the feedstock		This feedstock is still in its immaturity and has not been commercially applied, thus the yield factor or cellulose ratio is not defined.		
Elements enabling fraud (Amplifiers)	**Supply Chain Characteristics**	1. The feedstock is traded between a large number of intermediaries and/or globally				Not applicable as microalgae from land does not have established supply chains.
		2. The feedstock is typically produced in a country or region with weak rule of law.				
	Assurance	1. Feedstocks are not typically segregated in supply chain or are not easily tied to a particular origin.				Not applicable as microalgae from land does not have well established supply chains.
		2. Conversion technology is not well understood or transparent, and/or does not have typical values for yield/conversion			The conversion technology is still in its immaturity and has not been commercially applied, thus there are not typical factors.	
		3. Assurance providers lack specific knowledge/ experience of this feedstock and derivatives			This feedstock is still in its immaturity thus there is no knowledge or experience with it or its derivatives.	

F.3.2. Sea Algae

	Category	Indicator (Pointing to High Risk)	Low Risk	Medium Risk	High Risk	Not Applicable
ising fraud (Primar	**Physical Characteristics**	1. The physico-chemical properties of the feedstock and its		Sea algae has physical properties distinctly different than most land based biomass feedstocks. However, if only aquaculture (and not wild) sea algae were included in Annex IX, it would be difficult to physically distinguish between the two.		

		derivatives are difficult to distinguish from other feedstocks				
		2. The feedstock can be grown on lands with different properties (e.g. prime farmland vs degraded land) and carries a claim of being grown on incentivized land				Not applicable as sea algae by definition is grown at sea and not on land.
		3. Production process may be modified to generate more residue/waste; OR a different material could be altered to appear as this feedstock.		The production process is geared towards the production of sea algae only as so there is no risk of modifying the process to generate (more) residue/waste. If there were an incentive for sale to the biofuel or biogas market rather than food market, sea algae could intentionally be contaminated or degraded, thus made unfit for the food market.		
	Feedstock Definition Characteristics	1. The feedstock is not uniformly defined across all regions that it is traded		This can vary by sea algae species type and is not defined. Sea algae has a broad range of species and there are several types, such as brown, red or green algae.		
		2. The classification of a feedstock as a waste, residue or coproduct, varies by country, making it difficult to characterize with certainty				Not applicable as it is not a waste, residue, or co-product.
		3. The cellulose to non-cellulose ratio		This can vary by sea algae species type and is not defined. Sea algae has a broad range of species and there are several types, such as brown, red or		

		and/or combined yield factor is not known or defined for the feedstock		green algae.		
Elements enabling fraud (Amplifiers)	**Supply Chain Characteristics**	1. The feedstock is traded between a large number of intermediaries and/or globally			Sea algae (sea weed/ macroalgae) cultivation takes place in more than 50 countries with more than 30 million tonnes produced in 2015 (primarily from aquaculture). Sea algae is a commodity that is internationally traded. There are a large number of intermediaries in the supply chain, including the farmers, local collectors and traders, overseas traders, manufacturers and solution providers, and distributors in the sea algae food supply chain. Sea algae as biofuel could increase the number of these intermediaries.	
		2. The feedstock is typically produced in a country or region with weak rule of law.		For cultured species, China, Indonesia, Korea, and the Phillippines are the leading producers. East Asia has a significantly low Rule of Law Indicator score compared to the EU.		
	Assurance	1. Feedstocks are not typically segregated in supply chain or are not easily tied to a particular origin.		In the current food/cosmetic supply chains, feedstocks are segregated. It is unknown whether they can be easily tied to the aquaculture facility where they were produced.		
		2. Conversion technology is not well understood or transparent, and/or does not have typical values for yield/conversion			Conversion technologies for sea algae to biofuels or biogas are still very immature and does not have typical values for yield or conversion.	
		3. Assurance providers lack specific knowledge/ experience of this feedstock and derivatives			Conversion technologies for sea algae to biofuels or biogas are still very immature, thus assurance providers do not yet have knowledge or experience with this feedstock and its derivatives.	

F.3.3. Cyanobacteria

	Category	Indicator (Pointing to High Risk)	Low Risk	Medium Risk	High Risk	Not Applicable
Elements incentivising fraud (Primary risk indicators)	Physical Characteristics	1. The physico-chemical properties of the feedstock and its derivatives are difficult to distinguish from other feedstocks	Cyanobacteria has significantly different physical properties as compared to typical land based biomass feedstocks			
		2. The feedstock can be grown on lands with different properties (e.g. prime farmland vs degraded land) and carries a claim of being grown on incentivized land				Not applicable as cyanobacteria is not agricultural biomass grown on land, it is grown in photobioreactors.
		3. Production process may be modified to generate more residue/waste; OR a different material could be altered to appear as this feedstock.	The production process is geared towards the production of cyanobacteria only as so there is no risk of modifiying the process to generate (more) residue/waste. The only current significant commercial application of cyanobacteria is spirulina production for the nutraceuticals, cosmetics, food and beverage, animal feed, and other markets. One could thus conclude that cyanobacteria is more profitable in these markets than the biofuel market, so there is little incentive for fraud.			

	Feedstock Definition Characteristics	1. The feedstock is not uniformly defined across all regions that it is traded		The feedstock has a relatively small existing market and is not uniformly defined. Cyanobacteria can be genetically engineered in an infinite number of ways, but is not currently being traded across many regions.		
		2. The classification of a feedstock as a waste, residue or coproduct, varies by country, making it difficult to characterize with certainty				Not applicable as it is not a waste, residue, or co-product.
		3. The cellulose to non-cellulose ratio and/or combined yield factor is not known or defined for the feedstock		The cyanobacteria biofuel market is close to zero, so there is no yield factor or cellulose ratio defined. Spirulina yields would be different than biofuel yields.		
Elements enabling fraud (Amplifiers)	**Supply Chain Characteristics**	1. The feedstock is traded between a large number of intermediaries and/or globally	Cyanobacteria is not a highly traded commodity. Its existing commercial use is for spirulina, and does not have an existing market for biofuels. This market was valued at 400 million USD in 2019. Information is not available on the number of intermediaries.			
		2. The feedstock is typically produced in a country or region with weak rule of law.				
	Assurance	1. Feedstocks are not typically segregated in				Not applicable as cyanobacteria for biofuel production does not have established supply

		supply chain or are not easily tied to a particular origin.				chains, only for spirulina.
		2. Conversion technology is not well understood or transparent, and/or does not have typical values for yield/conversion			The conversion technology is in its nascency, thus there are not typical values available	
		3. Assurance providers lack specific knowledge/ experience of this feedstock and derivatives			Since cyanobacteria is not yet used commercially for biofuels or biogas, theere is close to zero knowledge of experience on this feedstock and its derivatives.	

F.4. Marginal/Degraded Land

F.4.1.i. Biomass from polluted lands

	Category	Indicator (Pointing to High Risk)	Low Risk	Medium Risk	High Risk	Not applicable
Elements incentivising fraud (Primary risk)	Physical Characteristics	1. The physico-chemical properties of the feedstock and its derivatives are difficult to distinguish from other feedstocks		The feedstock may contain pollutants, though the content of pollutants differs between tissues. i.e. leaves can contain much more pollutant than wood.		
		2. The feedstock can be grown on lands with different properties (e.g. prime farmland vs degraded land) and carries a claim of being grown on incentivized land			There is a high risk that a feedstock grown on non-polluted land will be delivered while the claim that it was grown on polluted land. This may be an	

					attractive fraud if the incentive is high enough.	
		3. Production process may be modified to generate more residue/waste; OR a different material could be altered to appear as this feedstock.		Mixing feedstock from polluted land with feedstock from non-polluted land may be difficult to distinguish based on physio-chemical properties, thereby increasing amount of double counted feedstock		
	Feedstock Definition Characteristics	1. The feedstock is not uniformly defined across all regions that it is traded		The criteria for deciding if biomass from polluted land can be used for food or feed may differ per country (outside of the EU). So the definition of biomass from polluted land may lack uniformity.		
		2. The classification of a feedstock as a waste, residue or coproduct, varies by country, making it difficult to characterize with certainty				The classification of feedstocks from polluted land is not the main issue if it has been established that the land is polluted and the feedstock is not to be used for feed or food.
		3. The cellulose to non-cellulose ratio and/or combined yield factor is not known or defined for the feedstock	As the crops grown on polluted land (for remediation) will generally be the same crops already used for biofuels, yield factor issues should be similar to other feedstocks.			
Elements enhancing fraud (Amplifiers)	**Supply Chain Characteristics**	1. The feedstock is traded between a large number of intermediaries and/or globally	Feedstocks from polluted land that are not suited for food or feed will not likely be traded widely.			
		2. The feedstock is typically produced in a country or region with weak rule of law.		Many of the polluted lands are situated in countries with a weak rule of law, such as newly independent states of the former Soviet Union.		
	Assurance	1. Feedstocks are not typically segregated in supply chain or are not easily tied to a particular origin.		Feedstocks from polluted land are specifically tied to a particular origin but can be mixed with non-double counting feedstocks in case of fraud.		

		2. Conversion technology is not well understood or transparent, and/or does not have typical values for yield/conversion		Conversion technology and typical yield values will be the same as for conventional feedstocks. However, applications of residues such as protein cake (in case of oil seeds) and digestate, in case of biogas production, may be different compared to feedstock from non-polluted land		
		3. Assurance providers lack specific knowledge/ experience of this feedstock and derivatives		Assurance providers may not have specific experience with polluted land feedstocks. As it is linked to definition of polluted land and remediation. Also the uses of residues is different from conventional residues.		

F.4.1.ii. Biomass from degraded lands

	Category	Indicator (Pointing to High Risk)	Low Risk	Medium Risk	High Risk	Not applicable
Elements incentivising fraud (Primary risk indicators)	Physical Characteristics	1. The physico-chemical properties of the feedstock and its derivatives are difficult to distinguish from other feedstocks			The crops grown on degraded land will be crops similar to normal crops. It will probably be very difficult to distinguish biomass from these crops based on physio-chemical properties from crops grown on normal land. This constitutes a high fraud risk if double counting has a large economic benefit, which it will likely have.	
		2. The feedstock can be grown on lands with different properties (e.g. prime farmland vs degraded land) and carries a claim of being grown on incentivized land		Similarly the definition of degraded land has to be well established and clear. This may pose an elevated risk for fraud to occur.		
		3. Production process may be modified to generate more residue/waste; OR a different material could be altered to appear as this feedstock.				Not applicable - The feedstock is not degraded or polluted.
	Feedstock Definition Characteristics	1. The feedstock is not uniformly defined across all regions that it is traded			It may be quite possible that de definition of degraded lands is not defined uniformly across regions even within the EU let alone outside the EU. This may open the possibility for fraud. The risk can be considered medium to high.	
		2. The classification of a feedstock as a waste, residue or coproduct, varies by country, making it difficult to characterize with certainty				Not applicable - Feedstock definition depends on land classification
		3. The cellulose to non-				Not applicable - Feedstock

		cellulose ratio and/or combined yield factor is not known or defined for the feedstock				definition depends on land classification
Elements enhancing fraud (Amplifiers)	Supply Chain Characteristics	1. The feedstock is traded between a large number of intermediaries and/or globally		Extra risk arising from many intermediaries is therefore considered medium to low.		
		2. The feedstock is typically produced in a country or region with weak rule of law.		Degraded lands on which biofuel crops are grown also exist in countries with a weak rule of law (i.e. newly independent countries) this can increase the risk of fraud to a higher level than within the EU.		
	Assurance	1. Feedstocks are not typically segregated in supply chain or are not easily tied to a particular origin.		As non-cellulosic/non-lignocellulosic feedstocks from degraded land should be similar or the same as crops as grown on normal (non-incentivized) land there is a risk of mislabelling – the origin cannot be tied to a specific location. This increases the risk of fraud.		
		2. Conversion technology is not well understood or transparent, and/or does not have typical values for yield/conversion	The conversion process into biofuels of feedstocks originating from degraded land is likely to be similar of the same as for conventional feedstocks. The conversion technology should therefore not pose a specific extra fraud risk.			
		3. Assurance providers lack specific knowledge/ experience of this feedstock and derivatives			Assurance providers may have to assess if land qualifies as degraded land. Lack of data may pose a challenge to less experienced assurance providers especially in combination with weak institutions. The risk is considered medium to high.	

