Assessment of Grid Connected Hydrogen Production Impact

Part II Implementation Considerations

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ACRONYMS AND ABBREVIATIONS

Acronyms	Description
45V	United States Code [U.S.C.] § 45V, Inflation Reduction Act
AIB	Association of Issuing Bodies
BIL	Bipartisan Infrastructure Law
CAISO	California Independent System Operator
CEBA	Clean Energy Buyers Association
CFE-ATC	Carbon Free Energy Around the Clock
DOE	U.S. Department of Energy
EAC	Energy Attribute Certificate
EIA	Energy Information Administration
EDF	Environmental Defense Fund
EPA	U.S. Environmental Protection Agency
ERCOT	Electric Reliability Council of Texas
ERM	Environmental Resources Management
EU	European Union
FERC	Federal Energy Regulatory Commission
G20	Group of 20
gCO_2/MJ	Grams carbon dioxide per megajoule
GGO	Geaux Green Option
GHG	Greenhouse gas
GREET	Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation
GW	Gigawatt
IRA	Inflation Reduction Act
ISO	Independent System Operator
ISO-NE	Independent System Operator - New England
ITC	Investment Tax Credit
$kg\ CO_2e/kg\ H_2$	Kilograms of carbon dioxide equivalent per kilogram of hydrogen
$kg\ CO_2e/MWh$	Kilograms of carbon dioxide equivalent per megawatt hour

Acronyms	Description
kWh	Kilowatt hour
lb CO_2/MWh	Pounds carbon dioxide per megawatt hour
LCA	Lifecycle analysis
LMP	Locational marginal price
MIRECS	Michigan Renewable Energy Certification System
MISO	Midcontinent Independent System Operator
M-RETS	Midwest Renewable Energy Tracking System
MW	Megawatt
MWh	Megawatt hour
NAR	North America Renewables Registry
NC-RETS	North Carolina Renewable Energy Tracking System
NEPOOL-GIS	New England Power Pool Generation Information System
NREL	National Renewable Energy Laboratory
NYGATS	New York Generation Attribute Tracking System
NYISO	New York Independent System Operator
PJM	Pennsylvania-New Jersey-Maryland Interconnection
PJM-GATS	Pennsylvania-New Jersey-Maryland Generation Attribute Tracking System
PPA	Power purchase agreement
PTC	Production tax credit
RE100	The 100% Renewable Energy Initiative
REC	Renewable energy certificate
RGGI	Regional Greenhouse Gas initiative
RMPA	Rocky Mountain Power Area
RPS	Renewable Portfolio Standards
RTO	Regional Transmission Organization
SPP	Southwest Power Pool
SPSO	Southwest Power Pool South
TCRS	The Congressional Research Service
Treasury	U.S. Secretary of the Treasury
U.S.	United States
WECC	Western Electricity Coordinating Council
WREGIS	Western Renewable Energy Generation Information System

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ABOUT ERM

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EXECUTIVE SUMMARY

This is Part II of a two-part assessment of grid-connected hydrogen production impacts. Part I is a literature review which summarizes key findings from approximately 30 reports about the three pillars of incrementality (also known as additionality), temporality, and deliverability, and recommends potential considerations for the guidance on life cycle greenhouse gas (GHG) emissions accounting for Inflation Reduction Act (IRA) Section 45V ("45V") eligible hydrogen. One of the findings from the literature review is that a framework with strong requirements for the three pillars can avoid material increases in emissions due to hydrogen demand while still providing enough flexibility to support and incentivize development of hydrogen value chains that will continue to be viable post-expiration of the tax credits.

Part II assesses key aspects of the three pillars within a regional context and further explores implementation considerations. It considers targeted flexibilities to address certain stakeholder concerns around the pillars while maintaining the overall integrity of a strong three-pillar framework. It also addresses some considerations which are independent of the pillars and may require clarification from the United States (U.S.) Department of the Treasury ("Treasury") in its rulemaking. Lastly, it discusses how the existing landscape of the electricity grid and the regional differences across the country in generation resource potential and in grid operation should be considered when developing and implementing the 45V guidance framework.

In December 2023, Treasury released its proposed guidance for the 45V Production Tax Credit and at the time of the publication of this this report, final guidance has not been released. Where appropriate, this report comments on the connections between the proposed guidance and the three-pillar framework.

Visit ERM's website to read the full report: https://www.erm.com/assessment-of-grid-connected-hydrogen-production-impacts.

REPORT OVERVIEW

This report aims to inform and support decisions around 45V implementation. Section 1 introduces key assessment principles that can help guide 45V design. These include support for economy-wide decarbonization, efficient investment of capital and taxpayer funds, equitable outcomes across disparate regional conditions, durability of hydrogen production after the tax credit expires, and workable solutions across the value chain. These principles are referenced throughout Section 2, which discusses regional factors influencing hydrogen deployment; Section 3, which outlines several implementation considerations and flexible design options; and Section 4, which assesses the overall suitability of a three-pillar framework.

REGIONAL FACTORS INFLUENCING HYDROGEN DEVELOPMENT

Regions within the U.S. have varying resource quality and opportunity to develop low- and zero-carbon power generation to support electrolysis production. Regions with high-quality wind and solar, particularly those which can leverage the effect of combining those resources to better align clean electricity supply to hydrogen production demand, are likely primary candidates for early development of electrolysis. Regional demand strength will also determine early uptake regions for establishing electrolytic hydrogen markets. While these regional differences in resources, market structures, and demand present challenges to uniform development of hydrogen value chains, effective well-designed hydrogen tax credit guidance from Treasury can enable optimal regional solutions across all hydrogen pathways. Appropriate incentives promote robust regional value chains that are more likely to endure past the expiration of the 45V tax credit. Although certain regions may not be conducive environments for early adoption of electrolysis, these regions may leverage alternative resources for low-carbon hydrogen production through other pathways, and electrolysis may become more feasible in the future once capital costs decline and the market is further established.

IMPLEMENTATION CONSIDERATIONS

Regional context also impacts various implementation considerations of the framework and three pillars that were introduced in Part I and are further discussed in this report. Some implementation considerations directly impact specific pillars, while others impact multiple pillars (albeit to varying degrees) or are unrelated to the pillars but will require additional guidance or clarity from Treasury. The primary pillar or pillars impacted by the implementation areas are indicated in parentheses below, with a more comprehensive table included at the start of Section 3.

GLOBAL VALUE CHAINS (ALL PILLARS)

Global value chains will require sufficient alignment on classification and eligibility requirements across national and regional standards for hydrogen produced from zero- and low-emission technologies. Near-term export demand is an additional opportunity to support hydrogen production while domestic value chains are still in the early stages of development. A strong three pillars framework would be more conducive to international hydrogen trade.

CERTIFICATES (DELIVERABILITY, OTHER NON-PILLAR CONSIDERATIONS)

Demonstrating compliance with the three pillars (or any other form of book-and-claim emissions accounting) will require the use of certificates. Proposed guidance from Treasury affirms the importance of certificates and requires the use and retirement of certificates to represent generation that meets incrementality, temporality, and deliverability requirements, whether they be bundled or unbundled. This report focuses on two main considerations: *sustainability criteria* and mechanisms to avoid *double counting*.

- **Sustainability criteria**. In the U.S., certificate issuance and tracking are driven by state compliance programs and requirements, including generation eligibility criteria such as sustainability requirements for biomass and hydro. This structure extends to the voluntary market. While the core mechanics are consistent, efforts will need to be made to establish overarching guidelines and/or a unified registry system, including ways to address attributes associated with fossil-based generation with carbon capture and storage, biogenic pathways, and fugitive methane.
- **Double counting.** The risk of two entities making a claim on the same volume arises due to various state-specific compliance programs and regulations, including renewable portfolio standards (RPS). Three primary risk areas are disaggregation of attributes, allocation of emission reduction benefits, and application or designation of generation towards RPS, which will be dependent upon the specific language of each standard. Treasury should provide additional clarity to address if and how the requirements may deviate from the GHG Protocol approach to double counting claim rights in the context of compliance programs such as RPS or carbon programs.

MARKET STRUCTURE AND SUPPLY OPTIONS (ALL PILLARS)

Market regulatory structures greatly impact the commercial electricity supply options available for end-users which can meet both volume and framework requirements. The stronger the requirements in the 45V framework, the more impactful the regulatory and electricity market structures will be on the availability and ease of transacting supply options which meet the criteria.

- The primary consideration is the existence of a competitive wholesale market that can enable financial power purchase agreements (PPAs). An even wider range of commercial options, including physical PPAs, are available in regions with fully competitive retail markets. Additionally, wholesale market regions tend to have existing systems for certificate tracking and curtailment data collection. Finally, compared to vertically integrated regions, market environments affect power plant economics and retirement decisions differently in ways that may impact tax credit eligibility.
- In regions with neither competitive wholesale nor retail markets, electricity supply options and power plant additions and retirements are determined more by local utility offerings. While many utilities are increasing options for customers to secure access to renewable electricity supplies, such as voluntary tariff programs, these vary in quantity, access, and structure, and currently may or may not be sufficient to meet the needs of hydrogen producers. This will likely evolve as utilities strive to participate in the hydrogen value chain, including as potential fuel buyers. Treasury guidance can help advance continued progress on structured customer offerings to meet evolving needs.

EMISSIONS CALCULATIONS AND APPLICATION OF TAX CREDIT TIERS (TEMPORALITY)

Emissions calculations are directly dependent upon the temporality of the data sources used to determine alignment of electricity usage and associated emissions with that of hydrogen production. The proposed guidance is not definitive on the methodology for determining the weighted average emissions intensity of electricity (e.g., where and when marginal emissions may be used). Several key issues warrant consideration:

- A Scope 2 attribute-based approach (i.e., one based on absolute emissions) is more consistent with specific end-user accountability for electricity procurement and more manageable regarding data management and validation than a marginal emissions approach. Treasury should consider ensuring that the GREET 45VH2 model allows for user inputs that reflect a Scope 2 attribute-based approach.
- There are options for retaining the integrity of a strong temporality requirement while providing a degree of operational flexibility, such as allowing a small buffer volume which could be met with unbundled attribute credits that do not meet the three pillars.
- Providing special allowances to legacy facilities would prolong the emissions impact introduced from a temporarily lax temporality requirement, as generation from such facilities would lock in higher emissions impacts from early hydrogen producers for a longer duration.

EXPANDED OPTIONS FOR INCREMENTALITY ELIGIBILITY

The incrementality pillar – the expectation that new low-carbon energy satisfies new hydrogen demand – has various interpretations depending on the context. In the case of 45V framework guidance, and in this report, it is defined more broadly than in other contexts such as RPS. Here incrementality is defined as new generation proximate in time to the hydrogen production (e.g., operational start date within 36 months), as well as generation which would otherwise not have existed but was enabled by demand from hydrogen production, such as capacity under threat of retirement or curtailed generation. This latter category has the same net impact as adding new generation to meet incremental new hydrogen demand and avoid increased grid emissions. However, any such provisions must be narrow, targeted and/or beneficial from a net emissions perspective. Several key implementation considerations warrant consideration:

- Nearly half of existing U.S. nuclear capacity is scheduled for license expiration by 2030. Access to hydrogen-based demand could open access to new markets to provide financial support and justification to avoid early retirements and/or extend operations for those at risk. Existing programs can provide frameworks for demonstration of need.
- The incrementality impact of additional new clean generating resources stands to diminish once the grid reaches sufficiently high levels of decarbonization, which is why the European Union (EU) has included exceptions for areas with high renewable penetration rates (e.g., >90 percent). Given the range of resource quality, few regions in the U.S. are likely to achieve the same levels of renewable penetration in the near future; however, emissions intensity thresholds that also account for the impact of nuclear generation have greater potential to be reached.
- Well-designed state or regional emission cap programs can limit potential consequential emissions growth from hydrogen production, but this is dependent upon the integrity of program design, including how potential leakage concerns are addressed.
- Curtailment volumes in the U.S. are more likely to be meaningful in the long term when electrolyzer costs decrease sufficiently to become economic operating at lower utilization

factors, and therefore have spare capacity to take advantage of hours with surplus generation. Validation of these volumes will be challenging outside of grid-mandated hourly signals. Due to the real-time nature of curtailment, it is also best suited to be paired with hourly temporal matching, which also becomes a market signal on which type of supply and grid solutions are most beneficial to optimize the system and investments.

DEMONSTRATION OF DELIVERABILITY (DELIVERABILITY)

The deliverability pillar is important to ensuring electricity supply and hydrogen production demand are physically connected via the electrical grid. Transmission constraints limit generation flow. This has a compounding effect on the ability for clean generation to supply hydrogen production the farther the designated electricity supply is physically on the grid from the hydrogen production. Constraints are the primary justification for a deliverability requirement and how the deliverability boundaries are defined to meet the objective of the pillar. Perhaps in light of this fact, Treasury’s proposed guidance adopts the geographic regions used in the U.S. Department of Energy’s (DOE's) *National Transmission Needs Study.* In this area, several implementation considerations warrant consideration:

- Investment in grid infrastructure (including transmission build out) is required to address existing constraints and support renewables growth to meet increased demand from decarbonization efforts including hydrogen production as highlighted by the *National Transmission Needs Study*. As transmission builds out and constraints are sufficiently resolved, deliverability regions should be periodically assessed to determine if these regions can be expanded.
- Electricity may be transmitted or "wheeled" between different regions. One example of satisfying the deliverability requirement is to permit wheeling of electricity along with attributes between regions, which could be demonstrated through transmission capacity rights. The relationship between the grid market prices at the generation source and hydrogen production could be considered as a modeling methodology or proxy.

ASSESSMENT OF A STRONG PILLARS-BASED FRAMEWORK

In light of the considerations above, the example below illustrates the potential design elements of a strong pillars-based framework (many of which are reflected in the proposed guidance from Treasury), and assesses it against the key principles, all of which are discussed further in this report.

In the assessment that follows, what emerges is how the various elements reinforce and enhance the efficacy of each other. Most notably, incrementality underpins temporality and deliverability. Without incrementality measures, temporality and deliverability measures alone would be challenged to safeguard against emission increases. In the case of no incrementality combined with lax temporality or deliverability requirements, electrolysis production would likely lead to notable net increases in grid emissions, contravening the spirit of the IRA. This speaks to synergy within the framework and the necessity of all three pillars supporting each other.

Example Strong Pillars-Based Framework (underlined elements represent new ideas presented in this report while the rest represent elements in Treasury proposed guidance)

1. **Incrementality:** Clean energy source placed in service no more than 36 months before the electrolyzer claiming the generated clean electricity
   - Can include direct connection, PPAs or equivalent utility program, or hourly matched energy attribute certificates (EACs) from generators that meet the same requirements
   - Can apply the 80/20 rule for renewable facility repowering
   - Can include uprates and resources that would otherwise be curtailed
   - Consider including resources that would otherwise be retired (e.g., nuclear) subject to demonstrated need beyond existing subsidies
   - Consider exceptions for deliverability regions with high renewables penetration (e.g., >90 percent), low grid carbon intensity, and/or states with emissions caps
2. **Temporality**: Clean electricity supply matched on an hourly basis by 2028
   - No legacy (a.k.a. grandfathering) of facilities
   - Consider potential buffer approaches to provide reasonable operational flexibility (e.g., small buffer volume for non-hourly-aligned, unbundled certificates)
3. **Deliverability**: Clean energy source procured from same region as defined by either eGRID boundaries or the *National Transmission Needs Study*
   - Ability to wheel from adjacent regions (e.g., based on transmission capacity rights or LMP differential)
   - Consider periodic updates to boundaries to reflect changing transmission constraints
4. **Calculation Methodology:** The calculation methodology should be Scope 2 attribute-based with electricity supply volumes accounting for transmission / distribution system losses

INCREMENTALITY ASSESSMENT

Strong incrementality requirements carry the opportunity for increased and efficient development and deployment of renewables within the grid and support continued grid decarbonization, including incentives for transmission solutions. This is a strong positive externality which connects the development of resource capacity and deployment of low-carbon generation sources with the deployment of low-carbon hydrogen, tying together establishment of the low-carbon hydrogen economy with the increased penetration of renewables in the grid.

TEMPORALITY ASSESSMENT

Strong temporality requirements in the form of hourly matching, paired with incrementality, create demand support for optimal grid solutions and system-wide investments, including efficient deployment of energy generation tax credits and further development of flexible electrolysis technologies. This includes other forms of grid management solutions by highlighting periods of low renewable generation as well as periods of high renewable generation, which can encourage more efficient use of curtailment volumes.

There has been much discussion on the potential cost impacts of a strong temporality requirement, specifically hourly matching, with varying views on the magnitude of this impact. The actual net cost effect will be dependent upon a variety of factors which become very location-specific and even project-specific, but which may be balanced by reduced market exposure through higher alignment of supply and demand. While commercial options for procuring high hourly matched electricity supply may be more prevalent for those located in competitive markets versus regulated markets, utilities are continually expanding their green tariff offerings. Temporality may be an opportunity to structure supply options which better meet the emissions tracking and reporting needs of end-users beyond hydrogen. This demand signal will indirectly support the continued evolution of the use and application of market-based mechanisms in the electricity market and robust emissions accounting through improved data management, including development of centralized certificate tracking and residual emissions reference resources.

DELIVERABILITY ASSESSMENT

By requiring low-carbon electricity for electrolysis production be both local and matched, deliverability and temporality drive the focus on leveraging local resources for the establishment of regional low-carbon hydrogen economies. This supports the DOE's goals for a hydrogen strategy, which underscores the development of regional networks of low-carbon hydrogen production. It also presents the opportunity to advance a diverse set of decarbonization solutions, as each region will develop and deploy a specialized toolkit tailored to the region’s specific available resource, whether that be high-quality low-carbon generation or abundant gas and sequestration.

VALUE CHAIN IMPACT ASSESSMENT

With strong requirements for all three pillars, there will be no need to transition from an initial state of non-optimized emissions reductions to a truly low-carbon hydrogen economy. Some of the challenges that come with a strong three pillar framework can be mitigated or managed in the short term with expanded eligibility and flexibility options, while others present the opportunity and incentive to support longer term goals. This diversity can be an opportunity to drive efficiency through leveraging local resources to enable and support the development of a range of hydrogen pathways, while setting precedent which enables broader progress across the energy sector and promotes efficient investment. By taking advantage of regional factors, the framework could facilitate the foundation of robust value chains which endure past the expiration of the tax credit.

Strong requirements will also support global value chains. The Group of 20 (G20) New Delhi Leaders’ Declaration from September 2023 laid out voluntary principles for sustainable hydrogen value chains. In particular, the declaration clarified the mutual ambition for a globally harmonized approach to classification requirements for hydrogen produced from zero and low-emission technologies. This ambition is most relevant as it pertains to aligning with or exceeding international market requirements such as those in the EU. Strong 45V framework guidance will fulfill this ambition for a transparent global approach, mitigate the perception of green-washing, and position U.S. hydrogen producers and end-users for success in global value chains.

Furthermore, the guidelines for 45V will provide guidance and a precedent which future tax credits, policies, or regulations may reference. In this manner, the 45V production tax credit (PTC) could be expected to continue to influence future hydrogen-related decarbonization initiatives, as well as other regulations relating to low-carbon grid-connect production, even after the expiry of the tax credit itself. 45V guidance represents an opportunity to set a strong precedent and establish principles that will influence future measures.

1. INTRODUCTION

The Inflation Reduction Act (IRA) section 45V ("45V") production tax credit (PTC), presents the opportunity to enable and accelerate the deployment of low-carbon hydrogen production, which has the potential to contribute to the decarbonization of fuel supplies. The value of the tiered tax credit depends on hydrogen lifecycle greenhouse gas (GHG) emissions rates. Three key pillars influence hydrogen lifecycle GHG accounting and the associated electricity required for production: incrementality, deliverability, and temporality. A framework with strong requirements for the three pillars can avoid material increases in emissions due to hydrogen demand, while still providing enough flexibility to support hydrogen deployment and incentivize development of hydrogen value chains that will continue to be viable post-expiration of the tax credits. Part I of this two-part report conducted a literature review to compile key findings about these pillars and initial considerations for implementation.

As Part II, this report builds on the findings from Part I and provides further discussion on the implications of the three pillars and the related impacts on potential implementation guidance. It considers targeted flexibilities to address certain stakeholder concerns around the pillars while maintaining the overall integrity of emissions impacts from a strong three-pillars framework. In addition to evaluating the key considerations, the report presents the regional context that will affect the deployment of hydrogen markets. Based on these factors, the report outlines a pillars-based implementation framework for the 45V PTC that is meant to ensure the intended levels of emissions reductions, while supporting increased growth of hydrogen production value chains.

1.1 ASSESSMENT PRINCIPLES

For the purposes of this report, specific principles were derived to reflect the criteria associated with the three pillars and influence the assessment of the implementation framework. These principles represent critical factors for success and include the following:

- **Progress toward economy-wide decarbonization.** Hydrogen is expected to play a key role in achieving this goal, particularly for hard-to-decarbonize sectors. However, grid emissions today remain a significant contributor to economy-wide emissions. For this reason, 45V implementation design must consider the cause-and-effect dynamics of the full energy system.
- **Efficient investment of capital and taxpayer funds.** As with all tax programs, the 45V program design and implementation should be held to high standards regarding efficient utilization of taxpayer funds and incentives for capital investment.
- **Equitable outcomes across disparate regional conditions.** The U.S. contains a diverse landscape of resources, demand, and regulatory and market structures, which make the design and implementation of the 45V framework challenging. Design and implementation should plan to manage these differences over the life of the tax credit while also acknowledging the influence they will have on the long-term viability of regional hydrogen pathways.

- **Durability.** The 45V tax credit will eventually sunset. A robust design and implementation will lay the foundation for robust value chains that endure past the expiration of the tax credit.
- **Workability.** Successful 45V design and implementation will provide workable solutions for the various actors in the hydrogen value chain and will also account for foundational considerations such as data availability.

These assessment principles provide the context for this report and contribute to the implementation framework that integrates the three pillars related to hydrogen production.

2. REGIONAL CONTEXT

Since diverse environments across the United States (U.S.) offer varying favorability for low-carbon hydrogen production, the finalized guidance on lifecycle emissions accounting for the 45V PTC will directly influence regional deployment of hydrogen. The guidance will be applicable to all hydrogen production pathways, and reflecting regional considerations, the U.S. Secretary of the Treasury's (Treasury's) proposed guidance seeks comments on, for example, fossil fuel-powered generation and biomass-powered generation with or without carbon capture and storage. However, this section's regional discussion and commentary on supply will be primarily from the perspective of electrolysis.

While certain regions will likely be early adopters of electrolytic hydrogen, it may be more advantageous for other regions to wait for the development of hydrogen markets and the establishment of value chains and diversified end-uses. Then, electrolysis production may become more feasible for these second-stage adoption regions, which may also be better suited for alternative primary hydrogen production pathway options. To a degree, there is a spectrum of how material each pillar and specific guideline will be for each region.

2.1 LOW-CARBON GENERATION RESOURCES

The U.S. Department of Energy (DOE) National Clean Hydrogen Strategy and Roadmap focuses on regional networks as one of the priority strategies for establishing and expanding a clean hydrogen market within the U.S.[1] The exact combination of supply by generation source and demand by end-use which could support the establishment of robust low-carbon hydrogen markets will look different across this regional landscape. A fundamental element of this strategy is leveraging regional resources and feedstocks, which depend heavily on the availability and quality of low-carbon generation sources in the local grid. Different regions of the U.S. have varying potentials for development of high-quality low-carbon generation sources that will shape the deployment of electrolysis in these regions. The maps below illustrate the resource quality for wind and solar, as well as the National Renewable Energy Laboratory's (NREL's) analysis for hydrogen potential from renewables (inclusive of biomass into steam methane reforming), accounting for land-use and environmental exclusions such as national parks.[2,3] NREL also indicates the proximity to nuclear power plants, which can significantly contribute to lower grid intensity. Enlarged versions of Figure 1 and Figure 2 are included in Appendix A.[4,5]

[1] DOE (U.S. Department of Energy). 2023. "*U.S. National Clean Strategy and Roadmap*." https://www.hydrogen.energy.gov/pdfs/us-national-clean-hydrogen-strategy-roadmap.pdf
[2] DOE (U.S. Department of Energy). 2023. "*U.S. National Clean Hydrogen Strategy and Roadmap.*" https://www.hydrogen.energy.gov/clean-hydrogen-strategy-roadmap.html
[3] DOE (U.S. Department of Energy). 2023. "*U.S. National Clean Hydrogen Strategy and Roadmap*." https://www.hydrogen.energy.gov/clean-hydrogen-strategy-roadmap.html
[4] Global Wind Atlas 3.0 by the Technical University of Denmark (DTU). 2023. "*IEC Class II capacity factor energy wind layer.*" https://globalwindatlas.info.
[5] Global Solar Atlas 2.0. 2023. "*Photovoltaic power output of a fixed-axis system measured in kWh/kWp, which is reflective of annual capacity factors*." https://globalsolaratlas.info.

FIGURE 1: WIND RESOURCE BY ANNUAL CAPACITY FACTORS

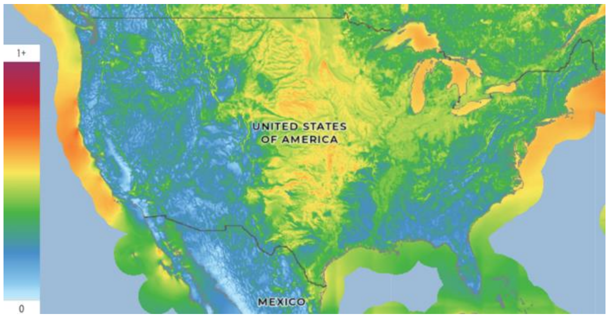


FIGURE 2: SOLAR RESOURCE BY ANNUAL CAPACITY FACTORS

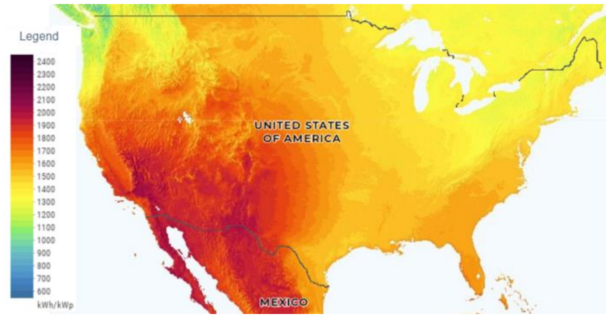


FIGURE 3: NREL HYDROGEN POTENTIAL FROM VARIOUS RENEWABLE RESOURCES

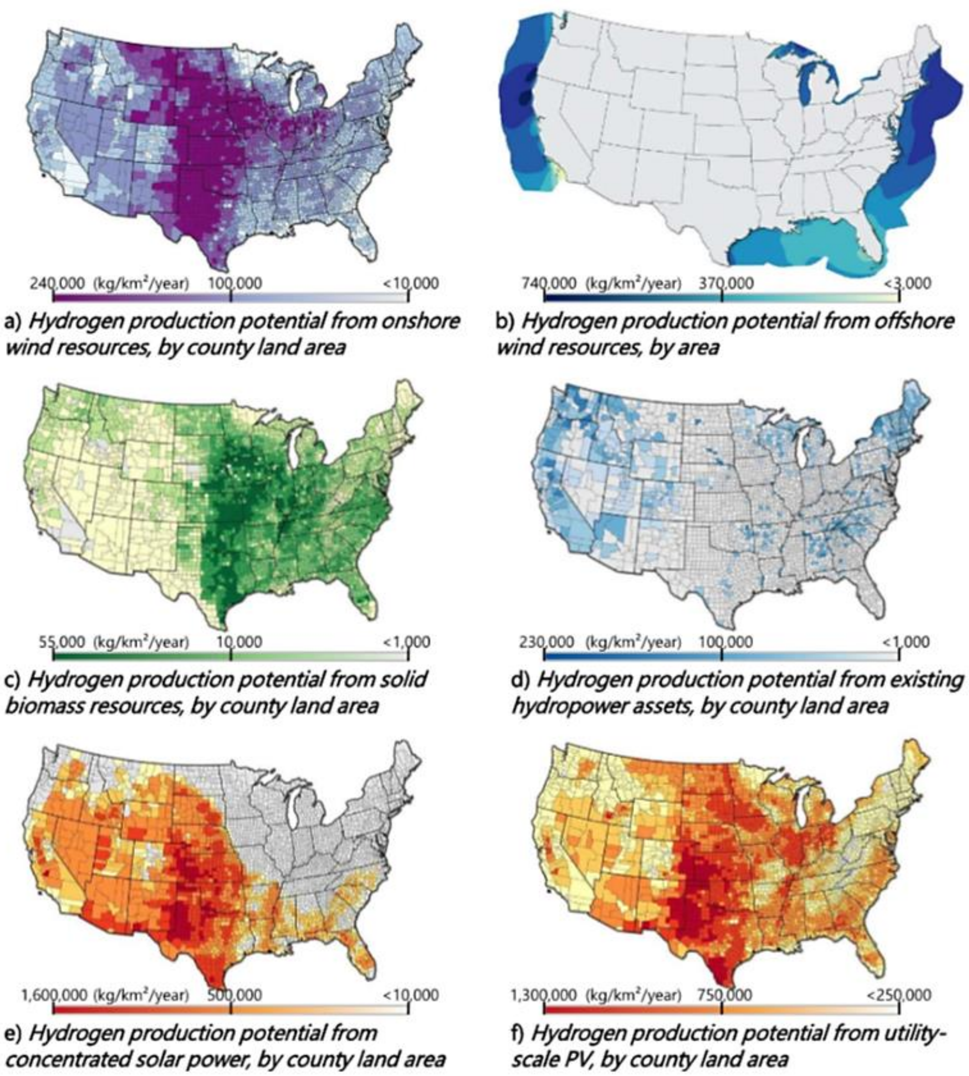
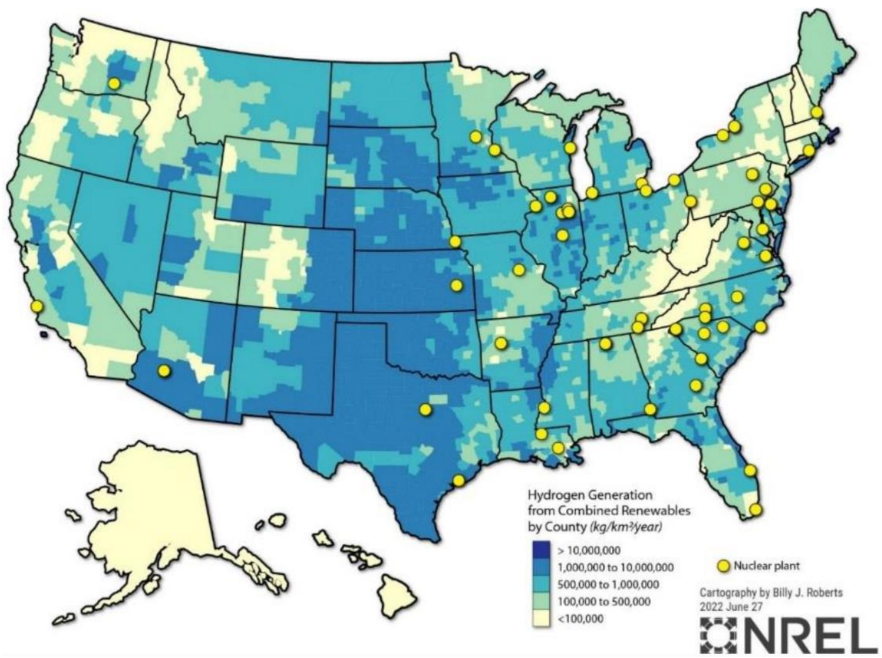


FIGURE 4: NREL HYDROGEN POTENTIAL FROM RENEWABLES RELATIVE TO EXISTING NUCLEAR PLANT LOCATIONS

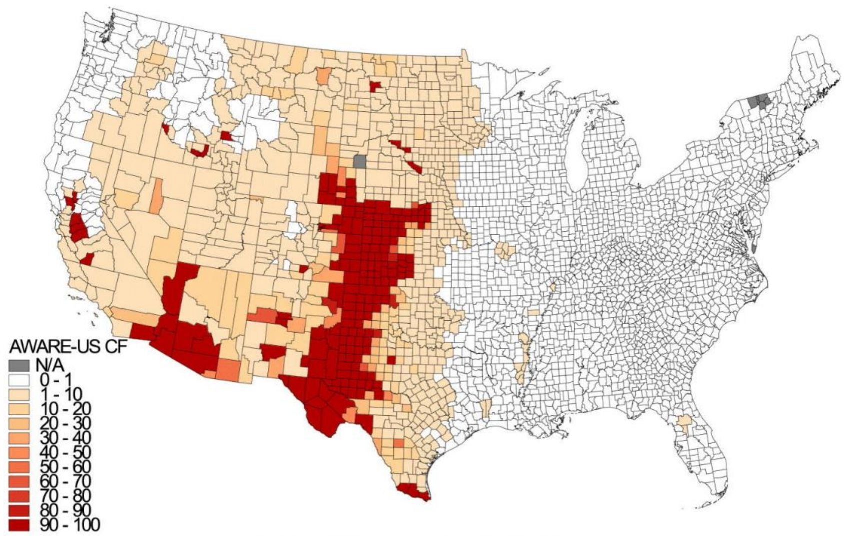


2.2 WATER, CARBON CAPTURE, AND NATURAL GAS

Availability of additional resources may impact the deployment of hydrogen production across the U.S. Aside from electricity, the other primary feedstock for electrolysis production is water. Although the demand for fresh water created by deployment of electrolysis in a region will be fractional compared to other demands for fresh water and overall fresh water usage, water could still represent a limiting factor for electrolysis production in regions where access to water is constrained. Figure 5 outlines areas with higher-than-average water stress levels, represented in red.[6] Areas with high levels of water stress include Southern California, parts of Arizona, New Mexico, Western Texas, and Southern Greater Plains. Potential electrolysis producers in these regions will need to consider the acquisition of adequate water resources along with low-carbon electricity when planning for electrolyzer installation.