F.4.2. Damaged crops

	Category	Indicator (Pointing to High Risk)	Low Risk	Medium Risk	High Risk	Not applicable
Elements incentivising fraud (Primary risk indicators)	Physical Characteristics	1. The physico-chemical properties of the feedstock and its derivatives are difficult to distinguish from other feedstocks		Crops affected by pests or pathogens can be distinguished.		
		2. The feedstock can be grown on lands with different properties (e.g. prime farmland vs degraded land) and carries a claim of being grown on incentivized land				Not applicable
		3. Production process may be modified to generate more residue/waste; OR a different material could be altered to appear as this feedstock.			If profitable a crop may be handled such that it becomes damaged. It is difficult to determine if a crop was damaged and then processed into a fuel or if a non-damaged crop was processed into a biofuel.	
	Feedstock Definition Characteristics	1. The feedstock is not uniformly defined across all regions that it is traded			Damaged crops unfit for food or feed are not defined uniformly across regions. But trade in such feedstocks across regions is less likely.	
		2. The classification of a feedstock as a waste, residue or coproduct, varies by country, making it difficult to characterize with certainty	This can complicate verification and may facilitate fraud			
		3. The cellulose to non-cellulose ratio and/or combined yield factor is not known or defined for the feedstock				Not applicable
ing fra	Supply Chain	1. The feedstock is traded between a		This cannot be excluded as damaged crops is a very diverse		

	Characteristics	large number of intermediaries and/or globally		category		
		2. The feedstock is typically produced in a country or region with weak rule of law.	This seems unlikely as crops damaged due to pests and pathogens are more or less unplanned.			
	Assurance	1. Feedstocks are not typically segregated in supply chain or are not easily tied to a particular origin.		A biofuel producer can make fuel (i.e. biogas) out of different feedstocks. Then double counted and non-double counted feedstocks could be processed together.		
		2. Conversion technology is not well understood or transparent, and/or does not have typical values for yield/conversion		Conversion technology can be understood. Yield can be unknown due to the diverse nature of the feedstock.		
		3. Assurance providers lack specific knowledge/ experience of this feedstock and derivatives		This may apply to damaged crops as they can originate from very diverse production chains and not generally be used for biofuel production		

F.5. Harvesting – Agricultural residues

F.5.1. Straw

	Category	Indicator (Pointing to High Risk)	Low Risk	Medium Risk	High Risk	Not Applicable
Elements incentivising fraud (Primary risk indicators)	Physical Characteristics	1. The physico-chemical properties of the feedstock and its derivatives are difficult to distinguish from other feedstocks	Straw's physico-chemical properties are similar to other feedstocks and materials. However, the other materials it could be mistaken for would also qualify for Annex IX list A under "other non-food cellulosic material"			
		2. The feedstock can be grown on lands with different properties (e.g. prime farmland vs degraded land) and carries a claim of being grown on incentivized land				Not applicable
		3. Production process may be modified to generate more residue/waste; OR a different material could be altered to appear as this feedstock.	It is unlikely that another material would be altered to appear as straw			
	Feedstock Definition Characteristics	1. The feedstock is not uniformly defined across all regions that it is traded	Straw is generally defined uniformly across all regions.			
		2. The classification of a feedstock as a waste, residue or coproduct, varies by country, making it difficult to characterize with certainty			The classification of straw is not uniform across countries.	
		3. The cellulose to non-cellulose ratio and/or	The cellulose to non-cellulose ratios for the feedstock have been determined for each type of straw			

		combined yield factor is not known or defined for the feedstock	but these ranges vary by type of straw (e.g. wheat straw vs. rapeseed straw). However, any material that could be mistaken as straw is likely already in Annex IX, part A.			
Elements enhancing fraud (Amplifiers)	**Supply Chain Characteristics**	1. The feedstock is traded between a large number of intermediaries and/or globally	Straw is a traded commodity but the number of intermediaries it is traded between is indeterminable from available data.			
		2. The feedstock is typically produced in a country or region with weak rule of law.		Feedstock is produced in nearly every country, including many with middling rule of law.		
	Assurance	1. Feedstocks are not typically segregated in supply chain or are not easily tied to a particular origin.	Straw is typically segregated in its supply chain but is not easily tied to a particular origin. However, any material that could be mistaken as straw is likely already in Annex IX, part A.			
		2. Conversion technology is not well understood or transparent, and/or does not have typical values for yield/conversion		There are multiple potential conversion processes and the yields are not standardized across feedstocks and are not well known for some processes		
		3. Assurance providers lack specific knowledge/ experience of this feedstock and derivatives	Assurance providers may lack specific knowledge to distinguish between straw and other lignocellulosic resources. However, other materials that could be mistaken for straw are likely already in Annex IX, part A.			

F.5.2. Other non-food cellulosic material

	Category	Indicator (Pointing to High Risk)	Low Risk	Medium Risk	High Risk	Not Applicable
Elements incentivising fraud (Primary risk indicators)	Physical Characteristics	1. The physico-chemical properties of the feedstock and its derivatives are difficult to distinguish from other feedstocks			This feedstock encompasses some others in Annex IX, part A, such as straw. Some feedstocks are similar to materials with a high starch or sugar content, such as sweet sorghum.	
		2. The feedstock can be grown on lands with different properties (e.g. prime farmland vs degraded land) and carries a claim of being grown on incentivized land				Not applicable
		3. Production process may be modified to generate more residue/waste; OR a different material could be altered to appear as this feedstock.		For agricultural field and processing residues, reduced extraction of the main crop could lead to increased residual oils, sugars, starches and protein mixed in, increasing the apparent weight or volume of other non-food cellulosic material		
	Feedstock Definition Characteristics	1. The feedstock is not uniformly defined across all regions that it is traded		The definition of cellulosic material, and where it exists, the threshold percentage of cellulose and hemicellulose in cellulosic material, likely varies across regions		
		2. The classification of a feedstock as a waste, residue or coproduct, varies by country, making it difficult to characterize with certainty			Various types of other non-food cellulosic material are likely classified differently in different regions and by various actors	
		3. The cellulose to non-cellulose ratio and/or combined yield factor is not known or defined for the feedstock			There is a very large range in the content of cellulose and hemicellulose in materials that may qualify as other non-food cellulosic material, and some materials with relatively high sugar and starch content may be confused with these	

Elements enhancing fraud (Amplifiers)	**Supply Chain Characteristics**	1. The feedstock is traded between a large number of intermediaries and/or globally			Some types of other non-food cellulosic material are traded globally, but it is unknown whether a large number of intermediaries are typically involved.	
		2. The feedstock is typically produced in a country or region with weak rule of law.		Feedstock is produced in nearly every country, including many with middling rule of law.		
	Assurance	1. Feedstocks are not typically segregated in supply chain or are not easily tied to a particular origin.		Some types of other non-food cellulosic material are likely segregated in the supply chain while others may not be. All of these materials will generally not be easily tied to a particular origin		
		2. Conversion technology is not well understood or transparent, and/or does not have typical values for yield/conversion		Conversion processes, especially cellulosic ethanol, are well understood but yields are not standardized		
		3. Assurance providers lack specific knowledge/ experience of this feedstock and derivatives		Assurance providers are likely familiar with some but not all types of other non-food cellulosic material		

F.6. Harvesting – Forestry residues

F.6.1. Biomass fraction of wastes and residues from forestry and forest-based industries, namely, bark, branches, pre-commercial thinnings, leaves, needles, tree tops, saw dust, cutter shavings, black liquor, brown liquor, fibre sludge, lignin and tall oil

	Category	Indicator (Pointing to High Risk)	Low Risk	Medium Risk	High Risk	Not Applicable
Elements incentivising fraud (Primary risk indicators)	**Physical Characteristics**	1. The physico-chemical properties of the feedstock and its derivatives are difficult to distinguish from other feedstocks	Liquid residues from forestry (black and brown liquor, fibre sludge, tall oil) and lignin have distinct physical characteristics.	Waste and residual woody material may be difficult or impossible to distinguish from primary woody material once chipped or pelletised, but the higher value of saw and veneer logs should limit the incentive for fraud.		
		2. The feedstock can be grown on lands with different properties (e.g. prime farmland vs degraded land) and carries a claim of being grown on incentivized land.				Not applicable
		3. Production process may be modified to generate more residue/waste; OR a different material could be altered to appear as this feedstock.				Not applicable
	Feedstock Definition Characteristics	1. The feedstock is not uniformly defined across all regions that it is traded	There is some variation in definitions of specific materials in this category (e.g. definitions of tree tops and of pre-commercial thinnings may vary between operators and regions), but the basic characteristics of most of the materials are widely understood.			

		2. The classification of a feedstock as a waste, residue or coproduct, varies by country, making it difficult to characterize with certainty	Harvest residues (leaves, needles, branches, tree tops) are consistently understood, as are woody process residues (saw dust, cutter shavings). Some stakeholders may consider these materials as wastes but this should not be consequential.	There is some inconsistency in characterisation of some feedstocks. Tall oil and brown liquor are identified as residues in the RED II but are treated as products under the RTFO. There may be differences in treatment of pre-commercial thinnings depending on the extent to which existing markets are available for the harvested wood.		
		3. The cellulose to non-cellulose ratio and/or combined yield factor is not known or defined for the feedstock				Not applicable.
Elements enabling fraud (Amplifiers)	**Supply Chain Characteristics**	1. The feedstock is traded between a large number of intermediaries and/or globally	Black and brown liquors are unlikely to be processed far from the associated mills as process chemicals need to be recycled.	Tall oil, lignin and fibre sludge may be traded between intermediaries prior to processing for biofuel use.	Woody feedstocks could be handled through multiple intermediaries and traded at distance, especially if aggregated from smaller sources and chipped or pelletised.	
		2. The feedstock is typically produced in a country or region with weak rule of law.	Some forestry residues are produced in countries with good governance, for example the United States, Canada, Germany and the Nordic countries.	Some forestry residues are produced in countries with middling governance such as Brazil and Indonesia.	Some forestry residues are produced in countries with weak governance such as Russia and China.	
	Assurance	1. Feedstocks are not typically segregated in supply chain or are not easily tied to a particular origin.		Once chipped/pelletised the supply of woody waste and residual material may not be segregated from other material. Liquid residues and wastes (liquors, sludge, tall oil) and lignin are likely to be kept segregated.		
		2. Conversion technology is not well understood or transparent, and/or does not have typical values for yield/conversion		Advanced technologies are required, but some of the technology options already have default values.		
		3. Assurance providers lack specific knowledge/ experience of this		Assurance providers are used to working with the forestry and forest products sectors but may not be used to working with these specific		

		feedstock and derivatives		resources.		

F.7. Processing residues derived from Food/Feed

F.7.1. Cereals

	Category	Indicator (Pointing to High Risk)	Low Risk	Medium Risk	High Risk	Not Applicable
Elements incentivising fraud (Primary risk indicators)	Physical Characteristics	1. The physico-chemical properties of the feedstock and its derivatives are difficult to distinguish from other feedstocks	Cobs cleaned from kernels of corn, dry starch, and DDGS are easily identified through a visual observation.	Technical corn oil cannot be visually distinguished from other vegetable oils but a chemical analysis of fatty acid content may allow for such distinction, unless it has been mixed with other oils. Starchy effluents and dextrose ultrafiltration retentate, hydrol and raffinate from sugar refining are liquid streams, which are not easily identified. Their chemical composition and solid content may vary significantly, thus making possible to purposefully modify their content in starch, sugars or other nutrients.		
		2. The feedstock can be grown on lands with different properties (e.g. prime farmland vs degraded land) and carries a claim of being grown on incentivized land				Not applicable. No specific incentive exists to produce these feedstocks out of degraded or abandoned land.
		3. Production process may be modified to generate more residue/waste; OR a different material could be altered to appear as this feedstock.	Due to visual characteristics or low value, no specific incentive exists to alter material to appear as cobs cleaned from kernels of corn, dry starch, DDGS, starchy effluents and dextrose ultrafiltration retentate, hydrol and raffinate from sugar refining.	A risk exists to purposefully alter other vegetable oil to visually look like technical corn oil. Food production processes could be modified to generate more residues, but standard ratios/yields exist, which would allow some monitoring.		
	Feedstock Definition Characteristi	1. The feedstock is not uniformly defined across all regions that it is traded	Cobs cleaned from kernels of corn; Corn dry starch; DDGS are uniformly defined across countries.	TCO can easily be confused with crude corn oil; Starchy effluents; Dextrose ultrafiltration retentate, hydrol and raffinate from sugar refining are not well defined.		

	cs	2. The classification of a feedstock as a waste, residue or coproduct, varies by country, making it difficult to characterize with certainty	Cobs cleaned from kernels of corn are uniformly described as waste; Corn dry starch is uniformly described as co-product.	DDGS; TCO are only explicitly defined in UK and the US. Starchy effluents are only defined in the UK.	Dextrose ultrafiltration retentate, hydrol and raffinate from sugar refining are not defined in polices.	
		3. The cellulose to non-cellulose ratio and/or combined yield factor is not known or defined for the feedstock	Yields and cellulose/non-cellulose ratios are well documented for cobs cleaned from kernels of corn; Corn dry starch; DDGS; TCO.	Limited documentation exists for yields of starchy effluents	Yields are not publicly documented for dextrose ultrafiltration retentate, hydrol and raffinate from sugar refining	
Elements enabling fraud (Amplifiers)	Supply Chain Characteristics	1. The feedstock is traded between a large number of intermediaries and/or globally	Cobs cleaned from kernels of corn, Starchy effluents and dextrose ultrafiltration retentate, hydrol and raffinate from sugar refining are typically used locally, due to their tendency to degrade rapidly.	Dry starch, Technical corn oil and DDGS are traded between a large number of intermediaries, globally and in large volumes.		
		2. The feedstock is typically produced in a country or region with weak rule of law.	Cobs cleaned from kernels of corn, dry starch, Starchy effluents and dextrose ultrafiltration retentate, hydrol and raffinate from sugar refining; Technical corn oil; DDGS used in the European Union are assumed to be produced in the European Union or primarily imported from the United States.			
	Assurance	1. Feedstocks are not typically segregated in supply chain or are not easily tied to a particular origin.	Cobs cleaned from kernels of corn; Starchy effluents; Dextrose ultrafiltration retentate, hydrol and raffinate from sugar refining are assumed to be used locally (partly due to rapid degradability) and therefore can easily be traced back to their origin.		Corn dry starch; DDGS; TCO are more difficult to trace back to their origin, given that they can be traded globally.	
		2. Conversion technology is not well understood or transparent, and/or does not have typical	Cobs cleaned from kernels of corn Corn dry starch; DDGS; TCO use conversion technologies (anaerobic digestion or ligno-cellulosic ethanol production) which are well understood and have typical yields.	No typical yield exists for the conversion of starchy effluents; Dextrose ultrafiltration retentate, hydrol and raffinate from sugar refining. Processing technologies are relatively well understood.		

		values for yield/conversion				
		3. Assurance providers lack specific knowledge/ experience of this feedstock and derivatives	Assurance providers are expected to know cobs cleaned from kernels of corn; Corn dry starch; DDGS; TCO. Default GHG values exist		Assurance providers are not expected to have significant expert with Starchy effluents; Dextrose ultrafiltration retentate, hydrol and raffinate from sugar refining. No Default GHG value exists. Assurance Providers may require additional training.	

F.7.2. Fruits and Vegetables residues and waste

	Category	Indicator (Pointing to High Risk)	Low Risk	Medium Risk	High Risk	Not Applicable
Elements incentivising fraud (Primary risk indicators)	**Physical Characteristics**	1. The physico-chemical properties of the feedstock and its derivatives are difficult to distinguish from other feedstocks		Fruit and vegetable residues can differ in their physico-chemical properties due to differences in their appearance (peels, seeds, stems, stones, pulp etc) and composition (e.g. carbohydrate, protein, lignin and cellulose contents). This makes fruit and vegetable residues hard to distinguish from other crops so there is risk of unincentivised feedstocks being mislabelled.		
		2. The feedstock can be grown on lands with different properties (e.g. prime farmland vs degraded land) and carries a claim of being grown on incentivized land				Fruit and vegetable residues are generated during processing , not produced directly on farmland.

		3. Production process may be modified to generate more residue/waste; OR a different material could be altered to appear as this feedstock.		If processed fruit and vegetables are intentionally labelled as contaminated/degraded then they will be deemed unsuitable for human consumption. However, there would be little economic incentive to intentionally label fruit and vegetables as defective (residues) if more value can be obtained from the main products.		
	Feedstock Definition Characteristics	1. The feedstock is not uniformly defined across all regions that it is traded		Processing of different fruits and vegetables produces a variety of residues. The feedstock includes fruits and vegetables deemed unsuitable for human consumption which do not conform to standards for end-use in the food chain. This is due to undesirable physical characteristic or incorrect chemical composition. If deemed unsuitable for food/feed use then the EU RED II definition of food waste applies. This would not be the case though if there is potential for use in food/feed applications regardless of whether economic incentives exist.		
		2. The classification of a feedstock as a waste, residue or coproduct, varies by country, making it difficult to characterize with certainty	Fruit and vegetable residues are also referred to as waste, pomace, pulp, cake etc which doesn't provide an accurate description of the composition. However, wastes and residues should be considered equal in terms of double counting so the risk of characterisation is low.			
		3. The cellulose to non-cellulose ratio and/or combined yield factor is not known or defined for the feedstock			The cellulosic content of fruits and vegetables is generally known. However, processing these in different plants with different equipment will affect the composition of these residues. The heterogeneity of these residues means comprehensive characterisation is needed to reliably	

					determine the cellulosic content which is difficult and therefore the risk of fraud is high.	
Elements enabling fraud (Amplifiers)	**Supply Chain Characteristics**	1. The feedstock is traded between a large number of intermediaries and/or globally	Transport and storage costs means fruit and vegetable residues are generally traded locally. Therefore, there is likely to be a small number of intermediaries in the supply chain suggesting lower risk.			
		2. The feedstock is typically produced in a country or region with weak rule of law.		Countries with high production of fruit and vegetables include Brazil, India, Mexico, Turkey, Egypt, Vietnam and Russia. However, unlikely that process residues would be exported from country of origin to the EU due to high moisture content resulting in high transport costs. More likely EU will import fruit and vegetables then residues will be generated from processing.		
	Assurance	1. Feedstocks are not typically segregated in supply chain or are not easily tied to a particular origin.	Fruit and vegetable residues are segregated at processing stage.			
		2. Conversion technology is not well understood or transparent, and/or does not have typical values for yield/conversion	Anaerobic digestion is mature and well understood with typical yield conversions. Methane yields are typically higher for fruits compared to vegetables due to the difference in carbohydrate, protein, lignin and cellulose composition.		Conversion of the feedstock to biochar, bio-oil and syngas via pyrolysis or gasification are less commonly applied routes. Verification of conversion yields via these thermal treatments is more difficult due to them being at an early stage of development when concerning this feedstock type and therefore present a higher risk of fraud.	
		3. Assurance providers lack specific knowledge/ experience of this feedstock and derivatives		Assurance provider is likely to have knowledge or experience with fruit and vegetable residues. However, the implementation of anaerobic digestion of fruit and vegetable residues is at a lower level compared to more commonly used feedstocks (manure and		

				sludge).		

F.7.3. Nut shells and husks

	Category	Indicator (Pointing to High Risk)	Low Risk	Medium Risk	High Risk	Not Applicable
Elements incentivising fraud (Primary risk indicators)	Physical Characteristics	1. The physico-chemical properties of the feedstock and its derivatives are difficult to distinguish from other feedstocks	Nut shells and husks can be distinguished from other feedstocks based on their physical appearance and chemical composition			
		2. The feedstock can be grown on lands with different properties (e.g. prime farmland vs degraded land) and carries a claim of being grown on incentivized land				Nut shells can be agricultural and/or process residues while husks are process residues. Nut shells and husks are not direct farm products.
		3. Production process may be modified to generate more residue/waste; OR a different material could be altered to appear as this feedstock.				Not applicable
	Feedstock Definition Characteristics	1. The feedstock is not uniformly defined across all regions that it is traded	Nut shells and husks appear to be uniformly defined.			
		2. The classification of a feedstock as a waste, residue or coproduct,	Nut shells and husks are unlikely to be treated as a co-product, though they may be considered as residue or waste.			

		varies by country, making it difficult to characterize with certainty				
		3. The cellulose to non-cellulose ratio and/or combined yield factor is not known or defined for the feedstock	The cellulose to non-cellulose ratios for the the feedstock have been determined for each type of nut shell and husk but these ranges vary by type of nut shell or husk (e.g. penut shell vs. cashew nut shell; rice husk vs sunflower husk). This may however be irrelevant since shells/husks will be incentivized regardless of cellulosic content and are not likely to be used for cellulosic processes.			
Elements enabling fraud (Amplifiers)	**Supply Chain Characteristics**	1. The feedstock is traded between a large number of intermediaries and/or globally		Husks and nut shells are traded commodities but the number of intermediaries it is traded between is indeterminable from available data. Husks, especially rice husk, are traded globally in fairly large volumes and can be bought from many sources. Similarly, shelled as well as in-shell nuts are traded globally leading to the accumulation of nut shells in the regions where nuts are processed. For example, Italy is a large importer of in-shell walnuts, which are shelled and further processed within the country. Some nut shells are being commercially supplied as solid fuel.		
		2. The feedstock is typically produced in a country or region with weak rule of law.		Nut shells and husks are produced across the world, including in many countries with weak rule of law.		
	Assurance	1. Feedstocks are not typically segregated in supply chain or are not easily tied to a particular origin.		Nut shells and husks are segregated in the supply chain and can be tied to their place of origin i.e. nut processing plants and seed grain processing plants, respectively, when used locally. However, they are also traded globally. Once mixed with locally generated feedstock, it would not be possible to trace the imported feedstock back to their place of origin.		

		2. Conversion technology is not well understood or transparent, and/or does not have typical values for yield/conversion		The technologies for conversion of nut shells/husks are mainly direct combustion as solid fuel, gasification and pyrolysis. These technologies may or may not be well understood on the part of auditors since there are relatively few commercial scale pyrolysis plants, especially those that convert feedstocks directly to liquid fuel. Furthermore, the conversion yields are not standardized.		
		3. Assurance providers lack specific knowledge/ experience of this feedstock and derivatives	Materials are generally known and understood, or easily researched.			

F.7.4. Potato and sugar beet pulp

	Category	Indicator (Pointing to High Risk)	Low Risk	Medium Risk	High Risk	Not Applicable
Elements incentivising fraud (Primary risk indicators)	Physical Characteristics	1. The physico-chemical properties of the feedstock and its derivatives are difficult to distinguish from other feedstocks		Chemical composition of potato pulp differs from other potato derivatives. Sugar beet pulp can be identified by chemical composition. Differences between beet and cane are sufficient to justify two separate industries. Chemical analysis and screening of potato and sugar beet pulp is required to ensure accurate reporting of contents and suitability in applications such as animal feed. There may be risk associated with the feasibility of testing these residues on a regular basis to ensure authenticity. The risk is assumed to be medium due to potato and sugar beet products having higher economic value than bioenergy/biofuel.		
		2. The feedstock can be grown on lands with different properties (e.g. prime farmland vs degraded land) and carries a claim of being grown on incentivized land				Potato pulp and sugar beet pulp are not direct farm products.
		3. Production process may be modified to generate more residue/waste; OR a different material could be altered to appear as this feedstock.		Food-grade potatoes or sugar beets may be intentionally labelled as degraded/contaminated directing them to processing facilities which will lead to the production of pulp (as a residue of the process). However, there would be little economic incentive to do this as more value can be obtained from whole potato and sugar beet products.		
	Feedstock Definition Characteristics	1. The feedstock is not uniformly defined across all regions	Both potato pulp and sugar beet pulp appear to be uniformly defined across regions that they are traded.			

		that it is traded				
		2. The classification of a feedstock as a waste, residue or coproduct, varies by country, making it difficult to characterize with certainty	Potato pulp was identified as a residue in the assessment but is also described as a waste in literature.	Sugar beet pulp was identified as a co-product in the assessment but is also described as a waste in literature.		
		3. The cellulose to non-cellulose ratio and/or combined yield factor is not known or defined for the feedstock		Potato pulp chemical and physical properties depends on the botanical origin and processing method applied. Sugar beet pulp yield is dependent on variety of environmental factors.		
Elements enabling fraud (Amplifiers)	**Supply Chain Characteristics**	1. The feedstock is traded between a large number of intermediaries and/or globally	High moisture content of potato pulp and wet sugar beet pulp so generally traded at local level.		Less than 100 sugar factories across Europe and the USA produce over 50% of the global dried sugar beet pulp supply which is transported in large volumes worldwide with Japan and Morocco being the largest importers. Dried sugar beet pulp is lighter and pelletized compared to wet pulp so transportation is more economically viable.	
		2. The feedstock is typically produced in a country or region with weak rule of law.	Europe is the leading producer of potato starch representing over 70% of the market share. USA is one of the largest producers of dried sugar beet pulp.	Ukraine is one of the largest producers of wet sugar beet pulp.	Russia and Egypt at amongst the largest producers of dried sugar beet pulp. Turkey, Russia and Iran are amongst the largest producers of wet sugar beet pulp.	
	Assurance	1. Feedstocks are not typically segregated in supply chain or are not easily tied to a particular origin.	Process residues are segregated at the processing stage. The origin of the pulp feedstocks could be tied to the processing plants on a local level.	May be more difficult to tie dried sugar beet pulp to processing plant on a global level because this can be traded in large volumes potentially crossing multiple non-EU borders.		

		2. Conversion technology is not well understood or transparent, and/or does not have typical values for yield/conversion	Anaerobic digestion is mature and well-understood with typical yield conversions.		Little reporting on application of pyrolysis/gasification treatments of these feedstocks so would be harder to audit conversion/ yield factors.	
		3. Assurance providers lack specific knowledge/ experience of this feedstock and derivatives		Assurance provider is likely to have knowledge or experience with biogas production from these potato and sugar beet pulp. However, the implementation of anaerobic digestion of these feedstocks is at a lower level compared to more commonly used feedstocks (manure and sludge).		

F.7.5. Sugar – Bagasse

	Category	Indicator (Pointing to High Risk)	Low Risk	Medium Risk	High Risk	Not Applicable
Elements incentivising fraud (Primary risk indicators)	Physical Characteristics	1. The physico-chemical properties of the feedstock and its derivatives are difficult to distinguish from other feedstocks	Bagasse from sugarcane and sweet sorghum have similar compositions and appearances to materials and feedstocks. However, the other materials it could be mistaken for would also qualify for Annex IX list A under "other non-food cellulosic material"			
		2. The feedstock can be grown on lands with different properties (e.g. prime farmland vs degraded land) and carries a claim of being grown on incentivized land				N/A
		3. Production process may be modified to generate more residue/waste; OR a different material could be altered to appear as this feedstock.		The sugar from sugarcane/sweet sorghum has a higher value than the bagasse. However if future incentives increase the economic value of bagasse relative to sugar, more sugar may be left in bagasse.		
	Feedstock Definition Characteristics	1. The feedstock is not uniformly defined across all regions that it is traded	Bagasse appears to be uniformly defined			
		2. The classification of a feedstock as a waste, residue or coproduct, varies by country, making it difficult to characterize with		The classification of bagasse varies		

		certainty				
		3. The cellulose to non-cellulose ratio and/or combined yield factor is not known or defined for the feedstock	The cellulose to non-cellulose ratio of bagasse is known and defined.			
Elements enhancing fraud (Amplifiers)	**Supply Chain Characteristics**	1. The feedstock is traded between a large number of intermediaries and/or globally		Bagasse is sometimes traded and exported/imported, but is often used close to the source.		
		2. The feedstock is typically produced in a country or region with weak rule of law.		Bagasse is produced in some countries with weak rule of law.		
	Assurance	1. Feedstocks are not typically segregated in supply chain or are not easily tied to a particular origin.		Bagasse is typically segregated in its supply chain but is not easily tied to a particular origin		
		2. Conversion technology is not well understood or transparent, and/or does not have typical values for yield/conversion		The conversion process and technology is well understood but the conversion yields are not standardized.		
		3. Assurance providers lack specific knowledge/ experience of this feedstock and derivatives		Assurance providers may lack specific knowledge to distinguish between bagasse and other lignocellulosic resources		

F.7.6. Sugar – Final molasses

	Category	Indicator (Pointing to High Risk)	Low Risk	Medium Risk	High Risk	Not Applicable
Elements incentivising fraud (Primary risk indicators)	Physical Characteristics	1. The physico-chemical properties of the feedstock and its derivatives are difficult to distinguish from other feedstocks			Final molasses from the third crystallisation are somewhat similar to molasses from the second crystallisation (B-molasses), but chemical tests are available to distinguish final from other molasses, for example by assessing sugar content.	
		2. The feedstock can be grown on lands with different properties (e.g. prime farmland vs degraded land) and carries a claim of being grown on incentivized land				Not applicable
		3. Production process may be modified to generate more residue/waste; OR a different material could be altered to appear as this feedstock.				Not applicable
	Feedstock Definition Characteristics	1. The feedstock is not uniformly defined across all regions that it is traded		Terminology for different grades of molasses is not universally applied, and traded molasses may not be explicitly distinguished by grade.		
		2. The classification of a feedstock as a waste, residue or coproduct, varies by country, making it difficult to characterize with certainty	Molasses are identified as a co-product in RED II and RTFO, but may be considered as a residue rather than as a co-product by some producers.			