[6] Connelly E., A. Milbrandt , M. Penev et al. 2020. "*Resource Assessment for Hydrogen Production." NREL.* https://www.nrel.gov/docs/fy20osti/77198.pdf

FIGURE 5: WATER STRESS LEVELS IN THE UNITED STATES

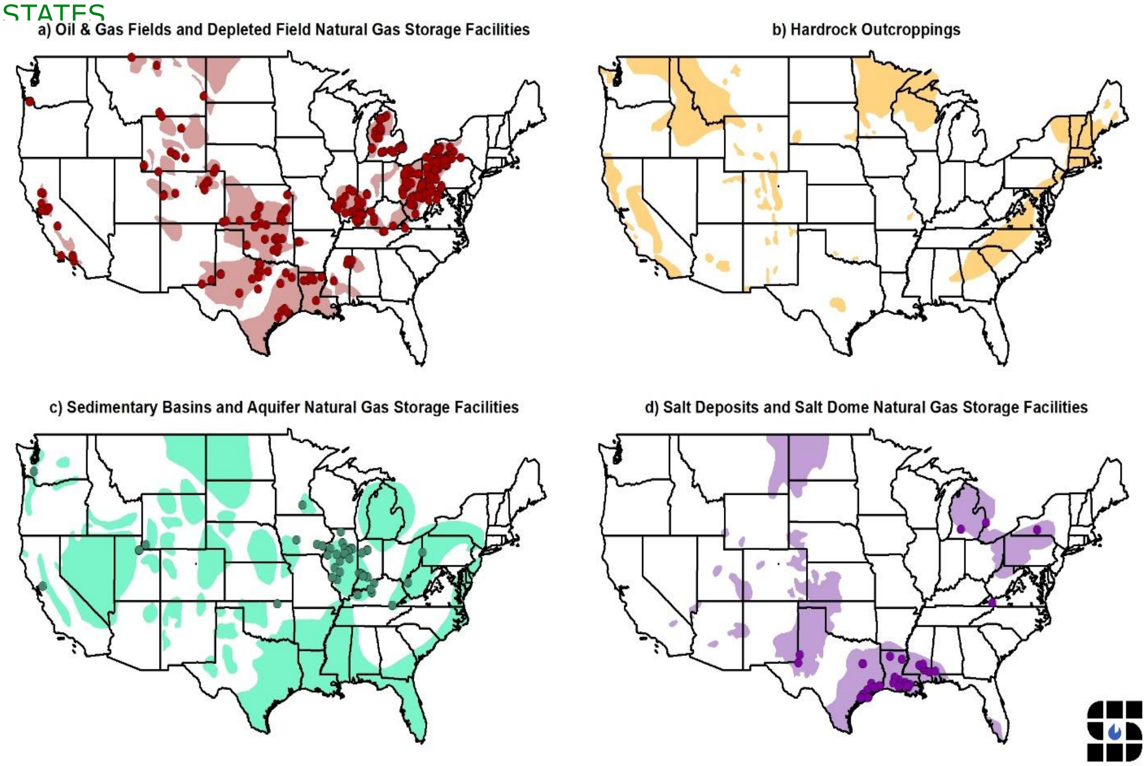


AWARE-US characterization factors by county

Characterization factors <1 (shown in white) represent water stress levels lower than the U.S. average, while factors >1 (shown in shades of red) represent higher than average water stress levels. Source: Lee et al. 2019, Figure 2(a).

Although this report focuses on regional and implementation considerations associated with electrolysis, there are also alternative pathways for low-carbon hydrogen production, which leverage different regional resources in the U.S. such as natural gas and geologic storage through either steam methane reforming with carbon capture or pyrolysis. All hydrogen production pathways need to be subject to accurate emissions accounting practices to ensure overall emissions reductions. These regions may have other strategic advantages relating to these alternative hydrogen production mechanisms. For example, salt dome caverns located in salt deposits near the point of hydrogen use have historically been used for underground hydrogen storage, along with limited demonstrations of storage in hard rock formations. The DOE suggests additional geologies currently used for natural gas storage could potentially provide storage options for hydrogen – although more research is needed regarding hydrogen leakage potential and other environmental impacts. Regions with potential for geological storage and existing natural gas storage facilities can be seen on Figure 6.

FIGURE 6: NATURAL GAS BASINS AND UNDERGROUND STORAGE IN THE UNITED STATES



2.3 REGIONAL CONSIDERATIONS FOR NEAR-TERM ELECTROLYSIS GROWTH

As described earlier, there are many areas within the U.S. which boast high-growth potential for low-carbon generation development, including solar or onshore and offshore wind. Some areas possess existing zero-carbon generation sources such as nuclear and hydropower, which can be significant contributors to lower grid intensity because of their abilities to operate at higher utilization factors and to be dispatched. The regions that offer both sufficient water resources and significant development opportunities for high-quality low-carbon generation have the greatest potential for early uptake of low-carbon electrolysis production, particularly in regions with proximity to high potential demand. These regions of priority, where quality supply aligns with high potential demand, could see high amounts of electrolysis deployment independent of the strength of released 45V guidelines.

While regions with high resource quality and high potential demand could be early adopters for low-carbon electrolysis, regions with less potential for low-carbon generation development, as well as a lack of demand from hydrogen-related industry, will likely be later players in this space. These regions may not be the focus of low-carbon electrolysis production in the near term but could see deployment of electrolysis at a later point in time. In the medium-to-long term, costs are expected to decline and end-uses for low-carbon hydrogen will likely develop and diversify, which could provide increased opportunity for these regions. Notably, some of the regions that lack quality low-carbon generation resources may be able to leverage other local resources which are more suited to fossil-based low-carbon hydrogen production pathways.

Between the early adopter focus regions and the less accelerated non-focus regions, there are also regions which could be on the margin for significant deployment of electrolysis for various reasons. In some regions, quality resource potential could exist, but lack of local sources of demand may challenge the ability to establish value chains in these early stages of establishing the market. In others, sufficient demand might be present, but quality of resources, including water, might be challenging. Insofar as the 45V guidelines drive eligible electricity generation supply in these marginal regions, the framework could have a notable effect on the extent and pace of electrolyzer deployment.

Brief regional overviews of electricity resources and hydrogen demand potential are included in Appendix A along with modeled projections of electricity fuel mix leveraging the NREL Cambium Midcase Scenario for the U.S. electricity market, and a brief discussion on the range of renewable generation projections for additional NREL Cambium scenarios.[7] Midcase fuel mix projections and ranges of renewable generation projections for other regions not highlighted in Appendix B are included in Appendix C.

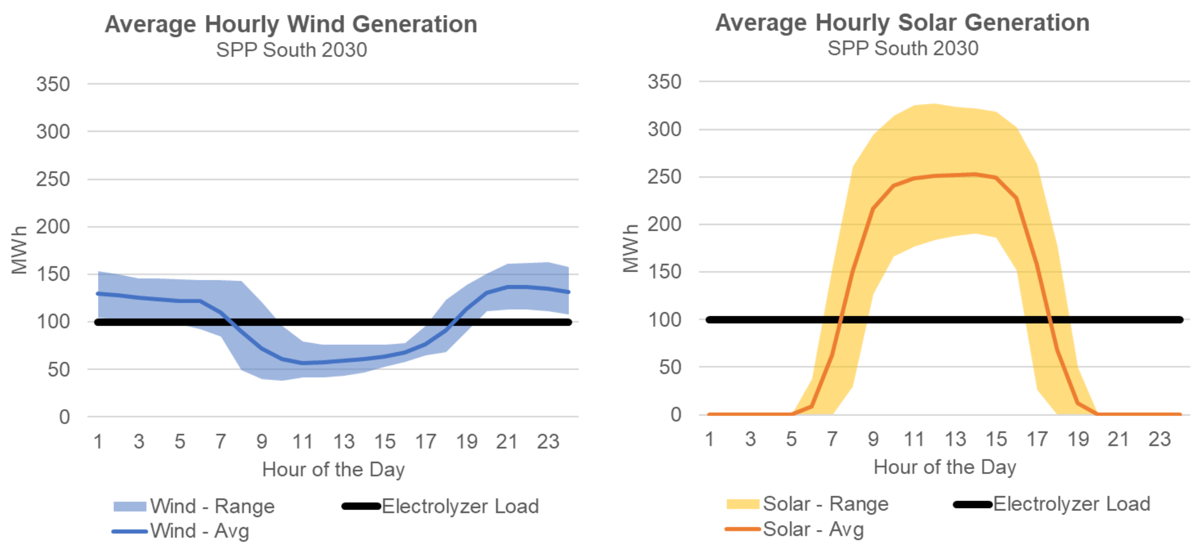
2.4 CAPACITY AND PROFILE MATCHING

In addition to impacting the opportunity for hydrogen production, regional resource quality is also a factor in the ability to reduce market exposure and potentially fulfill stronger temporality requirements. The value efficiency which comes from leveraging local supply resources is a key aspect of the DOE National Clean Hydrogen Strategy and Roadmap. This is particularly relevant to wind and solar resource quality considerations due to their differing generation profiles and impacts to electricity prices and supply costs as increased renewables drive down hourly grid commodity prices. Numerous studies, including those highlighted in Part I of the report, discuss potential impacts to levelized hydrogen costs in hourly versus annual temporal matching. The intent of this discussion is to add context to the topics of capacities, volumes, and exposure to market risk. Regardless of whether emissions are matched annually or hourly, the electricity supply and demand will still need to be balanced in real time. The analysis by Environmental Resources Management, Inc. (ERM) that follows is not a detailed modeling but is for illustrative purposes only, leveraging the NREL Cambium Midcase Scenario for the U.S. electricity market for the given years. It examines annually matched supply sources based solely on wind or solar and how that may compare to an hourly matched combination of wind plus solar.

[7] The Midcase scenario uses central estimates for inputs such as technology costs, fuel prices, demand growth, and that the IRA's clean electricity PTC and ITC are assumed to not phase out. A full description of each scenario can be found in the Cambium 2022 Scenario Descriptions and Documentation. Gagnon, P., B. Cowiestoll, and M. Schwarz. 2023. "*Cambium 2022 Scenario Descriptions and Documentation." NREL.* https://www.nrel.gov/docs/fy23osti/84916.pdf.

The hourly generation profile of wind and particularly solar is at the heart of the temporality discussion. Resource quality impacts the magnitude of the generation profile shape. However, while there may be some regional variation, particularly across seasons, the general average shapes of onshore wind and solar are consistent. Referencing the NREL Cambium Midcase dataset, the following charts on Figure 7 show a 100-megawatt (MW) electrolyzer load compared to average hourly profiles8 for onshore wind and solar generation in the Southwest Power Pool's South Zone (SPP South). This region has both high-quality wind and solar resources. The generation profiles below represent electrolyzer load relative to annual temporally matched generation equivalent to 275 MW of wind and 396 MW of solar.

FIGURE 7: AVERAGE HOURLY GENERATION PROFILES FOR WIND AND SOLAR



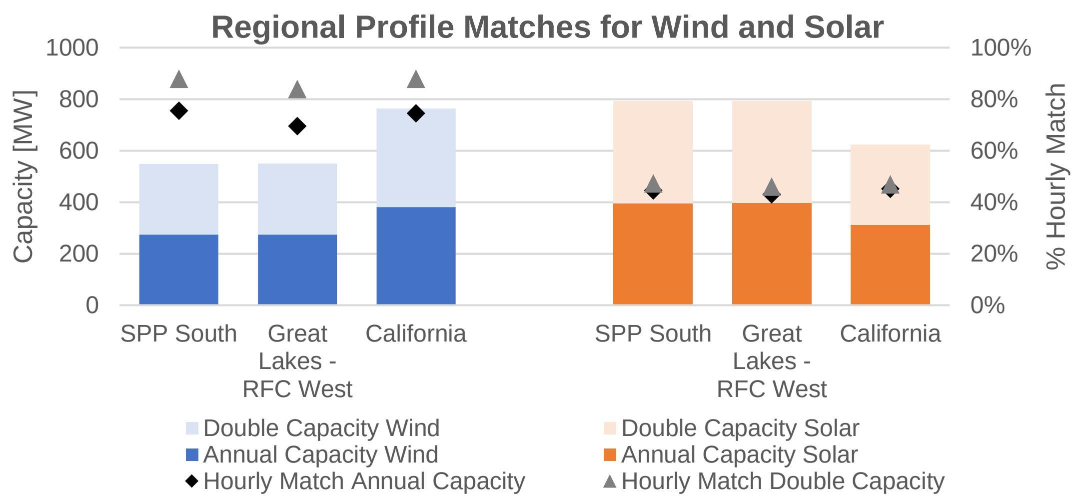
Excluding generation that exceeded the electrolyzer load for every hour, only 76 percent of the hydrogen load was matched with wind generation and 45 percent with solar in the above represented profiles. Doubling the renewable capacity only increased these percentages to 88 percent and 47 percent, respectively. Figure 8 below illustrates the order of magnitude of impact from overbuilding or over procuring capacity9 for wind and solar across three regions. Due to the general profile of wind which can blow during all hours, overbuilding can have a greater impact on hourly matching but is still very limited, and this

[8] Representative hourly generation model profiles for each technology type were derived from the dataset based on the total technology generation and capacity in a given region and year. Note the ranges reflect the seasonal or monthly averages but do not reflect the absolute minimum or maximum across all days for any given hour (i.e., there are hours of zero wind generation).

[9] Overbuilding capacity is defined as building or procuring more renewable capacity than is required for annual matching. The volume for project-specific PPAs tends to be a percentage of capacity which results in a percentage of electricity generated.

increases the amount of generation subject to market risk and curtailment for relatively little gain on the hourly match rate. There is effectively no impact on hourly matching with overbuilding of solar alone as the volume increases are primarily in hours when generation already exceeds the hourly demand.

FIGURE 8: EXAMPLE MODELED CAPACITIES VERSUS PROFILE TEMPORAL MATCH RATES



A combination of wind and solar is the more efficient option with potentially higher, if not more easily attained, hourly match rates for both the end-user and the grid itself.10 The following example using the same SPP South 2030 dataset is not an optimized combination of solar and wind, but illustrates the value of pairing these supply sources for better alignment between the supply and demand profiles, making it easier to achieve higher rates of hourly matched volumes. Wind and solar profiles can complement each other and reduce the amount of capacity investment and volume exposed to the market, including the excess generation supply sold back into the market and the load required to purchase from the market when renewables generation is short. Beyond the cost to an individual end-user, incentivizing better alignment of procured supply profiles to demand profiles also provides increased benefits to the grid by supporting and driving more efficient grid balancing generation investment solutions and continued grid decarbonization.

[10] While it can also result in slight improvements, battery storage is currently more suited to short duration applications and would not have a material impact on the overall order of magnitude of hourly matching rates.

FIGURE 9: EXAMPLE WIND + SOLAR AVERAGE HOURLY GENERATION

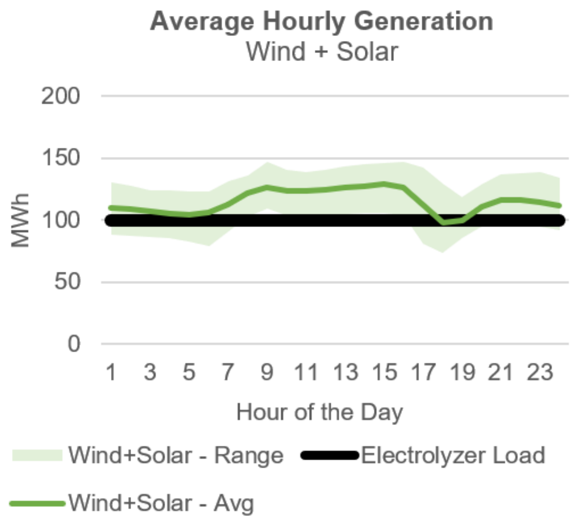
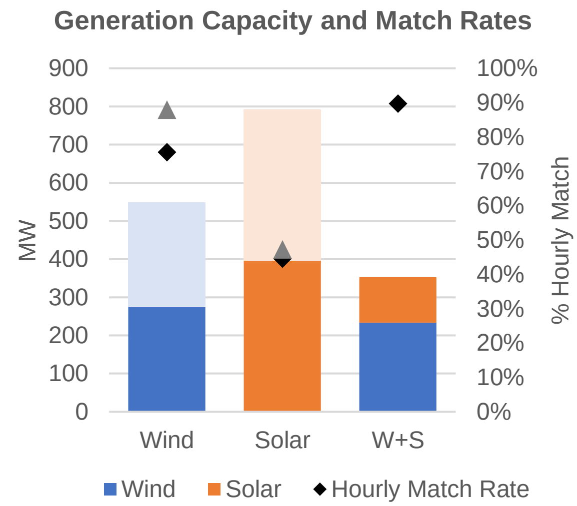


FIGURE 10: IMPACT OF COMBINED GENERATION SOURCES ON CAPACITY AND HOURLY MATCH RATES



3. SECTION 3: IMPLEMENTATION CONSIDERATIONS

Part I of this report introduced several implementation considerations related to eligibility, validation, and general awareness of the various electricity supply aspects that will be explored further in the subsequent sections. While some implementation areas will directly impact specific pillars, others may impact multiple pillars but to varying degrees. Furthermore, some implementation considerations have elements unrelated to the pillars but that may require additional guidance or clarity from Treasury. The table below illustrates where these elements interface with the pillars and beyond, and the following sections explore each element in more detail.