		3. The cellulose to non-cellulose ratio and/or combined yield factor is not known or defined for the feedstock				Not Applicable
Elements enabling fraud (Amplifiers)	**Supply Chain Characteristics**	1. The feedstock is traded between a large number of intermediaries and/or globally			Molasses are often likely to be processed to ethanol close to the point of origin given the integration between the sugar and sugar-ethanol industries. Molasses is however a tradable material and therefore be traded internationally through several intermediaries and then be processed into biofuel.	
		2. The feedstock is typically produced in a country or region with weak rule of law.	Some molasses production occurs in countries with good governance such as the USA, and in Europe.	Most molasses production in countires with middling goverance, including Brazil, India and Thailand.	Some molasses production occurs in countries with weak governance such as Pakistan, China and Mexico	
	Assurance	1. Feedstocks are not typically segregated in supply chain or are not easily tied to a particular origin.		Final molasses are likely to be segregated from other materials with the exception of B-molasses, with which they may be intermingled in some contexts.		
		2. Conversion technology is not well understood or transparent, and/or does not have typical values for yield/conversion	Ethanol production from molasses is a well understood pathway.			
		3. Assurance providers lack specific knowledge/ experience of this feedstock and derivatives		Assurance providers are likely to have experience with molasses, but may need additional training to identify cases where some B molasses may be mixed with final molasses.		

F.7.7.i. Oilseeds – Palm oil mill effluent (POME)

	Category	Indicator	Low Risk	Medium Risk	High Risk	Not Applicable
Elements incentivizing fraud (Primary risk indicators)	Physical Characteristics	1. The physico-chemical properties of the feedstock and its derivatives are difficult to distinguish from other feedstocks		Material is somewhat similar to other materials with high acid content (e.g. fatty acids) after moisture is removed.		
		2. The feedstock can be grown on lands with different properties (e.g. prime farmland vs degraded land) and carries a claim of being grown on incentivized land				Not applicable
		3. A different material could be altered to appear as this feedstock			Given its similarity to other materials with high acid content, it would be possible to blend in other materials. However chemical analysis could potentially determine if non-palm derived residues were declared as POME.	
	Feedstock Definition Characteristics	1. The feedstock is not uniformly defined across all regions that it is traded			Definitions are still unclear. Terms used include: Palm Sludge Oil, Minyak Kolam, Palm Acid Oil, POME. There has been significant discussion within ISCC about different definitions and terms for POME. Confusion around the terminology has created a potential risk of misclassification.	
		2. The classification of a feedstock as a waste, residue or coproduct, varies by country, making it difficult to characterize with certainty	General universal acceptance as a waste material.			

		3. The cellulose to non-cellulose ratio and/or combined yield factor is not known or defined for the feedstock				Not applicable
Elements enabling fraud (Amplifiers)	**Supply Chain Characteristics**	1. The feedstock is traded between a large number of intermediaries and/or globally			Collectors establishing businesses to collect POME from mills, aggregate, treat, and ship globally.	
		2. The feedstock is typically produced in a country or region with weak rule of law.		Produced mainly in Malaysia and Indonesia. Malaysia has a Rule of Law Ranking of 47, Indonesia has a Rule of Law Ranking of 59. Therefore rule of law is a moderate risk for these countries.		
	Assurance	1. Feedstocks are not typically segregated in supply chain or are not easily tied to a particular origin.		Materials are generally segregated, however collections may be grouped from a number of palm oil mills, increasing the risk of fraud.		
		2. Conversion technology is not well understood or transparent, and/or does not have typical values for yield/conversion		Production process is well understood. Typical yields are available in scientific literature, but may not be readily known to auditors.		
		3. Assurance providers lack specific knowledge/ experience of this feedstock and derivatives		Historically there was less experience in the market realted to POME yields, however this has been an area of attention lately and Voluntary Schemes have produced guidance documents to help auditors understand typical yields.		

F.7.7.ii. Oilseeds – Palm mesocarp

	Category	Indicator	Low Risk	Medium Risk	High Risk	Not Applicable
Elements incentivizing fraud (Primary risk indicators)	Physical Characteristics	1. The physico-chemical properties of the feedstock and its derivatives are difficult to distinguish from other feedstocks			Hexane extracted PPF oil has distinct chemical properties compared to CPO, including higher phosphorus, vitamin E and Carotenes than CPO, and a different fatty acid profile. However it is not easily physically distinguishable, and regular chemical testing is unlikely.	
		2. The feedstock can be grown on lands with different properties (e.g. prime farmland vs degraded land) and carries a claim of being grown on incentivized land				Not applicable
		3. A different material could be altered to appear as this feedstock		Communication with industry experts indicated that it would be relatively easy to relax the pressure on the extraction presses such that more oil is left in the mesocarp.		
	Feedstock Definition Characteristics	1. The feedstock is not uniformly defined across all regions that it is traded		Not a widely traded commodity with defined specifications. Feedstock is not well known and definitions need to be better established to identify this material. For example, PPF is not included currently in the list of ISCC approved materials, nor is it currently in any known national double counting material list.		
		2. The classification of a feedstock as a waste, residue or coproduct, varies by country, making it difficult to characterize with certainty		Definitions not very well established by regulatory authorities, and stakeholder feedback indicated poor knowledge of this material.		

		3. The cellulose to non-cellulose ratio and/or combined yield factor is not known or defined for the feedstock				Not applicable
Elements enabling fraud (Amplifiers)	Supply Chain Characteristics	1. The feedstock is traded between a large number of intermediaries and/or globally		Supply chains are mostly still being developed, but it appears that supply chains will be similar to CPO, with a number of traders serving as intermediaries.		
		2. The feedstock is typically produced in a country or region with weak rule of law.		Produced mainly in Malaysia and Indonesia. Malaysia has a Rule of Law Ranking of 47, Indonesia has a Rule of Law Ranking of 59. Therefore rule of law is a moderate risk for these countries.		
	Assurance	1. Feedstocks are not typically segregated in supply chain or are not easily tied to a particular origin.		For hexane extracted PPF oil the material will usually be segregated in the mill, as it is unsuitable for human consumption. Mechanically extracted PPF oil may or may not be segregated.		
		2. Conversion technology is not well understood or transparent, and/or does not have typical values for yield/conversion			Poorly understood extraction yields. Remnant oil constitutes 4-11% by dry mass of the mesocarp fibre. Evaluation found that mechanical and chemical extraction methods exist.	
		3. Assurance providers lack specific knowledge/ experience of this feedstock and derivatives			Novel feedstock, less experience by verifiers. Mechanical extraction represents higher risk due to potential to mix in regular CPO. Assurance providers are generally unfamiliar with PPF oils and will not usually be familiar with typical yields without technical training.	

F.7.7.iii. Oilseeds – Empty palm fruit bunches

	Category	Indicator	Low Risk	Medium Risk	High Risk	Not Applicable
Elements incentivizing fraud (Primary risk indicators)	Physical Characteristics	1. The physico-chemical properties of the feedstock and its derivatives are difficult to distinguish from other feedstocks		This material has distinctive physical characteristics coming out of the mill, however once densified into a bulk product it may be difficult to distinguish from other fibrous matter.		
		2. The feedstock can be grown on lands with different properties (e.g. prime farmland vs degraded land) and carries a claim of being grown on incentivized land				Not applicable
		3. A different material could be altered to appear as this feedstock		Communication with industry experts indicated that it would be relatively easy to leave FFB in the sun or intentionally abuse them physical to increase FFA content. However this is mitigated by restrictions from the CPO refiners, who require FFA content under a certain threshold.		
	Feedstock Definition Characteristics	1. The feedstock is not uniformly defined across all regions that it is traded		Historically there was confusion about definitions of EFB Oil and other palm oil mill residue materials, though they are being clarified recently through efforts by Voluntary Schemes.		
		2. The classification of a feedstock as a waste, residue or coproduct, varies by country, making it difficult to characterize with certainty	Universally accepted as a processing residue.			
		3. The cellulose to non-cellulose ratio and/or combined yield factor is not known or defined for the feedstock		Cellulosic content for the EFBs is variable, however it is currently used as a feedstock for cellulosic ethanol production.		NA for EFB Oil (no cellulosic content)

Elements enabling fraud (Amplifiers)	**Supply Chain Characteristics**	1. The feedstock is traded between a large number of intermediaries before reaching processing unit		Established Supply chains with a number of traders/intermediaries between the CPO mill and the biofuel facility are common.		
		2. The feedstock is typically produced in a country or region with weak rule of law.		Produced mainly in Malaysia and Indonesia. Malaysia has a Rule of Law Ranking of 47, Indonesia has a Rule of Law Ranking of 59. Therefore rule of law is a moderate risk for these countries.		
	Assurance	1. Feedstocks are not typically segregated in supply chain or are not easily tied to a particular origin.		Mostly segregated supply chains. Anecdotal evidence that material is being collected by aggregators, making it difficult to link to a particular point of origin.		
		2. Conversion technology is not well understood or transparent, and/or does not have typical values for yield/conversion		EFB Oil extraction yields were not well understood previously, though there are literature values and increasing attention is being paid to this by Voluntary Schemes.		
		3. Assurance providers lack specific knowledge/ experience of this feedstock and derivatives	Material is generally well known and understood from palm oil mill certification processes.			

F.7.7.iv. Oilseeds – Fatty acid distillates (FADs)

	Category	Indicator	Low Risk	Medium Risk	High Risk	Not Applicable
Elements incentivizing fraud (Primary risk indicators)	Physical Characteristics	1. The physico-chemical properties of the feedstock and its derivatives are difficult to distinguish from other feedstocks		This material has distinct characteristics compared to other products. It has distinct physical properties and a specific technical specification which can be tested through fairly simple analytical tools.		
		2. The feedstock can be grown on lands with different properties (e.g. prime farmland vs degraded land) and carries a claim of being grown on incentivized land				Not applicable
		3. A different material could be altered to appear as this feedstock		PFAD has a fairly distinct profile with physical properties that can be distinguished visually and a technical specification. Other types of high acid oil could potentially be blended in relatively small volumes. Risk is considered moderate.		
	Feedstock Definition Characteristics	1. The feedstock is not uniformly defined across all regions that it is traded	Definitional framework for this material is well established and specifications for this material to facilitate global trade are established.			
		2. The classification of a feedstock as a waste, residue or coproduct, varies by country, making it difficult to characterize with certainty			Refined palm oil (RBO) is the primary aim of the oil extraction process. Although PFAD does have a comparable economic value on a mass basis to palm oil, it only represents 4.9% of the total output by mass, thus its economic value is only 4.5% that of palm oil on an output weighted basis. Therefore, PFAD is generally categorized as a residue. Nevertheless, several EU Member States explicitly classify PFAD as a co-product (e.g. UK,	

					NL)	
		3. The cellulose to non-cellulose ratio and/or combined yield factor is not known or defined for the feedstock				Not applicable
Elements enabling fraud (Amplifiers)	**Supply Chain Characteristics**	1. The feedstock is traded between a large number of intermediaries and/or globally		Established Supply chains , typically with a number of traders/intermediaries between the refinery and the biofuel facility are common. Similar supply chains as with CPO and RPO.		
		2. The feedstock is typically produced in a country or region with weak rule of law.		Produced mainly in Malaysia and Indonesia. Malaysia has a Rule of Law Ranking of 47, Indonesia has a Rule of Law Ranking of 59. Therefore rule of law is a moderate risk for these countries.		
	Assurance	1. Feedstocks are not typically segregated in supply chain or are not easily tied to a particular origin.		Typically PFAD would be a segregated material, as it requires specific process technology. Due to it's nature as a globally traded commodity it will be difficult to tie to a particular origin.		
		2. Conversion technology is not well understood or transparent, and/or does not have typical values for yield/conversion	Fairly well understood conventional technology applies.			
		3. Assurance providers lack specific knowledge/ experience of this feedstock and derivatives		Assurance providers with experience with palm oil refiners are generally familiar with PFAD, however they may need technical training to know typical yields and identify possible fraud.		

F.7.7.v. Oilseeds – Olive oil extraction residues (de-oiled and non de-oiled pomace)

	Category	Indicator	Low Risk	Medium Risk	High Risk	Not Applicable
Elements incentivizing fraud (Primary risk indicators)	**Physical Characteristics**	1. The physico-chemical properties of the feedstock and its derivatives are difficult to distinguish from other feedstocks	De-Oiled: does not resemble any unincentivized materials		Non De-Oiled: Oil resulting from solvent extraction cannot be easily distinguished from other vegetable oils without chemical analysis, which is unlikely to regularly occur for biofuels markets (i.e. testing would occur for higher value food-grade virgin olive oil)	
		2. The feedstock can be grown on lands with different properties (e.g. prime farmland vs degraded land) and carries a claim of being grown on incentivized land				Not applicable
		3. A different material could be altered to appear as this feedstock	De-Oiled: not similar enough to unincentivized materials to warrant fraud		Non De-Oiled: Other vegetable oils could be diluted into this or mislabeled as this due to physical similarity	
	Feedstock Definition Characteristics	1. The feedstock is not uniformly defined across all regions that it is traded		Different primary extraction processes result in varying levels of residual oil in non de-oiled, and different types of solvent-based pomace extraction may result in different qualities of de-oiled. Some confusion may exist around the difference between non de-oiled and de-oiled pomace		
		2. The classification of a feedstock as a waste, residue or coproduct, varies by country, making it difficult to characterize with certainty	Material is clearly a residue of the olive oil extraction process; some chance that pomace oil may be considered co-product since it is available commercially			

		3. The cellulose to non-cellulose ratio and/or combined yield factor is not known or defined for the feedstock				Not appliable, not suited for cellulosic processes
Elements enabling fraud (Amplifiers)	Supply Chain Characteristics	1. The feedstock is traded between a large number of intermediaries and/or globally	Bulk nature of the material implies short travel distance			
		2. The feedstock is typically produced in a country or region with weak rule of law.	Approximately 70% of olive oil is produced within EU countries.			
	Assurance	1. Feedstocks are not typically segregated in supply chain or are not easily tied to a particular origin.		Often collected by aggregators that serve multiple mills, tracking to specific points of origin may be challenging		
		2. Conversion technology is not well understood or transparent, and/or does not have typical values for yield/conversion	De-oiled pomace would be converted by AD; non-de-oiled pomace would undergo oil extraction and esterification. Both are known processes.			
		3. Assurance providers lack specific knowledge/ experience of this feedstock and derivatives		Assurance providers may not have direct experience with these materials, but should be able to understand fairly quickly as they are similar enough to other biogas and FAME feedstocks		

F.7.7.vi. Oilseeds – High oleic sunflower oil extraction residues: FAV and PSK-Keto

	Category	Indicator	Low Risk	Medium Risk	High Risk	Not Applicable
Elements incentivizing fraud (Primary risk indicators)	Physical Characteristics	1. The physico-chemical properties of the feedstock and its derivatives are difficult to distinguish from other feedstocks			These materials are chemically distinct from other feedstocks, but regular analysis is unlikely. They are physically similar enough to other vegetable oils that visual distinction is difficult	
		2. The feedstock can be grown on lands with different properties (e.g. prime farmland vs degraded land) and carries a claim of being grown on incentivized land				Not applicable
		3. A different material could be altered to appear as this feedstock		Other vegetable oils could be diluted into FAV or PSK-Keto since regular chemical testing is unlikely and it would be difficult to visually detect that fraud had occurred		
	Feedstock Definition Characteristics	1. The feedstock is not uniformly defined across all regions that it is traded		Very little info about these materials from wider industry, currently available info provided by producers. Potential for misaligned definitions without agreed upon industry standard		
		2. The classification of a feedstock as a waste, residue or coproduct, varies by country, making it difficult to characterize with certainty		How countries will classify these materials once they become more widespread or incentivized is unknown, potential for significant disagreement on whether coproduct, residue, or waste		
		3. The cellulose to non-cellulose ratio and/or combined yield factor is not known or defined for the feedstock				Not applicable

Elements enabling fraud (Amplifiers)	**Supply Chain Characteristics**	1. The feedstock is traded between a large number of intermediaries and/or globally	Due to low number of current producers, limited trading occurs			
		2. The feedstock is typically produced in a country or region with weak rule of law.		Currently produced mainly in Italy which has relatively strong rule of law, while majority of sunflower producers are in countries with low WJP score. China produces some pelargonic/ azelaic acid, may become larger exporter of FAV/ PSK-Keto if incentivized		
	Assurance	1. Feedstocks are not typically segregated in supply chain or are not easily tied to a particular origin.		Uniqueness and relatively low volume should allow for tracing and segregation in supply chains. Will likely be used in local/regional biodiesel or coprocessing, possibly mixed with other feedstocks in the process		
		2. Conversion technology is not well understood or transparent, and/or does not have typical values for yield/conversion			Relatively novel conversion technology to create feedstock, difficult for assurance providers to assess whether it's being tuned to produce more incentivized residues. Final biofuel pathways are well understood FAME and HVO	
		3. Assurance providers lack specific knowledge/ experience of this feedstock and derivatives			Assurance providers have little to no knowledge of these feedstocks, and difficult to learn about them outside of what producers choose to share without advanced chemistry background	

F.7.8. Animal by-products (non-fats) – Category 2 and 3

	Category	Indicator	Low Risk	Medium Risk	High Risk	Not Applicable
Elements incentivising fraud (Primary risk indicators)	Physical Characteristics	1. The physico-chemical properties of the feedstock and its derivatives are difficult to distinguish from other feedstocks	Non-rendered ABP are easily distinguishable from other feedstocks. Rendered ABP non-fats (protein rich 'meals'), may be similar in appearance to crop meals. There would be little economic incentive to mislabel crop meal, due to existing demand as animal feed.			
		2. The feedstock can be grown on lands with different properties (e.g. prime farmland vs degraded land) and carries a claim of being grown on incentivized land				Not applicable - ABP non-fats arise at rendering points plants or at post-consumer points of origin
		3. Production process may be modified to generate more residue/waste; OR a different material could be altered to appear as this feedstock.	If ABP of different categories are mixed then the resulting mixture is by default the highest risk category. This applies to all ABP materials that are processed (i.e. fats and proteins). The risk of deliberate downgrading is considered low since the industry aims to maximise the overall value of the ABP outputs - the higher value of food grade and Category 3 ABP (particularly) proteins ultimately drives the market.			
	Feedstock Definition Characteristics	1. The feedstock is not uniformly defined across all regions that it is traded	The classification of ABP in Europe is set out under the ABP Regulations, and based on the level of risk. Third countries apply a different classification, however only Category 3 equivalent ABP can be exported to the EU.			

		2. The classification of a feedstock as a waste, residue or coproduct, varies by country, making it difficult to characterize with certainty	ABP non-fats in Europe is strictly regulated according to the level of risk. Category 2 and 3 ABP non-fats are likely to be regarded as either a residue or waste.			
		3. The cellulose to non-cellulose ratio and/or combined yield factor is not known or defined for the feedstock				Not applicable - ABP non-fats does not have these components
Elements enhancing fraud (Amplifiers)	**Supply Chain Characteristics**	1. The feedstock is traded between a large number of intermediaries and/or globally	The AF market is strictly regulated in the EU, involving licensed operators along the supply chain. ABP non-fats are not widely traded for biofuel production. The trade of human grade and Category 3 ABP into Europe is possible, but restricted to authorised establishments. All exports to the EU must be registered in the TRACES database. This implies there is a low risk of fraud.			
		2. The feedstock is typically produced in a country or region with weak rule of law.	See points 1 and 2 above.			
	Assurance	1. Feedstocks are not typically segregated in supply chain or are not easily tied to a particular origin.	ABP non-fats arise from specific PoO and are segregated in the supply chain. Transport of AF is strictly controlled via the ABP Regulations from origin to end-use. Commercial documentation accompanies each load of ABP and identifies the origin of the material, its category type and other relevant details (e.g. trailer ID) to ensure full traceability. Imports to the EU must be registered in the TRACES database.			

		2. Conversion technology is not well understood or transparent, and/or does not have typical values for yield/conversion		ABP non-fats are not widely used for biofuel or biogas production, although conventional conversion technologies (e.g. AD, trans-esterification) can in principle be applied. However, typical values for conversion yields may not be available.		
		3. Assurance providers lack specific knowledge/ experience of this feedstock and derivatives			Assurance providers are not likely to be very familiar with ABP non-fats as a feedstock for biofuel or biogas production given its niche application, but may be familiar in non-energy market contexts.	

F.7.9. Animal fats – Category 1, 2 and 3

	Category	Indicator (Pointing to High Risk)	Low Risk	Medium Risk	High Risk	Not Applicable
Elements incentivising fraud (Primary risk indicators)	**Physical Characteristics**	1. The physico-chemical properties of the feedstock and its derivatives are difficult to distinguish from other feedstocks		Animal fats (AF) may have characteristics that make it difficult to distinguish from some other waste oils (such as FFA content). Constituents such as salts, sulphur and phosphorous can be present in high concentrations in Category 1 AF. AF (including tallow) are typically solid at room temperature, whereas oils are typically liquids, which provides a way of differentiating between the two.		
		2. The feedstock can be grown on lands with different properties (e.g. prime farmland vs degraded land) and carries a claim of being grown on incentivized land				Not applicable - Animal fats arise at rendering plants
		3. Production process may be modified to generate more residue/waste; OR a different material could be altered to appear as this feedstock.	The risk of a slaughterhouse deliberately producing more ABP at the expense of food grade meat, or contaminating food grade meat, is considered to be very low. In the EU (and many third countries), all high risk (Category 1 and 2) material needs to be treated at a rendering plant; it is not possible to modify the production process to generate more ABP. The outputs from rendering lie within a typical range depending on the material rendered; it is not feasible to modify the production process to generate more animal fats. If ABP of different categories are mixed then the resulting mixture is by default the highest risk category. This applies to <u>all</u> ABP materials that are processed (i.e. fats and proteins). The risk of deliberate downgrading is considered low since the industry aims to maximise the overall economic value of the ABP outputs - the higher value of food grade and Category 3 ABP outputs (particularly proteins) ultimately drives the market.			
	Feedstock	1. The feedstock is	The classification of AF in Europe is set out under the			

	Definition Characteristics	not uniformly defined across all regions that it is traded	ABP Regulations, and based on the level of risk. Third countries apply different classifications, however only Category 3 equivalent AF can be exported to the EU.			
		2. The classification of a feedstock as a waste, residue or coproduct, varies by country, making it difficult to characterize with certainty	Category 1 and 2 AF are regarded as wastes uniformly across the EU. Category 3 AF may be regarded as either a residue or waste. The classification outside of the EU for equivalent material is likely to be consistent.			
		3. The cellulose to non-cellulose ratio and/or combined yield factor is not known or defined for the feedstock				Not applicable
Elements enabling fraud (Amplifiers)	**Supply Chain Characteristics**	1. The feedstock is traded between a large number of intermediaries and/or globally	The supply chains for AF are typically short and intra-EU, involving a limited number of intermediaries. AF are transported over relatively short distances, in particular Category 1 AF which is typically transported direct from the rendering plant to the biofuel plant without storage. The AF market is strictly regulated in the EU, involving licensed operators along the supply chain. The trade of AF into the EU is made challenging due to differences in material treatment methods and handling rules in third country markets. Only facilities that have been approved by the EC are permitted to export to the EU, this is limited to Category 3 equivalent AF. All exports to the EU must be registered in the TRACES database.			
		2. The feedstock is typically produced in a country or region with weak rule of law.	As per above, AF consumed for biofuels production in the EU are understood to be largely from EU origin.			
	Assurance	1. Feedstocks are not typically segregated in	AF arise from specific PoO and are segregated in the supply chain. Transport of AF is strictly controlled via the ABP Regulations from origin to end-use. Commercial documentation accompanies each load of animal fats			

		supply chain or are not easily tied to a particular origin.	and identifies the origin of the material, its category type and other relevant details (e.g. trailer ID) to ensure full traceability. Imports to the EU must be registered in the TRACES database.			
		2. Conversion technology is not well understood or transparent, and/or does not have typical values for yield/conversion	AF are widely used as a feedstock for biofuel production (FAME, HVO, HEFA).			
		3. Assurance providers lack specific knowledge/ experience of this feedstock and derivatives	Assurance providers are familiar with AF as a feedstock for biofuel production, including the different categories.			

F.7.10. Drinks, distillery and brewing products

	Category	Indicator (Pointing to High Risk)	Low Risk	Medium Risk	High Risk	Not Applicable
Elements incentivising fraud (Primary risk indicators)	Physical Characteristics	1. The physico-chemical properties of the feedstock and its derivatives are difficult to distinguish from other feedstocks	Grape marc, wine lees, fruit pulp and peels can be distinguished from other feedstocks given their physical appearance.	Distillery heads and tails, and fusel oils have specific chemical compositions that should be identifiable in the lab.		
		2. The feedstock can be grown on lands with different properties (e.g. prime farmland vs degraded land) and carries a claim of being grown on incentivized land				Not applicable as these are all process residues. They are not direct farm products.
		3. Production process may be modified to generate more residue/waste; OR a different material could be altered to appear as this feedstock.				Not applicable
	Feedstock Definition Characteristics	1. The feedstock is not uniformly defined across all regions that it is traded	Grape marc, wine lees, fruit pulp, peels, distillery heads and tails, and fusel oils are uniformly defined.			
		2. The classification of a feedstock as a waste, residue or coproduct, varies by country, making it difficult to characterize with certainty	Wine lees, fruit pulp, peels, distillery heads and tails, and fusel oils are unlikely to be treated as co-products, though they may be considered as waste.	Grape marc can be used to make grappa/pomace brandy and so can be considered a co-product when utilised, and as a residue or waste when discarded.		
		3. The cellulose to non-cellulose ratio and/or combined yield factor is not known or defined for the feedstock		The cellulose to non-cellulose ratios for grape marc and wine lees can vary by the species of grapes used. Cellulose can be extracted from different fruit pomace as well as orange peels, and the cellulose to no-cellulose ratios will vary by type of fruit.		Not applicable for distillery heads and tails, and fusel oils.

Elements enabling fraud (Amplifiers)	**Supply Chain Characteristics**	1. The feedstock is traded between a large number of intermediaries and/or globally	There is no evidence of distillery heads and tails, and fusel oils being traded globally.	In case of grape marc and wine lees, several companies have been certified as 'Collecting point' and 'Distillery' while a few are certified as 'Point of origin' and 'Ethanol plant'. As per the ISCC, collecting points of waste and residues are economic operators that collect or receive waste and residue materials directly from the points of origin. This could be an indication of grape marc and wine lees being aggregated by traders and processed within a certain region. 'Points of origin (PoO)' for waste or processing residues are operations where the waste or residue either occurs or is generated. Fruit pulp, peels, distillery heads and tails, and fusel oils may be converted into biogas/biofuels on site or may be aggregated by traders and processed within a certain region. Wine lees, orange peels, dried citrus pulp are traded globally. Grappa, which is produced using grape marc, is traded globally but there is little evidence of grape marc itself being traded.		
		2. The feedstock is typically produced in a country or region with weak rule of law.		Grape marc, wine lees, fruit pulp, peels, distillery heads and tails, and fusel oils are produced across the world, including in many countries with weak rule of law.		
	Assurance	1. Feedstocks are not typically segregated in supply chain or are not easily tied to a particular origin.	Grape marc, wine lees, fruit pulp, peels, distillery heads and tails, and fusel oils are segregated in the supply chain and can be tied to their place of origin, i.e., wineries, fruit processing plants, breweries/distilleries, respectively.			
		2. Conversion technology is not well understood or transparent, and/or does not have typical values for yield/conversion		The conversion process and technology is well understood for grape marc, wine lees, fruit pulp, peels, distillery heads and tails. But the conversion yields are not standardized.	The conversion process and technology associated with fusel oils is still a topic of research.	
		3. Assurance providers lack specific knowledge/ experience of this feedstock and derivatives	Grape marc, wine lees, citrus fruit pulp and peels, distillery heads and tails are generally known and understood, or easily researched.	Assurance providers may not be used to assessing fusel oils, but are likely to have experience working with the brewery/distillery industry.		