TABLE 1: PILLARS IMPACTED BY IMPLEMENTATION CONSIDERATIONS

Implementation Consideration	Incrementality	Deliverability	Temporality	Other
Global Value Chains	**Primary**	**Primary**	**Primary**	**Primary**
Certificates				
Issuance and Double Counting			Secondary	**Primary**
Tracking	Secondary	**Primary**	Secondary	
Market Structure and Supply Options				
Wholesale and Retail Markets	**Primary**	**Primary**	**Primary**	
Green Tariffs	**Primary**	Secondary	**Primary**	
Emission Calculation Method			**Primary**	
Expanded Incrementality Options				
Nuclear	**Primary**			
Low-Carbon Electricity Grids	**Primary**			
State Emissions Caps	**Primary**	Secondary		
Curtailment	**Primary**		Secondary	
Demonstration of Deliverability	Secondary	**Primary**		
Data Availability and Accessibility	**Primary**	**Primary**	**Primary**	**Primary**

3.1 GLOBAL VALUE CHAINS

Hydrogen and its derivatives, such as ammonia, are positioned to become key decarbonization tools in reaching the international goal of remaining under the global warming threshold of 1.5 degrees Celsius above pre-industrial levels and, therefore, a material part of the global fuel supply and energy value chains. As fuel source emissions validation grows in importance on both a regulatory compliance and voluntary basis, this impact on global fuel supplies necessitates a harmonized approach to hydrogen classification.

Recognizing the importance of a consistent position on hydrogen development globally, the Group of 20 (G20) New Delhi Leaders' Declaration from September 2023 developed voluntary principles that outline guidance for a sustainable hydrogen market. The statement highlighted the support for the "acceleration of production, utilization, as well as the development of transparent and resilient global markets for hydrogen produced from zero and low-emission technologies and its derivatives such as ammonia, by developing voluntary and mutually agreed harmonizing standards as well as mutually recognized and inter-operable certification schemes."[11]

Of most relevance to the 45V framework discussion within the G20 voluntary principles is encouraging collaboration on the development of national standards and working towards a globally harmonized approach to classification requirements for hydrogen produced from zero and low-emission technologies. In turn, this supports the other principles which promote free and fair trade and evolution of global value chains. In the context of the framework, the most direct example of these principles is leveraging export demand to provide further support for the development and growth of domestic U.S. hydrogen production. Near-term export demand is an additional opportunity for commercial and financial backing to underpin hydrogen production facilities while domestic value chains are still in the early stages of development. However, this requires sufficient alignment on classification and eligibility requirements to enable the flexibility required to capture market opportunities, including emerging domestic demand over the life of the hydrogen production asset. While the G20 principles are voluntary, a strong three-pillars framework will be more conducive to international trade.

3.2 CERTIFICATES

Certificates represent the attributes associated with specific volumes of electricity generation. Current GHG accounting standards allow for the use of energy attribute certificates (EACs) such as renewable energy certificates (RECs) to substantiate claims of specific electricity use and its intensity, given that physical energy consumed on a networked electricity grid is indistinguishable by origin and generation source. While certificates may be transacted together with the physical electricity that they represent such as in a power purchase agreement (PPA), they may also be detached or unbundled and transacted separately from the delivery of the associated electricity. Electricity itself may be physically constrained by the grid; however, attributes and certificates theoretically are not, so they are only constrained by the systems in which they exist and the regulations which govern those systems and/or the application of certificates. The proposed guidance requires the use and retirement of certificates to represent generation that meets incrementality, temporality, and deliverability requirements, whether they be bundled or unbundled certificates. The Center for Resource Solutions report on "The Legal Basis for Renewable Energy Certificates" summarizes the nuances associated with attribute certificates and highlights their ties to state law, which "underpins the legal basis of RECs transacted in both [voluntary and compliance] markets." This has also been supported by the Federal Energy Regulatory Commission (FERC), which concluded that unbundled REC transactions are under

[11] G20 New Delhi Leaders' Declaration. 2023. https://www.g20.org/content/dam/gtwenty/gtwenty_new/document/G20-New-Delhi-Leaders-Declaration.pdf.

state jurisdiction. [12] These legal interpretations are in alignment with the proposed guidance.[13]

Certificates were the result of a need to demonstrate compliance with state renewable portfolio standards (RPSs). As such, certificates currently represent the diversity of state-based definitions of energy attributes and eligibility of generation for certificate issuance based on state requirements. While the "core mechanics of how RECs function are remarkably consistent,"[14] the basis in a state-derived versus a federal system is a fundamental difference between the U.S. and the European Union (EU). Efforts will need to be made to establish overarching guidelines and/or a unified registry system to address these variances and ensure consistency in eligibility and certificate use.

3.2.1 CERTIFICATE ISSUANCE AND DOUBLE COUNTING

Certificate details and requirements vary depending on the issuer, energy source, and region as highlighted in the table below.[15] Solar and wind energy resources are the most common certificate type, but other sources can qualify for EACs. The 100% Renewable Energy initiative (RE100) considers energy sourced from wind, solar, geothermal, sustainable biomass, and sustainable hydropower as eligible for RECs. For biomass and hydropower to be considered sustainable, they must meet established criteria with an additional preference for a third-party verification for sustainability. Examples of criteria that can be used to assess sustainability for biomass and hydropower include the Independent Systems Operator (ISO) 13065:2015 (Bioenergy Supply Chain Sustainability Analysis), the Low Impact Hydropower Institute Certification, the Hydropower Sustainability Council's Hydropower Sustainability Standard, or the Green-e® Renewable Energy Standard. For biomass, the Green-e® Renewable Energy Standard includes emissions limits, facility examinations, and regional regulatory compliance.[16] Unlike hydropower and biomass, sustainability criteria and certification of attributes for newer fuel or generation sources such as fossil-based generation with post-combustion carbon capture are less evolved, as indicated by the various related requests for comment within the proposed guidance. This provides an opportunity to evolve methodologies and further advance book-and-claim applications.

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[12] CRS (Center for Resource Solutions). 2023. "*The Legal Basis for Renewable Energy Certificates*." https://resource-solutions.org/wp-content/uploads/2015/07/The-Legal-Basis-for-RECs.pdf.
[13] Proposed Rules. "Section 45V Credit for Production of Clean Hydrogen; Section 48(a)(15) Election To Treat Clean Hydrogen Production Facilities as Energy Property." Federal Register 88:246. December 26, 2023. https://www.govinfo.gov/content/pkg/FR-2023-12-26/pdf/2023-28359.pdf.
[14] CRS (Center for Resource Solutions). 2023. "*The Legal Basis for Renewable Energy Certificates*." https://resource-solutions.org/wp-content/uploads/2015/07/The-Legal-Basis-for-RECs.pdf.
[15] RE 100 The Climate Group. 2022. *"RE 100 Technical Criteria."* https://www.there100.org/sites/re100/files/2022-12/Dec%2012%20-%20RE100%20technical%20criteria%20%2B%20appendices.pdf.
[16] Green-e®. 2023. *Green-e® Renewable Energy Standard for Canada and the United States*. https://www.green-e.org/docs/energy/Green-e%20Standard%20US.pdf.

TABLE 2: GENERATION FUEL TYPES COVERED BY NORTH AMERICA TRACKING SYSTEMS

Tracking System	Geographic Coverage	Resources Tracked
ERCOT	Single state	Solar, Wind, Hydro, Geothermal, Landfill Gas, Wave, Tidal
MIRECS	Single state	Solar, Wind, Hydro, Geothermal, Landfill Gas, Wave, Tidal, Municipal Solid Waste
M-RETS	Multistate	Solar, Wind, Hydro, Nuclear, Landfill Gas, Biomass, Wastes, Renewable Thermal, Alternative Energy
NAR	Multistate	Solar, Wind, Hydro, Biomass
NC-RETS	Single state	Solar, Wind, Hydro, Biomass, Thermal
NEPOOL-GIS	Multistate	Solar, Wind, Hydro, Nuclear, Fossil Fuels, Biomass[17]
NYGATS	Single state	Solar, Wind, Hydro, Geothermal, Tidal, Nuclear, Fossil Fuels
PJM-GATS	Multistate	Solar, Wind, Hydro, Nuclear, Geothermal, Landfill Gas, Biomass, Fossil Fuels
WREGIS	Multistate	Solar, Wind, Hydro, Geothermal, Landfill Gas, Wave, Tidal, Biomass[18]

ERCOT = Electric Reliability Council of Texas; MIRECS = Michigan Renewable Energy Certification System; M-RETS = Midwest Renewable Energy Tracking System; NAR = North American Renewables Registry; NC-RETS = North Carolina Renewable Energy Tracking System; NEPOOL-GIS = New England Power Pool Generation Information System; NYGATS = New York Generation Attribute Tracking System; PJM-GATS = Pennsylvania-New Jersey-Maryland EIS's Generation Attribute Tracking System; WREGIS = Western Renewable Generation Information System

Beyond generation resources, additional certificate types may be issued for specific generations, attributes, or application of certificates based on various specific state programs or regulations. GHG Protocol Scope 2 guidance acknowledges multi-certificate systems and requires "only one instrument (or discrete set of instruments applied all at once) convey attribute claims about the energy type and its GHG emission rate."[19] However, there can still be a risk of double counting, or where multiple entities substantiate a claim with the same megawatt hour (MWh) of generation, particularly with regards to certificates used for compliance. For this reason, RE100 includes a requirement in its technical criteria

[17] Details: "Facilities using biomass fuel shall be low emission, use efficient energy conversion technologies and fuel that is produced by means of sustainable forestry practices." Source: NEPOOL-GIS (New England Power Pool Generation Information System). 2021. *New England Power Pool Generation Information System Operating Rules.* https://view.officeapps.live.com/op/view.aspx?src=https%3A%2F%2Fnepoolgis.com%2Fwp-content%2Fuploads%2Fsites%2F3%2F2020%2F07%2FGIS-Operating-Rules-Effective-7-1-21.doc.doc&wdOrigin=BROWSELINK
[18] Details: "For biomass co-fired with fossil fuels or using fossil fuels for startup or supplemental firing: in each month, the Certificates for each fuel in each Multi-Fuel Generating Unit will be created in proportion to the ratio of the net heat content of each fuel consumed to the net heat content of all fuel consumed in that month, adjusted to reflect differential heat rates for different fuels, if applicable." Source: WECC (Western Electricity Coordinating Council). 2022. *WREGIS Operating Rules*. https://www.wecc.org/Administrative/WREGIS%20Operating%20Rules%20October%202022%20Final.pdf
[19] Greenhouse Gas Protocol. 2023. *GHG Protocol Scope 2 Guidance*. https://ghgprotocol.org/sites/default/files/2023-03/Scope 2 Guidance.pdf

for attribute aggregations, or "ownership of all environmental and social attributes associated with generation, and that none of these attributes have been sold off, transferred, or claimed elsewhere."[20] Green-e® has also outlined what they consider to be specific potential double counting risks and justifications for positions they have taken within their standards on eligibility for their product programs, including applicable requirements.[21] There are three main categories of potential double counting risk areas:

1. **Multiple certificates issued for the same generation,** which can be transacted separately. Examples include Texas Compliance Premium certificates for non-wind generation and Michigan Incentive Renewable Energy Credit, which can be applied to RPS.
2. **Retention of all environmental benefits related to credit allocation of emission reduction benefits** and set-aside provisions governing rules and mechanisms for retiring emissions allowances on behalf of voluntary retail sales. This is applicable to states with emission caps programs including California, Washington, and Regional Greenhouse Gas initiative (RGGI) states (including differing state provisions within RGGI).
3. **Application or designation of specific generation towards RPS, or compliance versus voluntary single-entity claims**. Examples include Hawaii grid-connected generation, Duke Energy owned generation in North Carolina, and Arizona generation in the footprint of those providers subject to the Arizona Renewable Energy Standard and Tariff.

Refer to the Green-e® Renewable Energy Standards for Canada and the U.S. for more detailed information regarding their assessment of the double counting risk in the context of specific state programs and applications. This risk can increase in the case of certificates being retired on behalf of the consumer (either specifically in their name, as the result of participation in a specific program such as a voluntary green tariff, or as a part of a broader customer base), rather than certificates being transferred to and retired directly by a consumer. The intent of this report is not to address each of these specifically; however, it is intended to raise awareness of the potential need for additional clarity in the guidance on addressing potential double counting issues specifically with regard to claim rights in the context of RPS and carbon programs.

3.2.2 TRACKING SYSTEMS

The variety of tracking systems for certificates throughout the U.S. presents another factor to incorporate in an implementation framework, regardless of incrementality or temporality requirements. "With the exception of the North America Renewables Registry (NAR), all of the [existing] tracking system entities were established with the support of the U.S. states,

[20] RE 100 Climate Group & CDP. 2022. *RE100 Technical Criteria.* https://www.there100.org/sites/re100/files/2022-12/Dec 12 - RE100 technical criteria %2B appendices.pdf
[21] Green-e® Energy. 2023. *Green-e® Renewable Energy Standard for Canada and the United States*. https://www.green-e.org/docs/energy/Green-e Standard US.pdf

which have designated specific tracking systems to be used for issuing and tracking certificates and verifying compliance with state policies and programs."[22] Despite most being managed by grid operators, their geographical coverage tends to align with state boundaries and therefore border areas may be slightly misaligned with deliverable regions. For example, the Electric Reliability Council of Texas (ERCOT) manages the certificate tracking for the whole state of Texas versus just the ERCOT ISO.[23] The Western Renewable Energy Generation Information System (WREGIS) covers the whole of the Western Electricity Coordinating Council (WECC) and extends to any state "bisected by the boundaries" of WECC, such as New Mexico. A map of the North America tracking systems is shown on Figure 11.[24] However, unlike the EU, the North America tracking systems do not all interface with one another, thereby limiting the ability to import and export certificates between systems as represented on Figure 12.[25,26,27] As claims associated with attributes represented by certificates are dependent up on the retirement of those certificates,[28] the guidance should also provide additional clarity for whether certificates will be required to be retired within a tracking system aligned with the location of hydrogen production. Development of a centralized governance and management system could provide the necessary incentives to update tracking systems to enable broader imports/exports between systems, particularly between tracking systems which cover areas within the same ISO or balancing area. The larger impact would come from centralized data collection of claimed attributes, which would enable development of comprehensive residual intensity factors that would be used to strengthen Scope 2 emissions reporting more broadly (further discussed later in this section).

[22] CRS (Center for Resource Solutions). 2023. "*The Legal Basis for Renewable Energy Certificates*." https://resource-solutions.org/wp-content/uploads/2015/07/The-Legal-Basis-for-RECs.pdf
[23] ERCOT (Electric Reliability Council of Texas). 2023. *Renewable Energy Credit Program*. https://sa.ercot.com/rec/rec-program
[24] CRS (Center for Resource Solutions). 2022. "*Renewable Energy Certificate Tracking Systems in North America*." https://resource-solutions.org/wp-content/uploads/2018/02/Tracking-System-Map.pdf
[25] USEPA (U.S. Environmental Protection Agency). 2015. *EPA Green Power Partnership Webinar on REC Tracking Systems*. https://www.epa.gov/sites/default/files/2016-01/documents/webinar_20150430_fredregill.pdf.
[26] M-RETS (Midwest Renewable Energy Tracking System). 2023. *REC Market.* https://www.mrets.org/registries/.
[27] NEPOOL GIS (New England Power Pool Generation Information System). 2023. *Inter-Registry Transfers, Registries*. https://nepoolgis.com/registries/.
[28] Greenhouse Gas Protocol. 2023. *GHG Protocol Scope 2 Guidance*. https://ghgprotocol.org/sites/default/files/2023-03/Scope 2 Guidance.pdf.

FIGURE 11: NORTH AMERICA TRACKING SYSTEMS

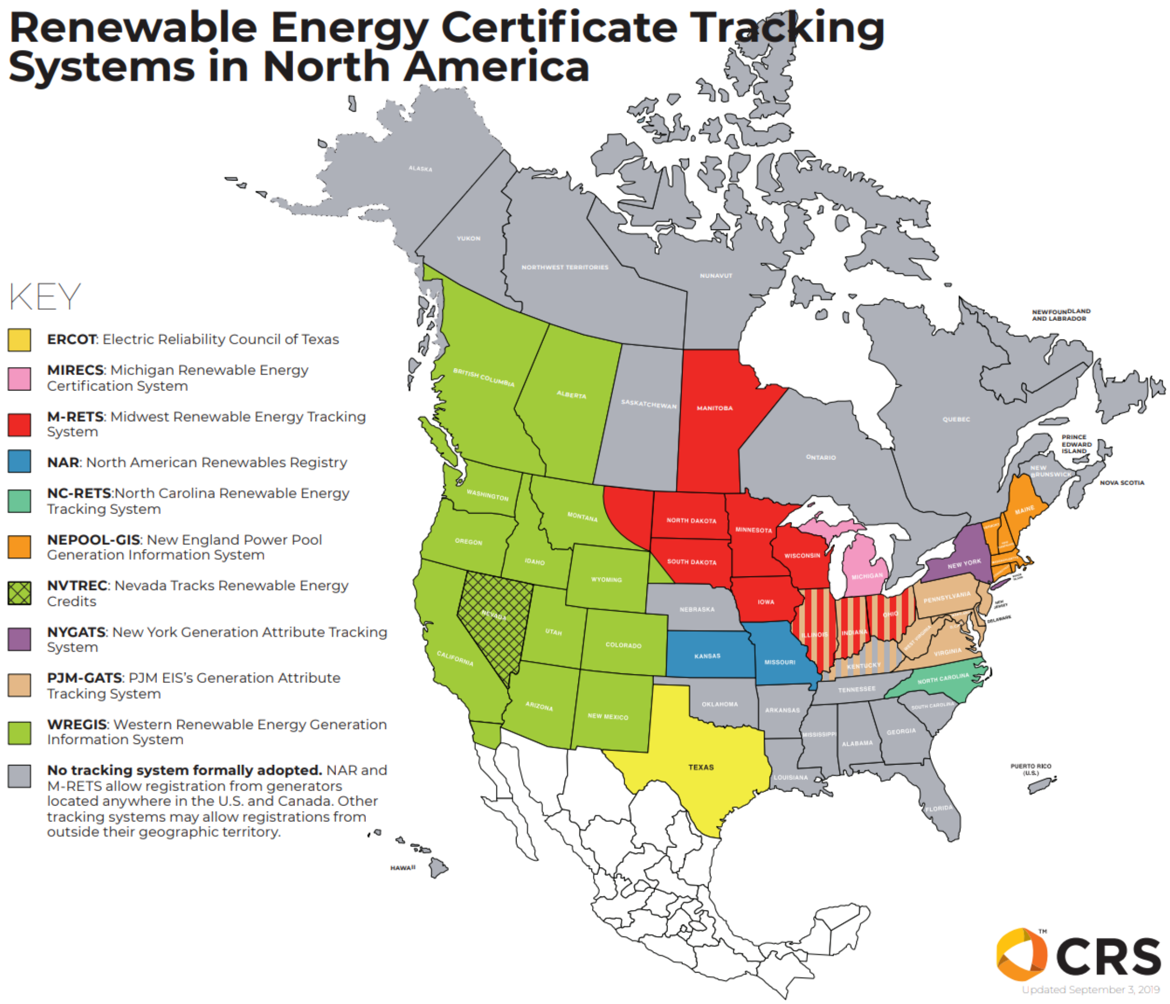
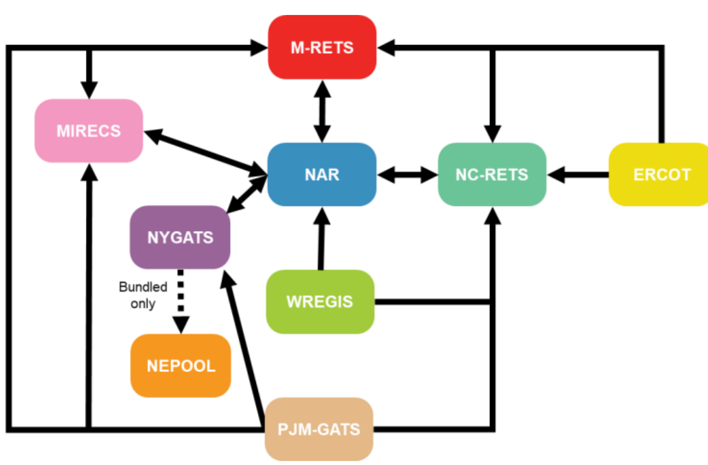


FIGURE 12: TRACKING SYSTEM INTERFACES FOR IMPORTS AND EXPORTS BETWEEN SYSTEMS



3.3 MARKET STRUCTURE AND SUPPLY OPTIONS

In addition to the generation potential and demand dynamics discussed in Section 2 on regional context, market regulatory structures are another important layer of regional context that impacts commercial options for hydrogen producers. Purchasing unbundled EACs on top of standard grid purchases will generally not be economic for hydrogen producers. To realize the lower electricity supply costs which are more reflective of renewable generation levelized costs inclusive of the energy PTC or investment tax credits (ITC), hydrogen producers will need to secure supply options that are more reflective in price to a project specific PPA (inclusive of associated EACs).

Market regulatory structures greatly impact the commercial electricity supply options available for end-users that can meet both volume and framework requirements. The stronger the 45V framework requirements, the more impactful the regulatory and electricity market structures are on supply options and the greater the importance of continuing to evolve the structure of supply offerings.

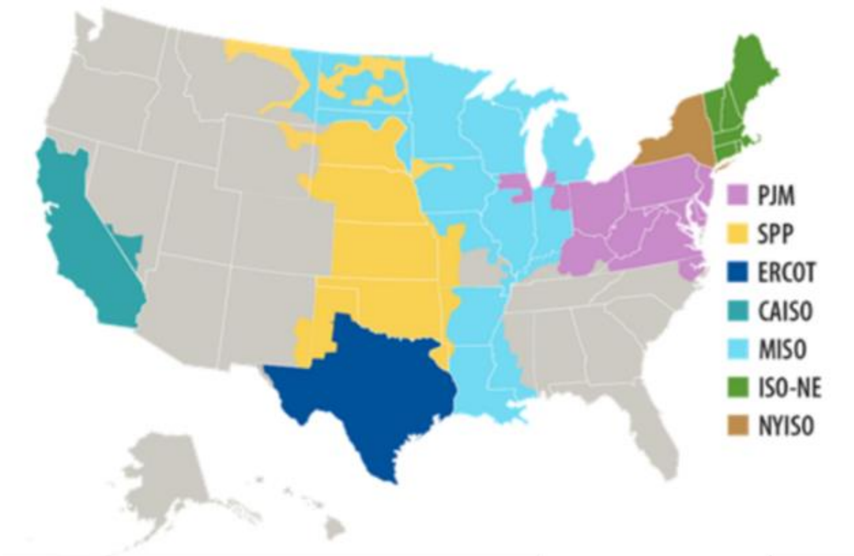
3.3.1 WHOLESALE AND RETAIL MARKETS

Regulatory and operational market structures vary across the country, but there are three primary categories dependent upon the existence of competition in the wholesale market, retail market, and the combination of the two for electricity commodity supply. With a deliverability requirement, this impacts the type of commercial options available to hydrogen producers to source and manage their electricity supply and any bundled EACs. A prime example is the very resource-rich areas of West Texas, western Oklahoma, and eastern New Mexico. While all benefit from high-quality renewables, both wind and solar, the competitive regulatory structure in the ERCOT portion of West Texas versus the regulated retail structure in the SPP covering the other two areas can have a notable impact on what commercial options are available to end-use consumers, reflecting the effective net economics of the electricity supply. Available commercial options are driven by the overlap of the regulatory structures of both the wholesale and retail markets.

The wholesale market involves electricity transactions among generators, utilities, and traders before it is sold to end-use customers. Competitive wholesale markets are managed by ISOs, which also define their geographical boundaries as shown on Figure 13.[29] The regions defined in the National Transmission Needs Study are fairly aligned with the ISO boundaries with the exception of splitting the Midcontinent Independent System Operator (MISO) and the non-ISO portion of the Western Interconnect to better account for interregional transmission constraints.

[29] USEPA and FERC (U.S. Environmental Protection Agency and Federal Energy Regulatory Commission). 2023. *U.S. Electricity Grid & Markets – Structure*. https://www.epa.gov/green-power-markets/us-electricity-grid-markets#structure.

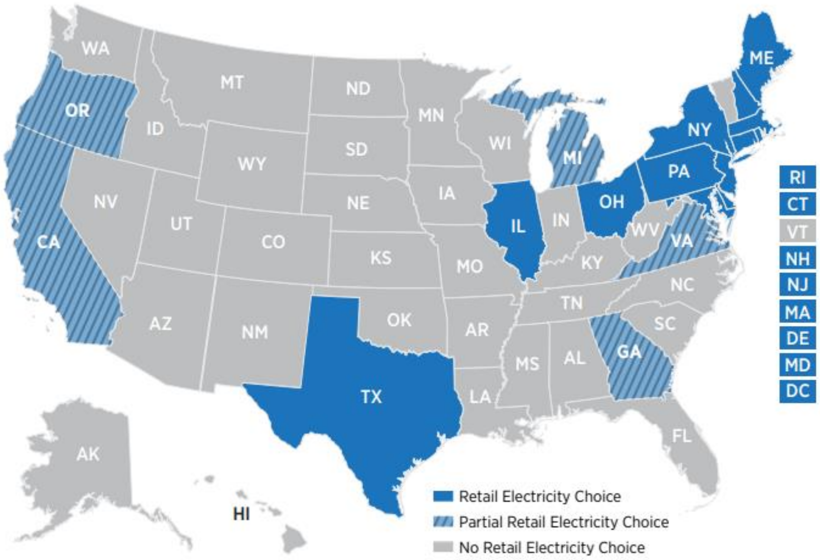
FIGURE 13: COMPETITIVE WHOLESALE MARKETS



The retail market is the sale of electricity to end-use customers and is determined by the states, which define which customer service levels are eligible for competitive retail choice as illustrated on Figure 14.[30.] For example, some states allow residential customers to select their electricity supplier. Others, such as California, only allow specific customers or customer types to engage in competitive retail supply.[31] Although not depicted on the map, Montana has also implemented partial retail choice. Competitive retail supply may not extend to customers located in service territories covered by electrical cooperatives.

[30] NREL (National Renewable Energy Laboratory). 2017. "*An Introduction to Retail Electricity Choice in the United States*." https://www.nrel.gov/docs/fy18osti/68993.pdf.
[31] USEPA and FERC (U.S. Environmental Protection Agency and Federal Energy Regulatory Commission). 2023. *U.S. Electricity Grid & Markets – Structure*. https://www.epa.gov/green-power-markets/us-electricity-grid-markets#structure.

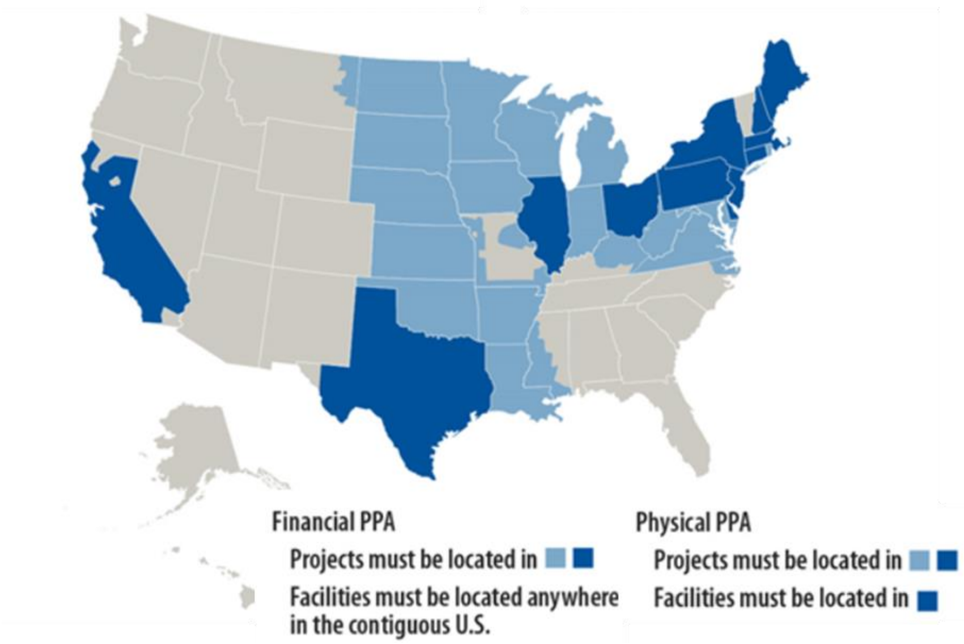
FIGURE 14: STATES WITH COMPETITIVE RETAIL CHOICE



The ability for an end-use customer, such as a hydrogen producer, to access a bilateral project specific PPA requires the project be located in a competitive market. The ability to engage in a physical PPA versus being limited to a financial PPA requires the end-user's facility to also be in an area eligible for competitive retail. Competitive retail markets provide more commercial optionality for sourcing electricity supply. This is illustrated on Figure 15 below.[32]

[32] USEPA and FERC (U.S. Environmental Protection Agency and Federal Energy Regulatory Commission). 2023. *U.S. Electricity Grid & Markets – Structure*. https://www.epa.gov/green-power-markets/us-electricity-grid-markets#structure.

FIGURE 15: ACCESS TO POWER PURCHASE AGREEMENTS



Physical versus financial is related to the delivery of electricity and settlement terms of the contract. Physical PPAs are where the buyer takes delivery of and title to the electricity, and the price is typically based on a single fixed or indexed price. Financial PPAs are where the buyer does not take physical delivery of or title to the electricity itself, and the price is typically a contract-for-differences between the price for a physical PPA and a market index. In either type of contract, attributes associated with the generation need to be specified in the contract, are transferred from the generator to the buyer, and therefore can be applied to electricity supply emissions calculations (subject to any deliverability requirements as applicable for the 45V PTC). The lack of physical delivery of electricity in a financial PPA enables end-users to engage in these types of contracts in the wholesale market. However, financial PPAs are also typically considered a form of derivative and, pending the contract terms, may trigger various financial reporting requirements for the contract parties.

Fully competitive markets, retail and wholesale as shown in the dark blue on the map on Figure 15, provide end-users with the most optionality for sourcing supply, either through engaging a supplier or directly managing it themselves. Markets with competitive wholesale but regulated retail as shown in light blue have similar options with financial PPAs, but the market may not be as competitive or liquid because the ultimate wholesale buyer of the physical electricity is limited to utilities. Fully regulated markets, as shown in grey, are subject to working with their utility on supply options that would most likely be subject to regulatory approval.

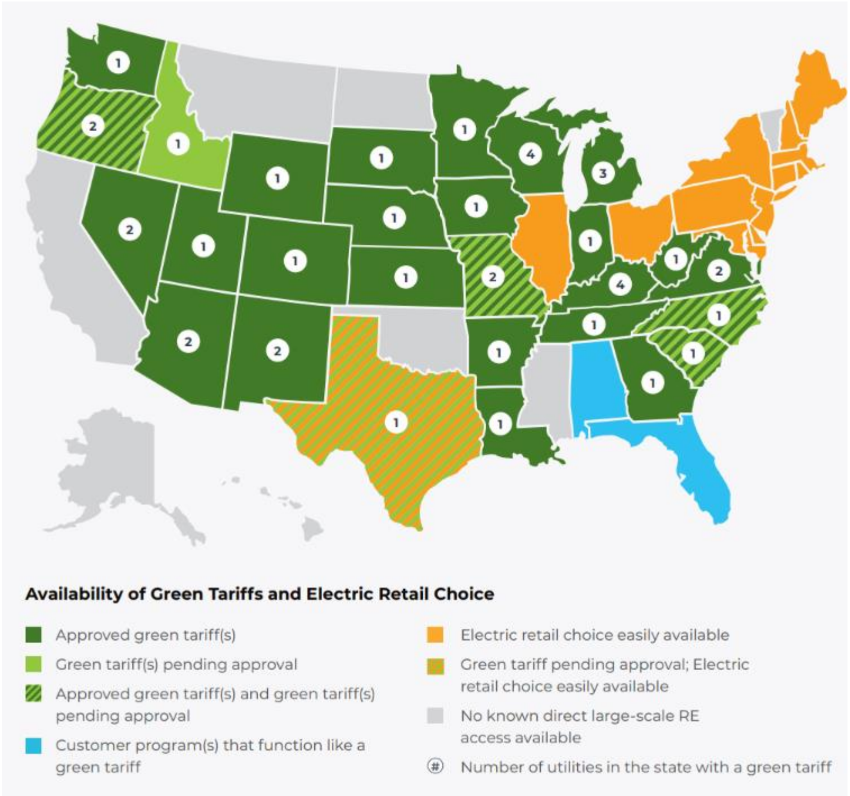
3.3.2 GREEN TARIFF AVAILABILITY

While hydrogen producers may be limited on options for direct bilateral PPAs, more regulated utilities are offering options to customers wanting to influence or dictate their electricity supply. Green tariffs are state public utility commission approved programs that allow corporate entities to procure bundled renewable energy or attributes.[33] While utilities are increasing voluntary tariff or program options for customers to secure access to renewable electricity supplies, they vary in quantity, access, and structure. Therefore, supply procured through a given utility option for a hydrogen producer may or may not currently meet strong three-pillar requirements, particularly with regards to incrementality. This is likely to evolve as utilities look to participate in the hydrogen value chain, including as potential fuel buyers. Treasury guidance can help advance continued progress on structured customer offerings that meet evolving needs.