F.7.11. Bakery and Confectionery products

	Category	Indicator (Pointing to High Risk)	Low Risk	Medium Risk	High Risk	Not Applicable
Elements incentivising fraud (Primary risk indicators)	Physical Characteristics	1. The physico-chemical properties of the feedstock and its derivatives are difficult to distinguish from other feedstocks	A risk exists that other types of biogenic wastes from food processing units (e.g. food waste from canteen, garden waste, etc.) are mixed with bakery/confectionery residues and waste, which would be challenging to track and identify. However, biowaste from industrial facilities are already incentivized (Annex IX point d) .	Bakery or confectionery (main) products could be mixed with residues and waste, which could not be easily detected, either via a visual inspection or through a chemical analysis. Such risk is assumed to be moderate, due to the higher economic value of food products, compared to biofuel/biogas.		
		2. The feedstock can be grown on lands with different properties (e.g. prime farmland vs degraded land) and carries a claim of being grown on incentivized land				Not applicable. No specific incentive exists to produce these feedstocks out of degraded or abandoned land.
		3. Production process may be modified to generate more residue/waste; OR a different material could be altered to appear as this feedstock.		A risk exists that bakery/confectionery main products are intentionally degraded or contaminated to qualify as waste. Such risk is assumed to be moderate, due to the higher economic value of food products, compared to biofuel/biogas.		
	Feedstock Definition Characteristics	1. The feedstock is not uniformly defined across all regions that it is traded		Bakery and confectionery residues and waste are not uniformly defined across all regions, due to the diversity of product supply chains they are generated from. Whenever these are considered unsuitable as food/feed, they would be covered under EU RED II or UK RTFO as food waste, but if a potential use as food/feed remains technically possible (even if economically unattractive), such definition would not apply.		

		2. The classification of a feedstock as a waste, residue or coproduct, varies by country, making it difficult to characterize with certainty			Neither the characteristics making bakery and confectionery residues and waste suitable for energy production rather than food/feed use nor their classification as residue or waste are clearly defined in EU or UK regulations.	
		3. The cellulose to non-cellulose ratio and/or combined yield factor is not known or defined for the feedstock		Conversion/yield factors for processing bakery and confectionery residues and waste into biogas are not documented. However, biogas/biofuel operators will likely test new feedstocks and have a pretty good sense of yields.		
Elements enabling fraud (Amplifiers)	**Supply Chain Characteristics**	1. The feedstock is traded between a large number of intermediaries and/or globally	No documented evidence was found that bakery or confectionery residues and waste are traded between a large number of intermediaries.	Bakery residues and waste are not traded globally, but they are produced in large volumes by industrial food facilities.		
		2. The feedstock is typically produced in a country or region with weak rule of law.	Bakery and confectionery waste or residues used in the EU for energy production are therefore expected to be produced in the European Union, where the rule of law can be considered robust.			
	Assurance	1. Feedstocks are not typically segregated in supply chain or are not easily tied to a particular origin.		According to the stakeholders consulted for this study, bakery and confectionery residues and waste are used locally, which means they could be traced back to their origin. It could however be assumed that residues and waste from different industrial facilities could be aggregated, which would make their tracking back to origin difficult.		
		2. Conversion technology is not well understood or transparent, and/or does not have typical values for yield/conversion		The technologies for conversion of bakery and confectionery residues and waste are mainly anaerobic digestion (biogas) and fermentation (ethanol), which are well understood. Typical yields for		

				bakery and confectionery residues and waste are however not documented.		
		3. Assurance providers lack specific knowledge/ experience of this feedstock and derivatives			Difficulties to distinguish between the different types of residues and waste, assess their potential for food/feed uses and determine whether they should be considered as residues or waste. Training required for assurance providers.	

F.8. Processing residues – others

F.8.1. Tall oil pitch

	Category	Indicator (Pointing to High Risk)	Low Risk	Medium Risk	High Risk	Not Applicable
Elements incentivising fraud (Primary risk indicators)	Physical Characteristics	1. The physico-chemical properties of the feedstock and its derivatives are difficult to distinguish from other feedstocks	Tall oil pitch has distinct properties as compared to tall oil or other low value oils.			
		2. The feedstock can be grown on lands with different properties (e.g. prime farmland vs degraded land) and carries a claim of being grown on incentivized land				Not applicable
		3. Production process may be modified to generate more residue/waste; OR a different material could be altered to appear as this feedstock.	It would be possible in principle for tall oil distillers to reduce the extraction of lighter fractions during distillation, effectively moving material from fractions such as distilled tall oil or tall oil fatty acids into the tall oil pitch fraction, but there is no incentive for this given that tall oil is also included in Annex IX.			
	Feedstock Definition Characteristics	1. The feedstock is not uniformly defined across all regions that it is traded	Tall oil pitch is well defined.			
		2. The classification of a feedstock as a waste, residue or coproduct, varies by country, making it difficult to characterize with certainty	Tall oil pitch is unlikely to be classed as a co-product in any region given its low value, and should not be understood as a waste given that energy recovery is standard in the absence of other market options.			

		3. The cellulose to non-cellulose ratio and/or combined yield factor is not known or defined for the feedstock				Not applicable
Elements enabling fraud (Amplifiers)	**Supply Chain Characteristics**	1. The feedstock is traded between a large number of intermediaries and/or globally		The market for tall oil pitch is limited so currently it is unlikely to be traded between a large number of parties before processing, but development of a market as biofuel feedstock could encourage aggregation and trade at longer distances.		
		2. The feedstock is typically produced in a country or region with weak rule of law.	More than half of kraft pulping occurs in low risk countries (e.g. Nordic countries, North America)	Some kraft pulp production occurs in countries with middling governance (e.g. Indonesia, Brazil).	Some kraft pulp production occurs in countries with weka governance (e.g. Russia, China).	
	Assurance	1. Feedstocks are not typically segregated in supply chain or are not easily tied to a particular origin.	Tall oil pitch is likely to be segregated in the supply chain.			
		2. Conversion technology is not well understood or transparent, and/or does not have typical values for yield/conversion			Biofuel production from tall oil pitch via hydrotreating is fairly well understood, but there are no widely accepted default values for the process and there is no GHG emission default in RED II.	
		3. Assurance providers lack specific knowledge/ experience of this feedstock and derivatives		Assurance providers may not be used to working with tall oil pitch specifically, but are likely to have experience working with the forest products industry.		

F.8.2. Crude glycerine

	Category	Indicator (Pointing to High Risk)	Low Risk	Medium Risk	High Risk	Not Applicable
Elements incentivising fraud (Primary risk indicators)	Physical Characteristics	1. The physico-chemical properties of the feedstock and its derivatives are difficult to distinguish from other feedstocks	Crude glycerine is clearly distinct from other biofuel feedstocks. Renewable glycerine may be difficult to distinguish from fossil derived glycerine, but global production of fossil glycerine is understood to be very limited.			
		2. The feedstock can be grown on lands with different properties (e.g. prime farmland vs degraded land) and carries a claim of being grown on incentivized land				Not applicable
		3. Production process may be modified to generate more residue/waste; OR a different material could be altered to appear as this feedstock.				Not Applicable
	Feedstock Definition Characteristics	1. The feedstock is not uniformly defined across all regions that it is traded	Crude glycerine is well defined			
		2. The classification of a feedstock as a waste, residue or		Crude glycerine is treated as a residue under RED II, but may be considered as a co-product by some stakeholders.		

		coproduct, varies by country, making it difficult to characterize with certainty				
		3. The cellulose to non-cellulose ratio and/or combined yield factor is not known or defined for the feedstock				Not Applicable
Elements enabling fraud (Amplifiers)	**Supply Chain Characteristics**	1. The feedstock is traded between a large number of intermediaries and/or globally			Crude glycerine could potentially be traded between several intermediaries, starting with aggregation from biodiesel producers, prior to processing to biofuel.	
		2. The feedstock is typically produced in a country or region with weak rule of law.	More than 50% of biodiesel production (and thus crude glycerine production) occurs in countries with strong rule of law (e.g. The United States, Germany, Spain, the Netherlands).	Some crude glycerine production occurs in countries with middling governance (e.g. Brazil, Indonesia, Argentina, Thailand)	There is a significant global trade in crude glycerine.	
	Assurance	1. Feedstocks are not typically segregated in supply chain or are not easily tied to a particular origin.	Crude glycerine is likely to be kept segregated from other feedstocks.			
		2. Conversion technology is not well understood or transparent, and/or does not have typical values for yield/conversion		Biofuel production from glycerine is not currently widely practiced and does not have default LCA values.		
		3. Assurance providers lack specific knowledge/ experience of this		Assurance providers are unlikely to have direct experience working with glycerine supply chains.		

		feedstock and derivatives				

F.8.3. Raw methanol

	Category	Indicator (Pointing to High Risk)	Low Risk	Medium Risk	High Risk	Not Applicable
Elements incentivising fraud (Primary risk indicators)	Physical Characteristics	1. The physico-chemical properties of the feedstock and its derivatives are difficult to distinguish from other feedstocks			Following purification, methanol from raw methanol may be difficult to distinguish from fossil methanol except through carbon 14 testing.	
		2. The feedstock can be grown on lands with different properties (e.g. prime farmland vs degraded land) and carries a claim of being grown on incentivized land				Not applicable
		3. Production process may be modified to generate more residue/waste; OR a different material could be altered to appear as this feedstock.				Not Applicable
	Feedstock Definition Characteristics	1. The feedstock is not uniformly defined across all regions that it is traded	Methanol and the kraft process are both well defined.			
		2. The classification of a feedstock as a waste, residue or coproduct, varies by country, making it difficult to characterize with certainty		Raw methanol may be considered a waste by some operators but a residue by others.		
		3. The cellulose to non-cellulose ratio and/or				Not Applicable

		combined yield factor is not known or defined for the feedstock				
Elements enabling fraud (Amplifiers)	**Supply Chain Characteristics**	1. The feedstock is traded between a large number of intermediaries and/or globally	Raw methanol is likely to be purified on site given the difficulty of transporting foul condensates.			
		2. The feedstock is typically produced in a country or region with weak rule of law.	More than half of kraft pulping occurs in low risk countries (e.g. Nordic countries, North America)	Some kraft pulp production occurs in countries with middling governance (e.g. Indonesia, Brazil).	Some kraft pulp production occurs in countries with weak governance (e.g. Russia, China).	
	Assurance	1. Feedstocks are not typically segregated in supply chain or are not easily tied to a particular origin.		Raw methanol is likely to be segregated until purification but could then enter wider methanol supply chains.		
		2. Conversion technology is not well understood or transparent, and/or does not have typical values for yield/conversion		The basics of the methanol purification process are understood, but there are no default values for the process.		
		3. Assurance providers lack specific knowledge/ experience of this feedstock and derivatives		Assurance providers are unlikely to have worked with raw methanol but are likely to be familiar with the kraft pulping industry.		

F.8.4. Soapstock and its derivatives

	Category	Indicator (Pointing to High Risk)	Low Risk	Medium Risk	High Risk	Not Applicable
Elements incentivising fraud (Primary risk indicators)	Physical Characteristics	1. The physico-chemical properties of the feedstock and its derivatives are difficult to distinguish from other feedstocks		The composition of soapstock and derivatives is heterogeneous and this material could potentially be confused with other types of materials.		
		2. The feedstock can be grown on lands with different properties (e.g. prime farmland vs degraded land) and carries a claim of being grown on incentivized land				Not applicable - Soapstock and its derivatives are process residues
		3. Production process may be modified to generate more residue/waste; OR a different material could be altered to appear as this feedstock.		Virgin vegetable oil could potentially be degraded or contaminated to appear as soapstock and derivatives		
	Feedstock Definition Characteristics	1. The feedstock is not uniformly defined across all regions that it is traded		Soapstock and its derivatives are not uniformly defined.		
		2. The classification of a feedstock as a		Soapstock and its derivatives are sometimes referred to residues and sometimes as as by-products or co-products		

		waste, residue or coproduct, varies by country, making it difficult to characterize with certainty		in the literature.		
		3. The cellulose to non-cellulose ratio and/or combined yield factor is not known or defined for the feedstock				Not applicable - Soapstock and its derivatives do not have these components
Elements enhancing fraud (Amplifiers)	**Supply Chain Characteristics**	1. The feedstock is traded between a large number of intermediaries and/or globally		Soapstock and its derivatives are used in multiple different industries that could have variable number of intermediaries involved.		
		2. The feedstock is typically produced in a country or region with weak rule of law.		Feedstock is produced in nearly every country, including many with middling rule of law.		
	Assurance	1. Feedstocks are not typically segregated in supply chain or are not easily tied to a particular origin.			Soapstock and derivatives are typically segragated in the supply chain but are not easily tied to a particular origin.	
		2. Conversion technology is not well understood or transparent, and/or does not have typical values for yield/conversion		Conversion technology is mature and well-understood but yields are not standardized		
		3. Assurance providers lack			Assurance provider likely to not have specific knowledge or experience with soapstock and its derivatives.	

		specific knowledge/ experience of this feedstock and derivatives				

F.9. Agriculture waste

F.9.1. Animal manure

	Category	Indicator (Pointing to High Risk)	Low Risk	Medium Risk	High Risk	Not Applicable
Elements incentivising fraud (Primary risk indicators)	Physical Characteristics	1. The physico-chemical properties of the feedstock and its derivatives are difficult to distinguish from other feedstocks	Animal waste does not share similarities with other feedstocks			
		2. The feedstock can be grown on lands with different properties (e.g. prime farmland vs degraded land) and carries a claim of being grown on incentivized land				Not applicable
		3. Production process may be modified to generate more residue/waste; OR a different	It is unlikely that other materials could easily be mistaken for manure, although possible that other materials (e.g. slaughter waste) could be mixed in with manure. Animal bedding is also sometimes mixed into manure, e.g. straw, but this would also be eligible in Annex IX, part A.			

		material could be altered to appear as this feedstock.				
	Feedstock Definition Characteristics	1. The feedstock is not uniformly defined across all regions that it is traded	Animal waste appears to be uniformly defined.			
		2. The classification of a feedstock as a waste, residue or coproduct, varies by country, making it difficult to characterize with certainty	Animal waste appears to be classified as a waste uniformly.			
		3. The cellulose to non-cellulose ratio and/or combined yield factor is not known or defined for the feedstock			Animal Waste may have varying ratios as a result of litter, consisting of straw or woodchips typically, mixing with manure. Other sources of variability include the animal feed, which could consist of cellulosic material, and the animal's digestibility of its feed.	
Elements enhancing fraud (Amplifiers)	Supply Chain Characteristics	1. The feedstock is traded between a large number of intermediaries and/or globally	Animal waste is not currently traded between a large number of intermediaries.			