According to a Clean Energy Buyers Association (CEBA) report on green tariffs, industrial and commercial customers purchased nearly 16 gigawatts (GW) of clean energy in 2022. Across the U.S., 26 states have existing approved green tariff programs as shown in the map on Figure 16[34]; Florida and Alabama have customer programs that function like green tariffs. A further two states at the time of the report are pending approval for green tariff programs.

[33] CEBA (Clean Energy Buyer's Association). 2023. "*U.S. Utility Green Tariff Report: January 2023 Update*." https://cebuyers.org/us-electricity-markets-utility-green-tariff-update-january-2023/.
[34] CEBA (Clean Energy Buyer's Association). 2023. "*U.S. Utility Green Tariff Report: January 2023 Update*." https://cebuyers.org/us-electricity-markets-utility-green-tariff-update-january-2023/.

FIGURE 16: GREEN TARIFFS AS OF JANUARY 2023



Green tariffs in the market have three general structures:

- A utility buys certificates to match the necessary volume of clean energy. These program offerings are typically managed as a portfolio at the utility level with at least some level of unbundled certificates purchased by the utility and are less likely to be aligned with strong framework requirements, particularly in the near term. There is typically less transparency to the consumer on the specific generation sources which contribute to the program.
- Project-specific options are similar to direct PPAs in terms and risk exposure, much like a sleeved PPA, where the utility is an intermediary between the energy project and the corporate buyer. These can range in duration for the end-user based on the utility's assessment of the offtake risk.
- Other offerings can be a hybrid of the first two and typically involve the utility managing a portfolio of supply sources from discrete projects to spot market purchases. Reference data for end-users may have an audit requirement and therefore have a time lag on the information release, like the Energy Information Administration's (EIA's) eGRID.

Below are example programs which illustrate these three general structures and represent the diversity of green tariff programs currently available.

Example Green Tariff Programs:

Certificate Volume Match

In Oregon, Pacific Power offers its Blue Sky renewable energy program, which is a residential and commercial subscription-based program that offers renewable energy certificates in several configurations, including unbundled options. The Blue Sky Usage configuration sells unbundled RECs that match up to 100 percent of electricity usage, but do not provide electricity. In 2022, the Blue Sky program accounted for 1,015,494 MWh of renewable energy across the various options. The program utilizes Green-e® Energy Certified new wind and solar.

Project Specific

In Colorado, Xcel Energy offers its Renewable*Connect program, which is a subscription-based program that provides clean energy through two options. The Renewable*Connect Flex program is aimed at residential or business customers who are interested in procuring wind and solar resources on a month-to-month basis. The Renewable*Connect Legacy option is for residential or business customers of any size who are interested in procuring specifically solar resources on a month-to-month basis, or longer-term 5- or 10-year contracts. Xcel Energy will either retire the associated RECs on behalf of the enrolled customer or transfer the RECs to the customer's account.

In Georgia, Georgia Power offers its Clean and Renewable Energy Subscription (CARES) Program, which has a program size of 2,100 MW for commercial, industrial, and public sector customers. Within CARES, there is a sub-program known as Carbon Free Energy Around the Clock (CFE-ATC). CFE-ATC encompasses 650 MW of the 2,100 MW and consists purely of carbon-free resources that are coupled with battery storage. Georgia Power customers can pay for a subscription for a pro rata share of renewables production, and Georgia Power retires RECs on behalf of the customers.

Hybrid

Entergy's Louisiana Geaux Green option (GGO) is an example of a hybrid green tariff, where there is a 1-year auto-renewing contract term for a subscription into a solar portfolio. The GGO program size is 475 MW, of which 365 MW are allocated to larger commercial, industrial, and government accounts. As of July 2023, Entergy's entire existing and developing renewable energy portfolio amounted for 10,155 MW across the U.S. RECs are retired by Entergy Louisiana on behalf of the customer. Entergy offers this green tariff to its existing large commercial and industrial customers that have a metered service and are in good standing. Interested customers have two options:

1. Fixed-Price, where the fee is based on the amount of capacity a customer subscribes to and a fixed capacity charge.
2. A volumetric price option that resembles a virtual PPA, where customers pay for the difference between the green tariff subscription fee and the monthly wholesale price of energy, which is then multiplied by their share of delivered energy each month.

35

[35] References for Green Tariff Programs:

a. Pacific Power. 2023. *About Blue Sky*. https://joinbluesky.com/about-blue-sky/.
b. Pacific Power. 2023. *Support Renewable Energy with Blue Sky*. https://www.pacificpower.net/savings-energy-choices/blue-sky-renewable-energy.html.
c. Pacific Power. 2023. *Blue Sky Content Label*. https://www.pacificpower.net/savings-energy-choices/blue-sky-renewable-energy/product-content-label.html.
d. Xcel Energy. 2023. *Renewable* Connect*. https://co.my.xcelenergy.com/s/renewable/renewable-connect.
e. Entergy. 2023. *Renewable Energy*. https://www.entergy.com/renewable-energy/.

3.4 EMISSIONS CALCULATIONS AND APPLICATION OF TAX CREDIT TIERS

3.4.1 EMISSION CALCULATION METHODOLOGY

Two main methodologies throughout reports suggested either use of marginal emission rates or an attribute or absolute emissions approach such as the GHG Protocol Scope 2 methodology to calculate life cycle emissions from electricity supply to a hydrogen producer. These two calculation approaches were introduced in Part I of the report. Treasury seeks comments on modeling as an alternative approach to demonstrating zero or minimal induced grid emissions. While marginal emissions are a very useful tool for modeling and monitoring both supply and demand impacts, there are challenges with data availability for marginal emissions that will be discussed in a subsequent section. More importantly, a Scope 2 approach is more consistent with specific end-user accountability for what is within their control to manage related to electricity supply.

The Scope 2 approach, specifically referencing the GHG Protocol's market-based methodology, is based on the attributes of the electricity supply, accounting for the conveyance of those attributes via market-based mechanisms such as EACs. This attribute-based approach is the most reflective of electricity procurement activities by hydrogen producers. The current version of the Greenhouse gases, Regulated Emissions, and Energy Use in Transportation (GREET) model references the GHG Protocol's location-based methodology, which is reflective of the average grid intensity and does not account for conveyance of market-based mechanisms. The GREET model will need to be updated to account for the attributes of specific electricity supply sources versus the average grid mix.

3.4.2 LIMITED VOLUME BUFFERS

As highlighted previously in the discussion on capacity and profile matching, Treasury should also consider options for providing some degree of operational flexibility in meeting an hourly temporal requirement while maintaining the framework's overall integrity. This might be necessary to mitigate short term disruptions, supply variability, or to accommodate lags in data sets. For example, some data references (including average grid factor, location-based, residual or even some supplier/utility-based factors) are currently only available as an annualized number or factor and may be referencing generation from the prior year due to the validation process of those factors. Use of eGRID factors directly or indirectly, such as Green-e® residual factors, could even be upwards of two years delayed as the U.S. Environmental Protection Agency's (EPA's) traditional posting is every other year with a 1-year lag.

Providing operational flexibility could take different approaches, including allowing a limited percentage of the annual electricity supply volume under the Scope 2 approach to be exempt from any hourly temporality requirement. This "exempted" volume can be accounted for by using average grid intensities, supplier-specific intensities or, if those values are too carbon-intensive, by utilizing unbundled EACs. In the event that Treasury provides mechanisms for limited volume buffers, it will be important to provide guidance on which of these intensities should be used, as assumptions of intensities will have material impacts on lifecycle emissions, as shown below.

The following examples illustrate a Scope 2 approach to an annualized electricity supply emissions calculation for a 100 MW electrolyzer demand in ERCOT in 2026, leveraging the 2022 NREL Cambium Midcase dataset. This example assumes an annual 70 percent electrolyzer utilization rate with an efficiency of 55 kilowatt hour (kWh) electricity requirement per kilogram of hydrogen production. This requires the intensity of the electricity supply to be less than 8.18 kilograms of carbon dioxide equivalent per megawatt hour (kg CO_2e/MWh) to achieve the maximum production credit with a hydrogen emission rate of 0.45 kilograms of carbon dioxide equivalent per kilogram of hydrogen (kg CO_2e/kg H_2). In this example, the hydrogen producer has a combination of electricity supply from wind and solar PPAs with associated EACs with an hourly match for 90 percent of the electrolyzer load. The two options considered for accounting for the emissions of the remaining volumes are to purchase unbundled certificates not temporally aligned, or to apply an average grid intensity factor only available on an annual basis. (Here we assume the supplier-specific intensity factor is not applicable and a published residual intensity factor is not available).

The first example in Table 3 illustrates the impact of needing to rely on a grid average for even a small percentage of the electricity load emissions – the total hydrogen intensity rises to 20 kg CO_2e/ kg H_2, far exceeding the 8.18 CO_2e/kg H_2 requirement. Rather than relying on an intensity factor, the second example illustrates the use of a limited percentage of unbundled EACs to supplement the hourly matched PPA volumes and reflects the degree of proactive supply management which will be necessary by hydrogen producers to achieve the overall carbon intensity threshold for the highest credit value. This is particularly material for electrolysis given the order of magnitude electricity supply has on the overall lifecycle analysis (LCA) of the process.

FIGURE 17: EMISSION CALCULATION EXAMPLE HOURLY SUPPLY AND DEMAND

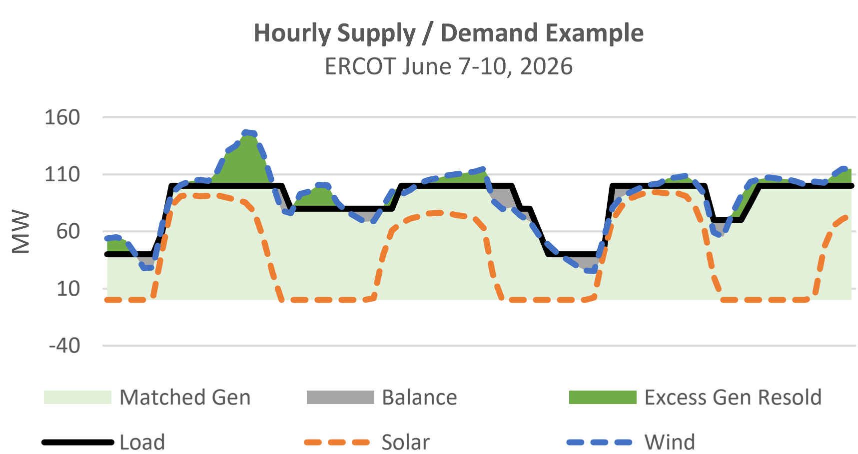


TABLE 3: EMISSION CALCULATION EXAMPLE IMPACT OF BALANCING OPTIONS

Example 1 (Full Year) Supply Source	Volume [MWh]	Volume % of Load	Intensity [kg/MWh]	Emissions [tonnes]
Wind + Solar Hourly Matched	551,880	90%	0	0
Balance – Avg Grid	61,320	10%	206	12,632
Total	**613,200**		**20.6**	**12,632**

Example 2 (Full Year) Supply Source	Volume [MWh]	Volume % of Load	Intensity [kg/MWh]	Emissions [tonnes]
Wind + Solar	551,880	90%	0	0
Unbundled EACs that are not three pillar compliant	37,000	6%	0	0
Balance – Avg Grid	24,320	4%	206	5,010
Total	**613,200**		**8.17**	**5,010**

EAC = Energy Attribute Certificate; MWh = Megawatt hour

LEGACY

As noted in Part I, some stakeholders have proposed transition periods of varying lengths, and the EU will introduce its hourly matching requirement in 2028. It is important to note that extending any transition phase to provide special allowances to legacy facilities (a.k.a. "grandfathering") would prolong the emission impact of a temporarily lax requirement. Production from such facilities could artificially reduce the claimed emissions intensity of generation and dilute the robustness of emissions calculations for the industry. It should be noted that the EU does not have a legacy clause and requires all facilities to comply with hourly matching on the same timeline.[36]

3.5 EXPANDED INCREMENTALITY OPTIONS

In its draft 45V rule, Treasury notes that “there are circumstances during which diversion of existing minimal emissions power generation to hydrogen production is unlikely to result in significant induced GHG emissions,” and seeks comment on alternative approaches to identifying those circumstances. Specifically, Treasury asks about the definition of incrementality, which could be expanded to include nuclear facilities that might otherwise retire, curtailed power, and resources on grids that could contribute minimal emissions. Each of these are targeted approaches that seek to identify specific resources or regions that might benefit from eligibility without undermining the rule’s overall emissions impact. These approaches are discussed in more detail in this section. They contrast notably with an

[36] European Commission. 2023. *Supplementing Directive (EU) 2018/2001 of the European Parliament and of the Council by Establishing a Union Methodology Setting out Detailed Rules for the Production of Renewable Liquid and Gaseous Transport Fuels of Non-biological Origin*. https://energy.ec.europa.eu/system/files/2023-02/C_2023_1087_1_EN_ACT_part1_v8.pdf.

alternative approach suggested by Treasury of applying a blanket 5 percent allowance of existing generation (not tailored to specific geographic or other conditions). Without mechanisms to guarantee that existing generation is only diverted during periods with low marginal emissions rates, research suggests that such a blanket allowance could cause a systemwide increase in emissions of up to 1.5 billion metric tons through 2035.[37]

3.5.1 NUCLEAR

Baseload zero-carbon electricity will play an important role in the continued decarbonization of the electricity grid. In some regions, such as the Southeast, which have relatively lower quality solar and wind resources and little to no renewables beyond limited hydro, nuclear generation is currently the primary zero-carbon generation source. This type of generation provides a unique value; therefore, there is broader interest in its continued economic viability and in avoiding early retirements.

Since 2013, 13 commercial reactors have closed early because of shifting energy markets and economic factors.[38] The DOE cannot provide a precise number of reactors that are currently at risk of closure due to economic factors. However, a study released by The Congressional Research Service (TCRS) in June 2021 found that state-driven financial incentives in the past decade helped save 15.7 GW worth of electricity generation capacity across 16 reactors.[39] The reactors were based in Connecticut, Illinois, New Jersey, New York, Ohio, and Pennsylvania. The report also mentioned the scheduled closure of seven other nuclear reactors which have a collective electricity generation capacity of 7.1 GW. Since the TCRS report, Illinois signed S.B. 2408 into law in September 2021, which resulted in the prevention of four of these reactor retirements with a combined capacity of 4.1 GW. The first application cycle of the Civil Nuclear Credit Program, introduced in the Bipartisan Infrastructure Law (BIL), helped save two more of these reactors and 2.2 GW of capacity.

There are 11 reactors with 10.1 GW of total capacity with licenses set to expire by 2030, as noted below in Table 4.[40] An alternative view of summer capacity is shown on Figure 18, where the average remaining life of reactors drops dramatically from around 15 years in 2023 to less than 10 years in 2035. These license expirations showcase an opportunity to prolong the contribution of existing nuclear in their respective markets. The table below includes two power plants from the TCRS report, Diablo Canyon and Palisades, under the "Capacity Demonstrating Need" label. Federal funding through the Civil Nuclear Credit Program can help extend these licenses, although its next application cycle will not require a

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[37] Rhodium Group. 2024. "*How Clean Will US Hydrogen Get? Unpacking Treasury's Proposed 45V Tax Credit Guidance*." https://rhg.com/research/clean-hydrogen-45v-tax-guidance/.
[38] DOE (U.S. Department of Energy). 2022. *"Biden-Harris Administration Announces Major Investment to Preserve America's Clean Nuclear Energy Infrastructure."* https://www.energy.gov/articles/biden-harris-administration-announces-major-investment-preserve-americas-clean-nuclear.
[39] Congressional Research Service. 2021. "*U.S. Nuclear Plant Shutdowns, State Interventions, and Policy Concerns*." https://crsreports.congress.gov/product/pdf/R/R46820/3.
[40] Nuclear Energy Institute. 2023. *U.S. Nuclear Plant License Information*. https://www.nei.org/resources/statistics/us-nuclear-plant-license-information.

publicly announced closure date as an eligibility criterion.[41] This change in eligibility will be beneficial for reactors that are not publicly sharing their economic situation. If sufficient, subsidy programs such as the Civil Nuclear Credit Program, and other incentives provided within the IRA specifically for existing nuclear generation, should be the first revenue support option for existing nuclear, particularly in the near term. Supplying hydrogen tax credit eligible generation could offer a potential revenue stream further into the next decade.

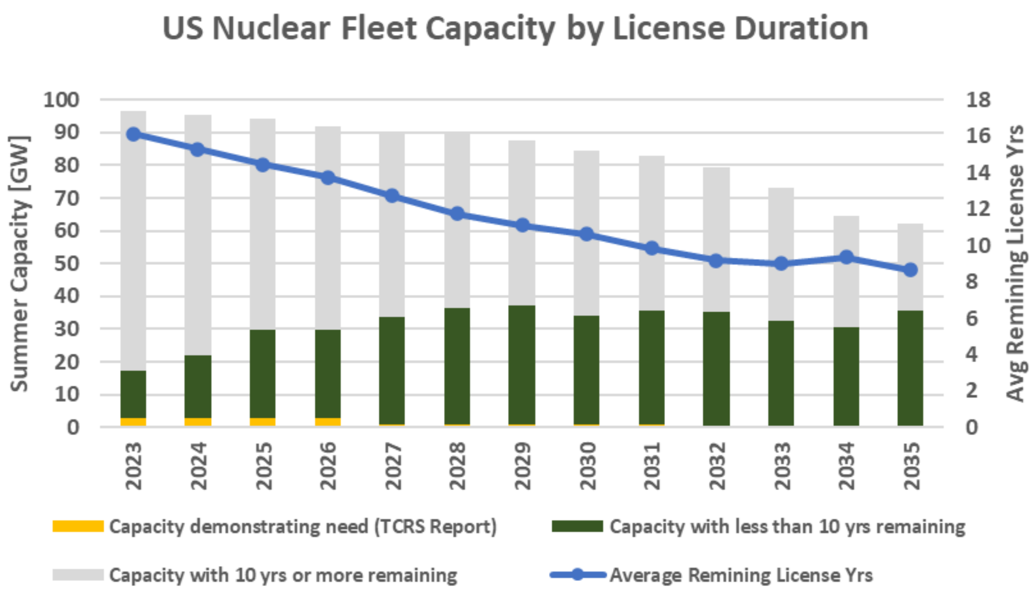
TABLE 4: REACTOR LICENSES EXPIRING BY 2030

	Reactor Licenses Expiring By 2030		
Reactor Name	**Generation Capacity (GW)**	**State**	**Expiration Date**
Diablo Canyon 1	1.1	CA	11/2/2024
Diablo Canyon 2	1.1	CA	10/26/2025
Clinton	1.1	IL	9/29/2026
Perry 1	1.3	OH	11/7/2026
Nine Mile Point 1	0.6	NY	8/22/2029
Ginna	0.6	NY	9/18/2029
Dresden 2	0.9	IL	12/22/2029
Commanche Peak 1	1.3	TX	2/8/2030
H.B. Robinson 2	0.8	SC	7/31/2030
Monticello	0.7	MN	9/8/2030
Point Beach 1	0.6	WI	10/5/2030
Total	**10.1**	**8 States**	

GW = gigawatts

[41] DOE (U.S. Department of Energy). 2023. "*Civil Nuclear Credit Award Cycle 2*." https://www.energy.gov/gdo/civil-nuclear-credit-award-cycle-2.

FIGURE 18: U.S. NUCLEAR FLEET CAPACITY BY LICENSE DURATION AND TCRS DEMONSTRATED NEED



Participation in clean hydrogen value chains could provide new financial opportunities for nuclear generators, either reducing their risk for early retirement or providing necessary support for operating license extensions. However, as discussed in Part I of the report, there has been significant debate on existing nuclear generation with regards to the 45V hydrogen tax credits, specifically its eligibility regarding the incrementality pillar and conditions under which existing generation could be deemed eligible by demonstrating the generation capacity would otherwise be retired. From a net impact perspective, preventing a resource from retiring and retaining that electricity in the grid supply is no different from a new project entering the market. However, if there is no potential for retirement along with no incrementality requirement, then the resource is simply diverted from existing demand to new hydrogen demand, and in most markets requires an equivalent net increased dispatch of fossil generation. For example, a recent report by Rhodium estimates that shifting all existing nuclear generation to hydrogen production results in increased net cumulative emissions by 1.3-4.7 billion metric tons through 2035.[42]

To maximize emissions reduction, the ideal solution is to identify and limit eligibility to those plants that are truly at risk of retiring without 45V support -- recognizing that proving a counterfactual can be challenging. Given this difficulty, Treasury has solicited input on a rigorous demonstration of need for financial support above and beyond other federal and state subsidies. Implementation of this type of demonstration should be aligned with other existing state or federal programs for both consistency in methodology and efficiency.

[42] Rhodium Group. 2024. "*How Clean Will US Hydrogen Get? Unpacking Treasury's Proposed 45V Tax Credit Guidance*." https://rhg.com/research/clean-hydrogen-45v-tax-guidance/.

One example is the Civil Nuclear Credit Program, which will distribute $6 billion in funding to help preserve the existing nuclear fleet in the U.S.[43] Eligible nuclear reactors are primarily those which are expected to close due to economic reasons and the closure will result in an increase in air pollution (due to fossil fuel generators fully or partially offsetting the supply). It may be that such a program serves only as a mechanism to establish eligibility but is not needed to dictate eligibility duration, as that could introduce additional project risk for 45V. The Civil Nuclear Credit Program has $1.2 billion in credits set aside for each fiscal year between 2022–2026.[44] If funding is available afterwards, it will be distributed through 2031, or when the credits run out. To date, the program has had two application cycles (2022 and 2023), each of which provided 4-year credits to the eligible reactors. The first application cycle selected the Diablo Canyon Nuclear Power Plant for an extension as its reactors were both scheduled to retire before the end of this program's four-year cycle. The second cycle has closed its application window, though a winner has not yet been announced.[45] For the second cycle, a scheduled retirement is not necessary, but rather a potential risk to closure due to economic reasons. The timeline for this second cycle is for reactors that expect to have an economic risk of shutdown by 2027. Eligible reactors may also qualify for the Zero-Emission Nuclear PTC under 45U, which provides a base credit of 0.3 ¢/kWh up to a maximum 1.5 ¢/kWh of electricity produced from a qualified facility and sold to an unrelated party between 2024 through 2032. Treasury is expected to issue a final rule this year which will provide further guidance to existing nuclear plants seeking to prevent premature closure. Treasury should consider aligning 45U and 45V guidance to allow a common framework for demonstrated need.

Another potential option for existing low-carbon baseload generator eligibility for 45V could be to require a binding long-term financial agreement between the hydrogen producer and generator that's seeking a license extension. This financial agreement could take the form of a long-term bundled PPA or be sleeved with a similar structure option in regulated markets, providing stronger incrementality connection than the use of unbundled certificates. A minimum term length (triggering a license extension) could be required of these PPAs on the order of 10 to 15 years to ensure sufficient additional capacity is created, in addition to a maximum share of capacity that could go toward hydrogen production. In the case of existing nuclear, many plants in the U.S. nuclear fleet would require a license extension to fulfill these term obligations for PPAs executed closer to 2030. If hydrogen producers could help avoid the retirement of those plants and make it economical to keep this low-carbon electricity generation on the grid, hydrogen producers could make an even stronger case for incrementality impacts. Even one nuclear facility that shuts down prematurely will have a significant impact on U.S. emissions in the electric power sector. However, the easier it is for

[43] DOE (U.S. Department of Energy). 2023. "*Civil Nuclear Credit Program*." https://www.energy.gov/gdo/civil-nuclear-credit-program.
[44] DOE (U.S. Department of Energy). 2023. "*Civil Nuclear Credit Program.*" https://www.energy.gov/gdo/civil-nuclear-credit-program.
[45] DOE (U.S. Department of Energy. 2023. "*Civil Nuclear Credit Award Cycle 2*." https://www.energy.gov/gdo/civil-nuclear-credit-award-cycle-2.

a plant to claim 45V eligibility, the greater the risk of both diverting a zero-carbon resource from supporting existing demand to new hydrogen demand, as well as a deadweight loss of subsidy funds. It's important to strike a balance, and Treasury will have to weigh these relative risks when crafting the final rule.

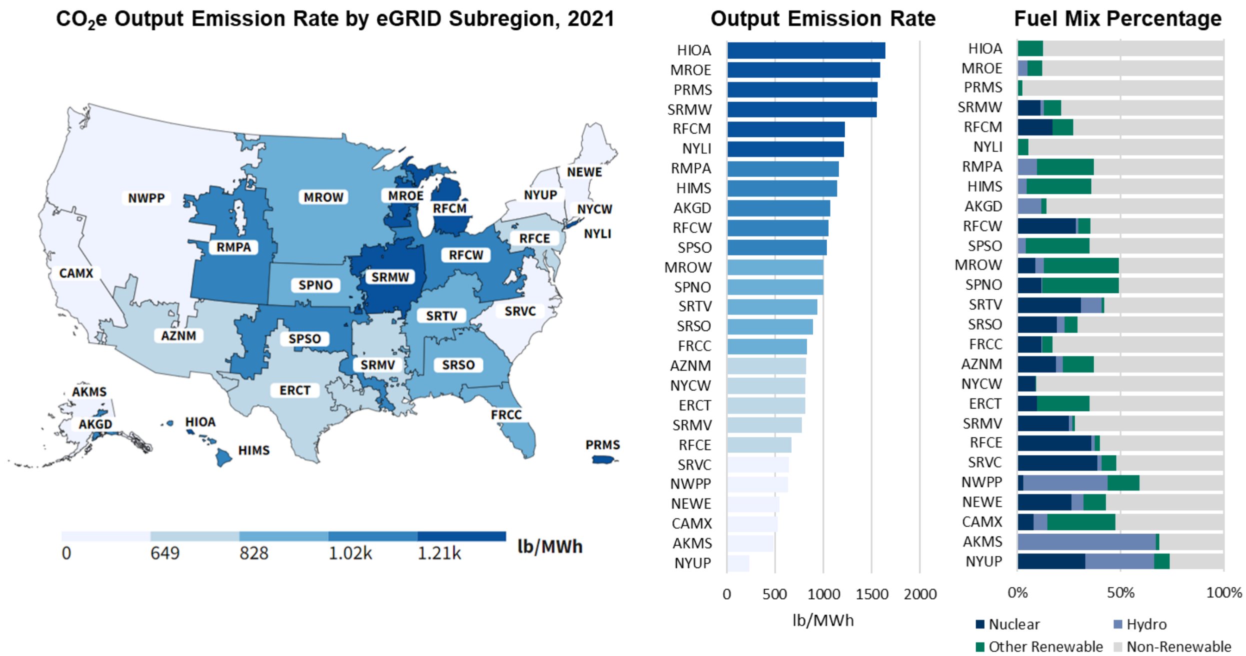
3.5.2 LOW-CARBON ELECTRICITY GRIDS

The incrementality impact of additional new clean generating resources stands to diminish once the grid reaches sufficiently high levels of decarbonization. While under this scenario there would still be opportunities for new investments, including repowering or fully replacing old assets, over time additional demand-driven support for new generation investment would become less material to continued decarbonization progress. In addition, highly decarbonized grids (i.e., those with around 90-95 percent clean power) will be at lower risk for increasing emissions from marginal resources because the overall grid has a lower carbon intensity. For this reason, the EU in their Delegated Act on the methodology for renewable fuels of non-biological origin has allowed for an exception to incrementality for low emission intensity grids (defined as less than 18 grams carbon dioxide per megajoule [gCO_2/MJ] or less than 143 pounds carbon dioxide per megawatt hour [lb CO_2/MWh] inclusive of all generation) as well as for a high percentage of renewables (defined as greater than 90 percent) in the grid mix. Once either of these grid conditions are met in a calendar year, they shall be continued to be considered met only for the subsequent five calendar years (i.e., the incrementality exception is not guaranteed in perpetuity). Also under this exception, hydrogen producers are still required to meet temporality and deliverability requirements along with securing supply through a PPA.[46] The EU intensity and renewable percentage thresholds are used on an example basis in the following discussion and need not be the same in the U.S., though it may be worth considering alignment with EU thresholds to support global industry growth.

As of 2021, eGRID data represented below on Figure 19 shows there are currently no U.S. regions which have met either of the EU threshold requirements, with nuclear and hydro being key contributors in many regions with the lowest intensities.[47]

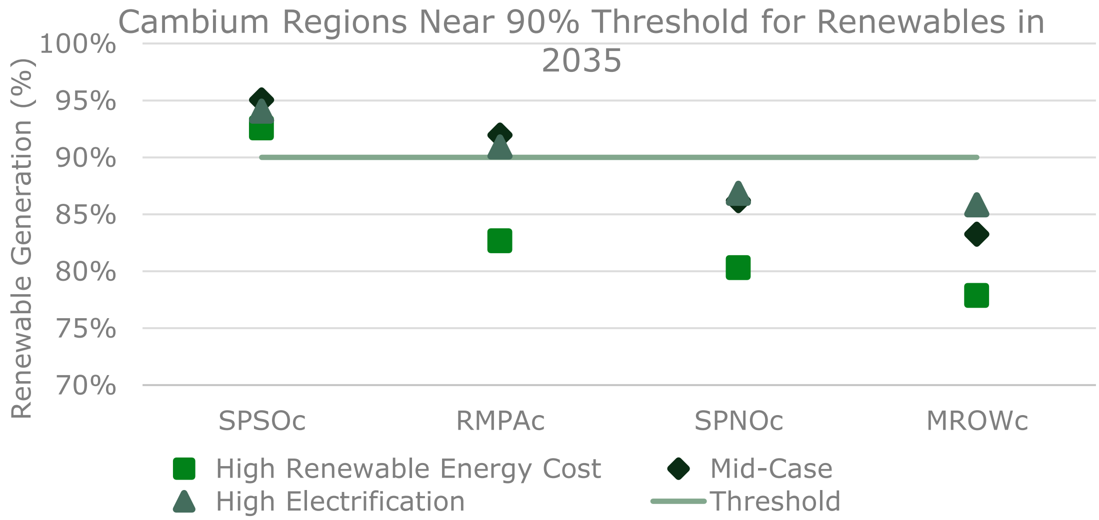
[46] European Commission. 2023. *Delegated regulation on Union methodology for RFNBOs.* https://energy.ec.europa.eu/system/files/2023-02/C_2023_1087_1_EN_ACT_part1_v8.pdf
[47] USEPA (U.S. Environmental Protection Agency). 2023. *Emissions & Generation Resource Integrated Database (eGRID)*. https://www.epa.gov/egrid

FIGURE 19: 2021 EGRID SUBREGION INTENSITY FACTORS AND FUEL MIX PERCENTAGES



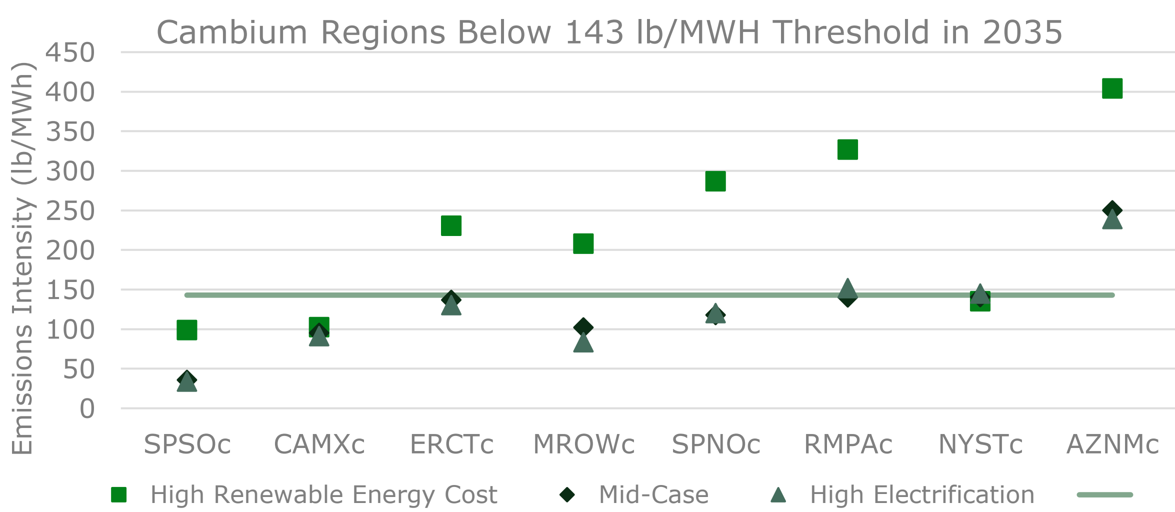
However, there are a few regions with notable projected growth in the next decade, which, if projections are actualized, might become relevant for demonstrating minimal emissions effects. Growth from renewables in these regions will be dominated by wind, mostly onshore, and solar. Leveraging the Cambium datasets across the three scenarios, the Central Plains regions, which benefit from high-quality wind resources, may be the most likely regions to reach 90 percent or higher amounts of electricity generation from renewable sources by 2035, as illustrated on Figure 20. Two of these regions, SPP South (SPSO) and the Rocky Mountain Power Authority (RMPA) have the potential to reach 90 percent by 2030 in the modeled Midcase. Under the alternative scenario with high renewable energy costs, only SPSO is likely to reach 90 percent given the quality of both wind and solar resources. The EU has both significant offshore wind, which has higher capacity factors than onshore wind, and hydro supplying the continent, which may make it easier for some of their regions to meet this requirement (though doing so within the timeframe of the tax incentives will be challenging).