		2. The feedstock is typically produced in a country or region with weak rule of law.	Animal manure is produced across the world, including in countries with weak rule of law, but is not likely exported from those countries to the EU			
	Assurance	1. Feedstocks are not typically segregated in supply chain or are not easily tied to a particular origin.	Manure management is regulated in the EU with third countries also being held to the EU's standards of management. The EU's TRACES system documents and regulates the import and export of manure.			
		2. Conversion technology is not well understood or transparent, and/or does not have typical values for yield/conversion		Anaerobic digestion is a mature technology for biogas production. The conversion yields for manure are heterogenous.		
		3. Assurance providers lack specific knowledge/ experience of this feedstock and derivatives		Assurance providers may lack the knowledge and experience to deal with the variability of this feedstock and its derivatives.		

F.10. Food/feed production waste

F.10.1. Brewers' Spent Grain and Whey Permeate

	Category	Indicator (Pointing to High Risk)	Low Risk	Medium Risk	High Risk	Not Applicable
Elements incentivising fraud (Primary risk indicators)	Physical Characteristics	1. The physico-chemical properties of the feedstock and its derivatives are difficult to distinguish from other feedstocks		Potential risk of grains damaged at the brewery being mixed with brewers' spent grains (BSG) (no external reference to substantiate this). Whey permeate and whey composition is quite similar and there could be the potential risk of the latter being mixed to increase volumes of the former (no external reference to substantiate this).		
		2. The feedstock can be grown on lands with different properties (e.g. prime farmland vs degraded land) and carries a claim of being grown on incentivized land				BSG and whey permeate are process residues or waste, and not direct farm products.
		3. Production process may be modified to generate more residue/waste; OR a different material could be altered to appear as this feedstock.		Grains damaged at the brewery may appear similar to BSG.		
	Feedstock Definition Characteristics	1. The feedstock is not uniformly defined across all regions that it is traded	BSG and whey permeate are uniformly defined			
		2. The classification of a feedstock as a waste, residue or coproduct, varies by country, making it difficult to characterize with certainty	BSG and whey permeate are unlikely to be treated as a co-product, though they may be considered as residue/ waste.			
		3. The cellulose to non-cellulose ratio and/or combined yield factor is not known or defined for the	Cellulose to non-cellulose ratio of BSG is well defined.			Whey permeate does not have these components

		feedstock				
Elements enabling fraud (Amplifiers)	**Supply Chain Characteristics**	1. The feedstock is traded between a large number of intermediaries and/or globally	BSG and liquid whey permeate are difficult to transport over large distances without spoilage. Therefore, these feedstocks are not traded between many intermediaries before reaching the processing unit. BSG and liquid whey permeate are not traded globally.	Whey permeate powder can be traded between many intermediaries. Whey permeate powder is being traded globally and volumes are projected to increase. However, there is little evidence of liquid whey permeate being converted to powder and then being sent to a processing unit for biofuel production.		
		2. The feedstock is typically produced in a country or region with weak rule of law.	A review of whey permeate sources reveals it is mostly produced in countries with strong rule of law.	China, Brazil and Russia are among the leading producers of BSG. East Asia, South America and Russia have a singificantly low Rule of Law Indicator score compared to the EU		
	Assurance	1. Feedstocks are not typically segregated in supply chain or are not easily tied to a particular origin.	BSG and whey permeate are segregated in the supply chain and can be tied to their place of origin i.e. breweries and dairy processing plants, respectively.			
		2. Conversion technology is not well understood or transparent, and/or does not have typical values for yield/conversion		Biogas or ethanol production from BSG and whey permeate via AD and fermentation respectively are fairly well understood, but there are no widely accepted default values for the processes.		
		3. Assurance providers lack specific knowledge/ experience of this feedstock and derivatives	As BSG or draff is single counted under the UK's RTFO, assurance providers may be used to assessing BSG.	Assurance providers may not be used to assessing whey permeate specifically, and may or may not have any experience working with the dairy processing industry.		

F.11. Waste – others

F.11.1. Vinasse

	Category	Indicator (Pointing to High Risk)	Low Risk	Medium Risk	High Risk	Not Applicable
Elements incentivising fraud (Primary risk indicators)	Physical Characteristics	1. The physico-chemical properties of the feedstock and its derivatives are difficult to distinguish from other feedstocks	Vinasse has distinct characteristics.			
		2. The feedstock can be grown on lands with different properties (e.g. prime farmland vs degraded land) and carries a claim of being grown on incentivized land				Not Applicable
		3. Production process may be modified to generate more residue/waste; OR a different material could be altered to appear as this feedstock.		Vinasse could in principle be contaminated with primary materials.		
	Feedstock Definition Characteristics	1. The feedstock is not uniformly defined across all regions that it is traded		Vinasse may be used interchangeably with some other terms such as thin stillage. In some regions the term vinasse may be applied to process water from a wider group of processes.		

		2. The classification of a feedstock as a waste, residue or coproduct, varies by country, making it difficult to characterize with certainty		Vinasse is unlikely to be treated as a co-product given its low value, though it may be considered a waste in some contexts.		
		3. The cellulose to non-cellulose ratio and/or combined yield factor is not known or defined for the feedstock				Not Applicable
Elements enabling fraud (Amplifiers)	**Supply Chain Characteristics**	1. The feedstock is traded between a large number of intermediaries and/or globally	Vinasse is expensive to transport and therefore unlikely to pass through several intermediaries before processing.			
		2. The feedstock is typically produced in a country or region with weak rule of law.	Some vinasse production occurs in countries with good governance such as the USA, and in Europe.	Most vinasse production in countries with middling governance, including Brazil, India and Thailand.	Some vinasse production occurs in countries with weak governance such as Pakistan, China and Mexico	
	Assurance	1. Feedstocks are not typically segregated in supply chain or are not easily tied to a particular origin.	Vinasse is likely to be segregated from other materials.			
		2. Conversion technology is not well understood or transparent, and/or does not have typical values for yield/conversion		Biogas production from vinasse has been studied for some years but is not widely implemented, and no widely accepted defaults exist.		
		3. Assurance providers lack specific knowledge/		Assurance providers are unlikely to have worked with vinasse, but it is a product of the sugar		

		experience of this feedstock and derivatives		processing industry which should be well understood.		

F.11.2. Thin stillage

	Category	Indicator (Pointing to High Risk)	Low Risk	Medium Risk	High Risk	Not Applicable
Elements incentivising fraud (Primary risk indicators)	Physical Characteristics	1. The physico-chemical properties of the feedstock and its derivatives are difficult to distinguish from other feedstocks	Thin stillage has distinct characteristics.			
		2. The feedstock can be grown on lands with different properties (e.g. prime farmland vs degraded land) and carries a claim of being grown on incentivized land				Not Applicable
		3. Production process may be modified to generate more residue/waste; OR a different material could be altered to appear as this feedstock.		Thin stillage could in principle be contaminated with primary materials.		Not applicable
	Feedstock Definition Characteristics	1. The feedstock is not uniformly defined across all regions that it is traded		Thin stillage may be used interchangeably with some other terms such as vinasse.		
		2. The classification of a feedstock as a waste, residue or coproduct, varies by country, making it difficult to characterize with certainty		Thin stillage is identified as a residue in the context of the RED II but may be considered a co-product by some stakeholders.		

		3. The cellulose to non-cellulose ratio and/or combined yield factor is not known or defined for the feedstock				Not applicable
Elements enabling fraud (Amplifiers)	**Supply Chain Characteristics**	1. The feedstock is traded between a large number of intermediaries and/or globally		Thin stillage is expensive to transport is dilute form, but after evaporation it is possible that distillers' solubles could be traded through intermediates.		
		2. The feedstock is typically produced in a country or region with weak rule of law.	Grain ethanol is mostly produced in the EU and U.S. in countries with good governance.	There is significant corn ethanol production in Brazil with middling governance.	There is significant corn ethanol production in China which is identified as having weak governance.	
	Assurance	1. Feedstocks are not typically segregated in supply chain or are not easily tied to a particular origin.	Thin stillage is likely to be segregated from other materials.			
		2. Conversion technology is not well understood or transparent, and/or does not have typical values for yield/conversion		Biogas production from thin stillage has been studied for some years but is not widely implemented. There is no default GHG emission value for biogas from thin stillage in RED II, and no widely accepted default GHG emissions values or yield values.		
		3. Assurance providers lack specific knowledge/ experience of this feedstock and derivatives		Assurance providers are unlikely to have worked with thin stillage, but it is a product of the grain ethanol industry which should be well understood.		

F.11.3. Brown grease

	Category	Indicator	Low Risk	Medium Risk	High Risk	Not Applicable
Elements incentivizing fraud (Primary risk indicators)	Physical Characteristics	1. The physico-chemical properties of the feedstock and its derivatives are difficult to distinguish from other feedstocks	Brown grease is chemically and visually distinct from similar FOGs such as UCO and animal fat, though it may become visually similar after pretreatment			
		2. The feedstock can be grown on lands with different properties (e.g. prime farmland vs degraded land) and carries a claim of being grown on incentivized land				Not applicable
		3. A different material could be altered to appear as this feedstock		Fats and oils could be intentionally contaminated to pass as BG		
	Feedstock Definition Characteristics	1. The feedstock is not uniformly defined across all regions that it is traded		BG is generally well defined as FOG extracted from kitchen grease traps, but at least one exception has been found online		
		2. The classification of a feedstock as a waste, residue or coproduct, varies by country, making it difficult to characterize with certainty	BG generally regarded as waste material in all jurisdictions.			
		3. The cellulose to non-cellulose ratio and/or combined yield factor is not known or defined for the feedstock				Not applicable

Elements enabling fraud (Amplifiers)	**Supply Chain Characteristics**	1. The feedstock is traded between a large number of intermediaries and/or globally		Currently small volumes are traded among limited number of entities, but this could change as pretreatment tech improves and incentives become better defined		
		2. The feedstock is typically produced in a country or region with weak rule of law.	A review of BG sources reveals it mostly comes from countries with strong rule of law.			
	Assurance	1. Feedstocks are not typically segregated in supply chain or are not easily tied to a particular origin.		BG is typically segregated in supply chain and should be traceable back to points of origin with self-declarations provided to collecting points, though as with UCO perfect oversight of all PoOs is not possible		
		2. Conversion technology is not well understood or transparent, and/or does not have typical values for yield/conversion		Pre-treatment steps are more complex than some wastes (e.g. UCO), but not overly complex technology. Standard FAME, HVO, and possibly biogas processes likely to be used		
		3. Assurance providers lack specific knowledge/ experience of this feedstock and derivatives		Auditors may not be especially experienced with BG, though the collection and pretreatment infrastructure is fairly similar to UCO which they are familiar with		

F.11.4. Used Cooking Oil

	Category	Indicator	Low Risk	Medium Risk	High Risk	Not Applicable
Elements incentivizing fraud (Primary risk indicators)	Physical Characteristics	1. The physico-chemical properties of the feedstock and its derivatives are difficult to distinguish from other feedstocks			Non-incentivized fats and oils could be falsely labeled as or diluted into UCO since they are physically similar and chemical analysis is not common or practical on a comprehensive basis	
		2. The feedstock can be grown on lands with different properties (e.g. prime farmland vs degraded land) and carries a claim of being grown on incentivized land				Not applicable
		3. A different material could be altered to appear as this feedstock			Other fats and oils can easily be diluted into UCO or simply falsely labelled, and there are recent lawsuits alleging this	
	Feedstock Definition Characteristics	1. The feedstock is not uniformly defined across all regions that it is traded		While UCO itself is fairly clear, the distinction between entirely veg origin and mixed with animal may not always be known or labeled. Also synonym "yellow grease" may cause confusion		
		2. The classification of a feedstock as a waste, residue or coproduct, varies by country, making it difficult to characterize with certainty	UCO is uniformly considered a waste by virtue of it being "used," though some countries do not incentivize UCO with animal components			
		2. The cellulose to non-cellulose ratio and/or combined yield factor is not known or defined for the feedstock				Not applicable
enabli ng fraud	Supply Chain Characteristics	1. The feedstock is traded between a large number of			UCO is traded on a massive scale, often passing through multiple entities before	

		intermediaries and/or globally			arriving at processing unit	
		3. The feedstock is typically produced in a country or region with weak rule of law.		UCO is produced in many countries around the world, some with weak rule of law and high corruption		
	Assurance	1. Feedstocks are not typically segregated in supply chain or are not easily tied to a particular origin.		Depending on storage vessel, UCO may be shipped along with similar products (i.e. IBC totes). May be difficult to trace to origin depending on detail of record keeping		
		2. Conversion technology is not well understood or transparent, and/or does not have typical values for yield/conversion	Conversion to biodiesel/ FAME and renewable diesel/ HVO is very well understood			
		3. Assurance providers lack specific knowledge/ experience of this feedstock and derivatives		Assurance providers are very familiar with UCO, but in practice it can be difficult to ensure that all 100% of material comes from verified sources due to scale and weak rule of law sources		

F.12. Wastewater

F.12.1. Sewage sludge

	Category	Indicator (Pointing to High Risk)	Low Risk	Medium Risk	High Risk	Not Applicable
Elements incentivising fraud (Primary risk indicators)	Physical Characteristics	1. The physico-chemical properties of the feedstock and its derivatives are difficult to distinguish from other feedstocks	Sewage sludge is easy to distinguish from other feedstocks - irrespective of whether it has undergone pre-treatment.			
		2. The feedstock can be grown on lands with different properties (e.g. prime farmland vs degraded land) and carries a claim of being grown on incentivized land				Not applicable - Sewage sludge arises at a wastewater treatment plant (sewage plant) and is not a direct farm product.
		3. Production process may be modified to generate more residue/waste; OR a different material could be altered to appear as this feedstock.	The risk of intentional mislabelling or altering another feedstock to look like sewage sludge is considered to be low. Sewage sludge is a material that arises from the treatment of wastewater. The incentive to deliberately generate more sewage sludge is therefore considered to be low. Furthermore, modifying the wastewater treatment process to produce more material is not feasible. Sewage sludge cannot be (further) contaminated or degraded.			
	Feedstock Definition Characteristics	1. The feedstock is not uniformly defined across all regions that it is traded	Sewage sludge is not traded globally.			
		2. The classification of a feedstock as a waste, residue or coproduct, varies by	Sewage sludge is assumed to be uniformly treated as a waste material in the EU/globally.			

		country, making it difficult to characterize with certainty				
		3. The cellulose to non-cellulose ratio and/or combined yield factor is not known or defined for the feedstock				NA - Sewage sludge does not have these components.
Elements enhancing fraud (Amplifiers)	**Supply Chain Characteristics**	1. The feedstock is traded between a large number of intermediaries and/or globally	Sewage sludge is typically treated on-site at the waste water treatment plant. Very limited trade of pre-treated sewage sludge occurs across Europe and is understood to involve a limited number of intermediaries.			Current trade is restricted to use as a bio-fertiliser (i.e. bio-solids).
		2. The feedstock is typically produced in a country or region with weak rule of law.	Sewage sludge is produced globally in countries where waste water treatment plants exist.. Production is concentated in/near to large population centres. However sewage sludge used in the EU is primarily of EU origin due to the limited global trade that exists.			
	Assurance	1. Feedstocks are not typically segregated in supply chain or are not easily tied to a particular origin.	Sewage sludge is typically treated on-site at the wastewater treatment plant.			
		2. Conversion technology is not well understood or transparent, and/or does not have typical values for yield/conversion	Sewage sludge is commonly treated using anaerobic digestion, at commercial scale.			
		3. Assurance providers lack specific knowledge/ experience of this feedstock and derivatives	Assurance providers are familiar with sewage sludge as a feedstock for biogas production.			

F.12.2. Municipal wastewater and derivatives (other than sludge) also referred to as 'Fats Oil and Greases' (FOGs)

	Category	Indicator (Pointing to High Risk)	Low Risk	Medium Risk	High Risk	Not Applicable
Elements incentivising fraud (Primary risk indicators)	Physical Characteristics	1. The physico-chemical properties of the feedstock and its derivatives are difficult to distinguish from other feedstocks	FOGs extracted from sewers are a highly degraded and contaminated material. They will have a distinct physico-chemical profile, including significant share of long chain free fatty acids (53% palmitic, 18% oleic), along with significant concentrations of metal ions, such as calcium. They are easy to distinquish from other feedstocks.			
		2. The feedstock can be grown on lands with different properties (e.g. prime farmland vs degraded land) and carries a claim of being grown on incentivized land				Not applicable - FOGs are always a waste and not a direct farm product
		3. Production process may be modified to generate more residue/waste; OR a different material could be altered to appear as this feedstock.	There is no economic incentive for food service establishments or households, to deliberately increase the volume of FOG discharge to the sewers. Mixing with other FOGs such as rapeseed oil or UCO would immediately decrease the value more than waste incentives could justify. There may a risk if mixed with lower quality FOGs such as brown grease.			
	Feedstock Definition	1. The feedstock is not uniformly defined across all	FOGs are not traded globally. (FOGs are typically landfilled.)			

	Characteristics	regions that it is traded				
		2. The classification of a feedstock as a waste, residue or coproduct, varies by country, making it difficult to characterize with certainty	FOGs are assumed to be treated as a waste material in the EU/globally.			
		3. The cellulose to non-cellulose ratio and/or combined yield factor is not known or defined for the feedstock				Not applicable - FOGs do not have these components
Elements enhancing fraud (Amplifiers)	Supply Chain Characteristics	1. The feedstock is traded between a large number of intermediaries and/or globally	FOGs extracted from sewers are traded in very limited volumes (the material is typically landfilled), between few parties, and over relatively short distances. FOGs extracted at a sewage works are likely to be used at on-site AD plants. Trade into the EU will be subject to strict regulations in light of the sanitary risk of the material.			
		2. The feedstock is typically produced in a country or region with weak rule of law.	FOGs are produced globally where sewer systems or waste water treatment plants exist. Production is concentated in/near to large population centres. However it is likely that the use of FOGs will be focussed on in-country sources within the EU.			
	Assurance	1. Feedstocks are not typically segregated in supply chain or are not easily tied to a particular origin.	FOGs are typically segregated in the supply chain, and will be tied to specific PoOs (i.e. sewer systems or sewage plants).			

		2. Conversion technology is not well understood or transparent, and/or does not have typical values for yield/conversion		Pre-treatment steps are more complex than some wastes (e.g. UCO), but not overly complex technology.		
		3. Assurance providers lack specific knowledge/ experience of this feedstock and derivatives		Since FOGs are less common than other feedstocks, auditors may be less prepared to assess.		

F.13. Solid waste

F.13.1. Biogenic Fraction of Municipal Solid Waste and Biowaste

	Category	Indicator	Low Risk	Medium Risk	High Risk	Not Applicable
Elements incentivizing fraud (Primary risk indicators)	Physical Characteristics	1. The physico-chemical properties of the feedstock and its derivatives are difficult to distinguish from other feedstocks		The wide variety of materials present in this category creates inherent risk due to the difficulty in ascertaining exactly what does and does not fit		
		2. The feedstock can be grown on lands with different properties (e.g. prime farmland vs degraded land) and carries a claim of being grown on incentivized land				Not applicable
		3. A different material could be altered to appear as this feedstock		The wide variety of materials present in this category means that other materials could potentially be altered or mislabeled to pose as these feedstocks		
	Feedstock Definition Characteristics	1. The feedstock is not uniformly defined across all regions that it is traded		The complexity of EU waste classification could lead to confusion as to which materials fall under this definition, creating opportunities to exploit that uncertainty through mislabeling		
		2. The classification of a feedstock as a waste, residue or coproduct, varies by country, making it difficult to characterize with certainty	Despite the complexity, these materials should easily be uniformly considered wastes. There may be some discrepancy between countries in terms of which wastes are incentivized (e.g. animal vs non-animal)			

		3. The cellulose to non-cellulose ratio and/or combined yield factor is not known or defined for the feedstock		Given the mixed, variable nature of this category as a whole, could be challenging to accurately define cellulosic content for subcategories		
Elements enabling fraud (Amplifiers)	**Supply Chain Characteristics**	1. The feedstock is traded between a large number of intermediaries and/or globally	Wet/ heavy materials: Currently touched by very few entities, either directly landfilled or taken to compost or bioenergy facility by contractor or processor	Dry materials: potentially traded across greater distances and between more entities		
		2. The feedstock is typically produced in a country or region with weak rule of law.		Many aquaculture and industrial food processing operations are in countries with weak rule of law		
	Assurance	1. Feedstocks are not typically segregated in supply chain or are not easily tied to a particular origin.	Countries with robust waste segregation schemes will have effectively segregated supply chains	Countries that do not have robust waste segregation schemes will have much more difficulty in keeping particular materials segregated in the supply chain		
		2. Conversion technology is not well understood or transparent, and/or does not have typical values for yield/conversion		Low risk if biowaste being fed to AD for biomethane, but higher risk if pyrolysis or other new tech that has not been available commercially for long		
		3. Assurance providers lack specific knowledge/ experience of this feedstock and derivatives		Assurance providers may not be familiar with the EU nomenclature on biowaste and the specificities of their supply chain and processing		

Annex G – Feedstock definitions and standards (Task 3)

	Feedstock Category	Feedstocks	Technical Specification
1	Agriculture	Intermediate and Cover Crops - Niche or primarily soil-improving cover crops	Food and Agriculture Organization of the United Nations (UN FAO) United States Department of Agriculture - Risk Management Agency
		Intermediate and Cover Crops - Commodity crops (corn, soy, wheat)	United States Department of Agriculture - Economic Research Service
2	Forestry	Other ligno-cellulosic material except saw logs and veneer logs	Solid biofuels - CEN/TC 335 ISO 17225-2:2021, Solid biofuels — Fuel specifications and classes — Part 2: Graded wood pellets
3	Algae/ Microbes	Algae cultivated on land in ponds or photobioreactors	EN 17399:2020
4		Sea algae	EN 17399:2020
5		Cyanobacteria	EN 17399:2020
6	Marginal/Degraded Land	Biomass from degraded lands	FAO Soil Degradation definition
		Biomass from polluted lands	EU Joint Research Centre - Soil Contamination definition
			Not Available
7		Damaged crops	Not Available
8	Harvesting – Agricultural residues	Straw	Not Available
9		Other non-food cellulosic material	Not Available
10	Harvesting – Forestry residues	Biomass fraction of wastes and residues from forestry and forest-based industries - black liquor, brown liquor, fibre sludge, lignin and tall oil	Solid biofuels - CEN/TC 335

		Biomass fraction of wastes and residues from forestry and forest-based industries - bark, branches, pre-commercial thinnings, leaves, needles, tree tops, saw dust, cutter shavings	Solid biofuels - CEN/TC 335
11	Processing residues derived from food/feed	Cereals - Cobs cleaned from kernels of corn	Not Available
		Cereals - Corn dry starch	Not Available
		Cereals - DDGS	Not Available
		Cereals - Technical corn oil (TCO)	Not Available
		Cereals - Starchy effluents	Not Available
		Cereals - Dextrose ultrafiltration retentate, hydrol and raffinate from sugar refining	Not Available
12		Fruits and vegetable residues and waste	Not Available
13		Nut shells	Not Available
		Husks	Not Available
14		Potato pulp	EU Directive 242/2010
		Sugar beet pulp	EU Directive 242/2011
15		Sugar - Bagasse	Not Available
16		Sugar - Final molasses	EU Directive 242/2013
17		Oilseeds - Palm oil mill effluent (POME)	Heuzé V., Tran G., Bastianelli D., Lebas F., 2015. Palm oil mill effluent. Feedipedia, a programme by INRAE, CIRAD, AFZ and FAO.
		Oilseeds - Palm mesocarp	Not Available
		Oilseeds - Empty palm fruit bunches	MS 1408:1997 (P) SPECIFICATION FOR OIL PALM EMPTY FRUIT BUNCH FIBRE
		Oilseeds - Fatty acid distillates (FADs)	Wilfarin DP-1601 - DISTILLED PALM OIL FATTY ACID

		Oilseeds - Olive oil extraction residues (de-oiled pomace)	Not Available
		Oilseeds - Olive oil extraction residues (non de-oiled pomace)	Not Available
		Oilseeds - High oleic sunflower oil extraction residues: FAV and PSK-Keto	Not Available
18		Animal by-products (non-fats) – Category 2 and 3	Regulation (EC) No 1069/2009 of the European Parliament and of the Council of 21 October 2009 laying down health rules as regards animal by-products and derived products not intended for human consumption and repealing Regulation (EC) No 1774/2002 (Animal by-products Regulation) UK Government - Animal by-product categories, site approval, hygiene and disposal
19		Animal fats – Category 1, 2 and 3	Regulation (EC) No 1069/2009 of the European Parliament and of the Council of 21 October 2009 laying down health rules as regards animal by-products and derived products not intended for human consumption and repealing Regulation (EC) No 1774/2002 (Animal by-products Regulation) UK Government - Animal by-product categories, site approval, hygiene and disposal
20		Drinks, distillery and brewing products - Grape marc and wine lees	EU Directive 242/2013
		Drinks, distillery and brewing products - Citrus fruit pulp and peels	EU Directive 242/2013
		Drinks, distillery and brewing products - Distillery heads and tails and fusel oils	Fusel Oil, European Chemicals Agency (ECHA) Database
21		Bakery and Confectionery products	EU Directive 242/2013
22	Processing residues – others	Tall oil pitch	EINECS: 232-304-6
23		Crude glycerine	EINECS: 200-289-5

24		Raw methanol	EINECS: 200-659-6
25		Soapstock and its derivatives	EINECS: 273-179-8
26	Agriculture waste	Animal manure	Not Available
27	Food/feed production waste	Brewers’ Spent Grain (BSG)	EU Directive 242/2013
		Whey Permeate	Milk Trade - EU Trade Association
28	Waste – others	Vinasse	EU Directive 242/2013
29		Thin stillage	Not AVailable
30		Brown grease	Brown grease is an emulsion of vegetable and animal oil, fat, grease, solids and water. It is separated from the wastewater in a grease interceptor (grease trap) from where it can be collected for different purposes. (Alm, Martin, EFPRA)
31		Used Cooking Oil	European Biomass Industry Association - UCO definition
32	Wastewater	Sewage sludge	CEN/TC 308 - CHARACTERIZATION OF SLUDGES
33		Municipal wastewater and derivatives (other than sludge)	CEN/TC 308 - CHARACTERIZATION OF SLUDGES
34	Solid waste	Biogenic Fraction of Municipal Solid Waste and Biowaste	Waste Framework Directive 2008/98/EC

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