FIGURE 20: 2035 CAMBIUM 22 FORECASTED RENEWABLE ENERGY GENERATION



Accounting for the intensity of the remaining grid, including nuclear, increases the regions which may reach EU exemption thresholds if considering a grid intensity versus just a renewables percentage mix. Figure 21 below illustrates the average grid intensities against a 143 lb CO_2/MWh threshold from the same Cambium datasets for 2035. In addition to the regions which may reach 90 percent renewables, California (CAMX), ERCOT (ERCT), New York (NYST), and Arizona/New Mexico (AZNM) also have potential to reach the EU intensity threshold under certain scenarios. Regions that are close to the threshold should be noted, as under different scenarios the threshold limit may not be reached. For example, when looking at the high renewable energy cost scenario, only California and New York join SPP South in reaching the threshold.

FIGURE 21: 2035 CAMBIUM 22 FORECASTED EMISSION INTENSITY



3.5.3 STATE EMISSIONS CAPS

Similar to low-carbon electricity grids, the role of incrementality of additional new clean generating resources becomes less critical to avoiding increased emissions from hydrogen production demand in states or regions with effective, high-integrity caps on economy-wide or power sector emissions.

To date, GHG emissions targets have been established in multiple states through either state legislation, governor executive action, or a combination of the two, with an additional three states publishing recommended targets.[48,49] States have adopted various other actions, with some focusing on deploying technology-forcing policies, while others have adopted regulations to directly limit GHG emissions from particular sources and sectors, including emission cap and trade programs. Emissions limits and clean energy standards are complementary but not equivalent policies. The former provides certainty in achieving emissions reductions while the latter may require the addition of zero- or lower-emitting resources but does not necessarily ensure that these will directly displace higher-emitting ones.

States that have finalized emissions cap and trade regulations include California, Washington, and the current 11 state members of RGGI. California and Washington have adopted economy-wide programs, covering roughly 80 percent of statewide emissions, including emissions associated with all in-state power generation and electricity imports, whereas the RGGI program covers electric power generation in participating states.[50,51,52] In addition, Colorado and Oregon have both adopted statutes requiring emissions from electricity sales to decline by at least 80 percent below 2005 levels by 2030.

Well-designed high integrity emission cap programs can provide an alternative mechanism to address concerns of increased grid emissions from hydrogen production, which is a primary driver for the incrementality pillar. Some administrability challenges may exist in translating emissions caps into fulfillment of incrementality requirements, including the need for strong enforcement and leakage protections. Enforcement mechanisms vary across different programs and even within multi-state programs. For example, while RGGI requires a minimum penalty of surrendering allowances, further consequences are at the discretion of each state.[53]

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[48] Center for Climate and Energy Solutions. 2022. *"U.S. State Greenhouse Gas Emissions Targets."* https://www.c2es.org/document/greenhouse-gas-emissions-targets/
[49] Environmental Defense Fund. 2023. "*U.S. States with Binding Economy-wide Climate Targets."* https://blogs.edf.org/climate411/wp-content/blogs.dir/7/files/2023/02/US-States-with-Binding-Economy-Wide-Targets.pdf
[50] California Air Resources Board. 2023. *Cap-and-Trade Program*. https://ww2.arb.ca.gov/our-work/programs/cap-and-trade-program/about
[51] Washington State Department of Ecology. 2023. *Cap-and-Invest.* https://ecology.wa.gov/air-climate/climate-commitment-act/cap-and-invest.
[52] Regional Greenhouse Gas Initiative. 2023. *Elements of RGGI.* https://www.rggi.org/program-overview-and-design/elements
[53] International Carbon Action Partnership. 2022. *USA - Regional Greenhouse Gas Initiative (RGGI) – ETS Data*. https://icapcarbonaction.com/en/ets/usa-regional-greenhouse-gas-initiative-rggi

In contrast, failure to comply in California, either through a lack of compliance instruments or through disclosure violations, will lead to a surrender of allowances alongside varying financial penalties.[54] Washington State has a similar compliance mechanism, with a surrender of allowances, as well as $10,000 fines per day and/or per specific violation.[55]

Under an emission caps approach, the risk of GHG leakage outside of the capped state or region would have to be addressed. Electricity imports would need to be covered under the cap (as is the case in California and Washington), and the capped area would need to effectively become the new geographical boundary for the deliverability pillar to prevent diverting a resource from supporting existing demand to new hydrogen demand. That is, the California cap would prevent any emissions increases from electrolysis so long as the electricity used to power the electrolyzer was covered by the cap. Lastly, change-of-law guidance should be written in the event of changes to an emissions cap policy.

3.5.4 CURTAILMENT

Curtailment can either be voluntary, typically driven by economics, or mandated to balance grid operations. Voluntary economic curtailment is dependent upon and may be limited by contractual terms, but it can occur when variable costs exceed variable revenue sources inclusive of production-based subsidies and any market basis differentials borne by the generator. Grid mandated curtailment, or downward dispatch, occurs when supply exceeds demand or transmission capacity at specific points in the grid, and the grid operator requires generators to reduce output to balance the grid (including frequency).

Wind and solar are non-dispatchable, meaning the grid operator cannot call on them to increase generation as they can with thermal generators, as they are typically already producing as much generation as technically capable due to their low variable costs. As wind and solar generation increase as a percentage of the overall grid mix, demand-side management to balance the grid will increase in importance and opportunity. Electrolyzers which can quickly ramp up or down to follow these non-dispatchable resources can become a demand-side resource for grid balancing. However, this would require their base operations to be at lower utilization factors for them to have spare capacity in reserve to enable them to ramp up and create demand to consume excess renewables. Declines over time in electrolyzer capital costs along with potential new capacity ancillary services as another revenue source (i.e., a demand response program in reverse) will further enable operating with a level of base spare capacity.

Even in regions like California, which are seeing an increase in curtailment of solar generation, it is important to put this current volume into context over the course of a year and at a facility level to understand the extent to which curtailment is likely to play a factor in near-term versus long-term electrolyzer production.Figure 22 below is the amount of

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[54] California Air Resources Board. 2018. *Enforcement Policy*. https://ww2.arb.ca.gov/sites/default/files/2018-06/Enforcement%20Policy.pdf

[55] Washington State Department of Ecology. 2023. *Cap-and-Invest Program Compliance and Enforcement Guidelines.* https://apps.ecology.wa.gov/publications/documents/2302026.pdf

solar curtailment in dark green relative to actual generation in light grey for the California ISO (CAISO) in 2022.[56]

Figure 23 below puts average curtailment volumes into context as capacity factors relative to the 17,856 MW of solar capacity for 2022 .[57]

FIGURE 22: CALIFORNIA HOURLY SOLAR GENERATION AND CURTAILMENT

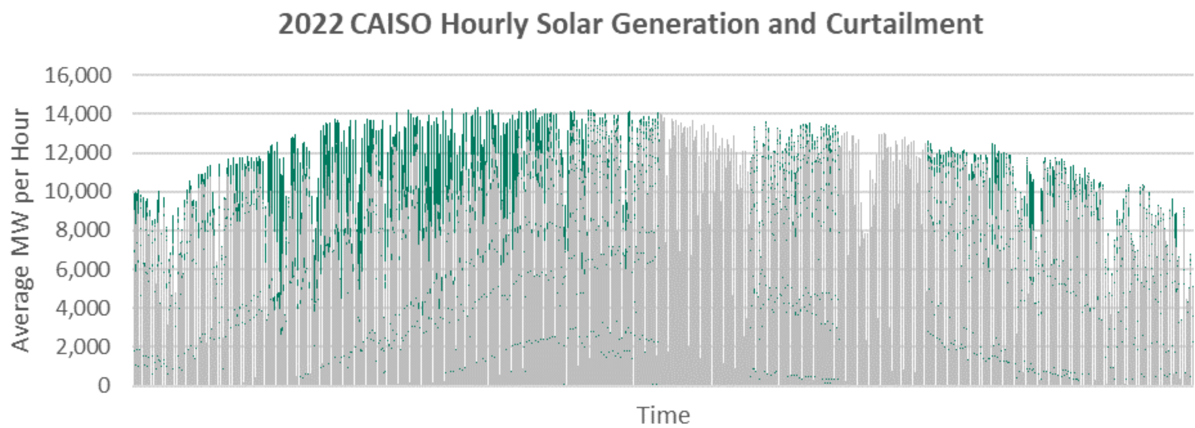


FIGURE 23: AVERAGE MONTH-DAY CALIFORNIA CURTAILMENT AS A CAPACITY FACTOR

Average Day in the Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
2	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
3	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
4	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
5	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
6	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
7	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
8	0%	1%	1%	1%	2%	2%	1%	0%	0%	0%	0%	0%
9	0%	2%	3%	5%	5%	3%	2%	0%	1%	1%	0%	0%
10	1%	5%	6%	9%	8%	4%	2%	0%	1%	2%	1%	0%
11	2%	7%	9%	13%	9%	4%	2%	1%	1%	2%	1%	0%
12	2%	8%	11%	14%	11%	4%	2%	1%	1%	2%	2%	0%
13	1%	8%	11%	14%	11%	4%	2%	1%	1%	2%	2%	0%
14	2%	8%	12%	14%	12%	4%	2%	1%	1%	2%	3%	1%
15	1%	7%	11%	13%	9%	4%	2%	1%	1%	2%	2%	1%
16	1%	5%	9%	11%	8%	3%	1%	1%	1%	2%	1%	0%
17	0%	1%	6%	9%	5%	2%	1%	1%	1%	0%	0%	0%
18	0%	0%	2%	3%	3%	1%	1%	0%	0%	0%	0%	0%
19	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
20	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
21	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
22	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
23	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
24	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%

[56] California ISO. 2022. *Production and Curtailment Data*. http://www.caiso.com/Documents/ProductionAndCurtailmentsData_2022.xlsx
[57] California ISO. 2022. *Production and Curtailment Data.* http://www.caiso.com/Documents/ProductionAndCurtailmentsData_2022.xlsx

As reflected on Figure 23 above, higher levels of curtailment occur during peak hours of the day and during select months but equate to an impact of less than 2 percent on annual capacity factors. These curtailment periods will also be concurrent with times when solar contracted by hydrogen producers will be producing at higher levels. Grids must balance in real time, so there must be sufficient demand in real time for curtailment not to occur. As discussed in Part I of the report, the additional benefit of stronger temporality requirements is the market signal for which types of supply and grid solutions are most beneficial to optimize the system and investments, including renewables generation. This includes demand for newer electrolysis technologies with faster ramping capabilities that are better suited to supply from variable renewables generation.

Grid and weather forecasts can predict when curtailment is most likely to occur, but there are many real-time variables. Validation of the use of curtailed volumes will depend upon it being economic or grid mandated. Economic curtailment would be theoretical, based on a formula of price signals which would determine when the effective net price to the generator in the hour is negative (inclusive of an energy PTC) and mechanical potential output based on weather data which would determine the theoretical generation amount curtailed. Apart from demand response program participation, the most viable option for curtailment as an expanded option for incrementality will likely be to apply it on a geographic basis versus project-specific, similar to electricity prices in a pricing zone reflecting the marginal generation (i.e., locational marginal prices [LMPs]). Due to the real-time nature of curtailment, it is also best suited to be paired with hourly versus annual temporal matching.

3.6 DEMONSTRATION OF DELIVERABILITY

3.6.1 DEMONSTRATION OF WHEELING FROM ADJACENT REGIONS

As outlined in Part I of the report, a flexible and technically feasible approach needs to be considered for deliverability to ensure low-carbon energy is generated in a location that is connected to hydrogen production through the electrical grid. When the geographic boundaries are large, there are potential transmission connectivity issues, but boundaries can be inefficient or not feasible if too small. The challenge is in finding a compromise between these two extremes. As discussed in Part I, the best fitting options here may be the eGrid subregions, which were defined by EPA in a way that limits the number of imports or exports across regions.

Flexibility could also be incorporated by extending eligibility to wheeling or importing of electricity along with the EACs from a neighboring deliverability region, leveraging Green-e®'s approach within their electricity standard.[58] Green-e® does not stipulate how that wheeling is to be demonstrated; however, there are a few options depending on the

[58] Green-e®. 2023. *Renewable Energy Standard for Canada and United States*. https://www.green-e.org/docs/energy/Green-e%20Standard%20US.pdf.

neighboring regions. Each of these options will be subject to the EAC tracking system limitations discussed previously.

One option for demonstrating the wheeling of the electricity is through direct transmission capacity rights. If not held directly, there would need to be sufficient "on behalf of" designation. This would be an effective requirement for cross-regional grid transmission operation boundaries. A second option is referencing the relationship of LMPs between neighboring grids. This option would currently be limited to ISO regions due to data availability issues, which will be discussed in a subsequent Section. The use of LMP differentials would also only be appropriate for demonstrating wheeling between deliverability areas within the same ISO as they become less indicative of power flows the farther apart the price points are geographically. This is further discussed in the following section.

3.6.2 CONSIDERATIONS FOR DELIVERABILITY REGION DEFINITIONS AND POTENTIAL FUTURE EXPANSION

Transmission represents a significant consideration for the design of deliverability measures, both in the drawing and demarcation of deliverability boundaries and in their potential expansion. Transmission constraints dictate the need for clearly specified deliverability boundaries to ensure delivery of low-carbon electricity. Transmission constraints emerge from the physical connectivity of the grid and can be remedied through the build-out of new connections. Sufficient build-out could facilitate the expansion of deliverability boundaries and outweigh the risk of constraints with the benefits of a larger boundary, such as increased alignment with market boundaries. Transmission build-out would also facilitate the integration of increased amounts of renewable generation onto the grid and allow clean electricity to be wheeled across greater distances. This could allow for increased clean electrolysis production in areas where local low-carbon generation resources may be low-quality or high-cost.

Transmission considerations also have potential impacts on incrementality measures. Many U.S. electric grids currently experience long interconnection queues with high costs, and constrained capacity available for new transmission. These long wait times could throttle the deployment of new low-carbon generation sources and make project planning difficult for electrolysis producers who require new, clean generation to operate. Developer interest in new wind, solar, and storage, projects is strong, with 10,000 projects representing 1,350 GW of generator capacity and 680 GW of storage actively seeking interconnection at the end of 2022, though completion rates are low as only 20 percent of wind and 14 percent of solar projects requesting interconnection from 2000-2017 reached commercial operations by the end of that year.[59] Reform of permitting aimed at lowering interconnection queue wait times and costs could help alleviate challenges for electrolyzers. In addition to permitting and

[59] Lawrence Berkely National Laboratory. 2023. "*Queued Up: Characteristics of Power Plants Seeking Transmission Interconnection As of the End of 2022*." LBNL. https://emp.lbl.gov/sites/default/files/queued_up_2022_04-06-2023.pdf.

policy reforms, physical build-out of new transmission can increase transmission capacity and facilitate connection of new generation sources to the grid.

3.6.3 DATA AVAILABILITY AND ACCESSIBILITY

The successful implementation of incrementality and hourly temporality requires data access to operationalize and validate supply sources. The comprehensive availability and accessibility of various energy-related data points both drives the procurement strategy for hydrogen producers and, more importantly, validates the eligibility of their supply and emission factors according to the requirements.

Hourly LMPs have been discussed as a mechanism to demonstrate renewable generation as the marginal generation in a given hour, which could also be an indicator of potential renewable curtailments, and as a way to demonstrate electricity flows for expanded deliverability options. They are an hourly average electricity price at a specific location which can be a specific node on the grid, a zone, or a hub.[60] The zones and hubs are made up of many individual nodes that provide highly granular pricing details. They can be either a straight average or a volume weighted average of the nodes depending on the ISO definition. The nodes typically provide a data update every 5 minutes, with the hourly LMP being the average of those more granular updates within the time period. ERCOT is an example of an ISO which has real-time price reports that are produced every 5 minutes for resource nodes, load zones, and trading hubs.[61] Hourly price indices, the primary basis for contracts, are an average of the LMPs during the hour. Outside of the ISOs, these hourly prices are not publicly available. Any pillar exception or expanded eligibility mechanism would need to take into consideration not only the validation capabilities but also the data sources available to those managing electricity supply decisions, perhaps in real time. LMPs are one example of where data availability and accessibility vary greatly between ISOs and non-ISOs. There is a significant amount of data the ISOs manage and make publicly accessible including LMPs, congestion prices, generation, demand, transmission constraints, etc., all of which are valuable for both supply optimization and validation against various pillar requirements.

One area of data availability that is lacking across both non-ISOs and some ISOs is the state of marginal emissions data. While marginal emission assumptions are useful for electricity system modeling, real-world data availability limitations is one of the primary reasons outlined within Part I of the report as to why it is not the recommended calculation methodology over an attribute or Scope 2 approach. Most ISOs and balancing authorities do not have this data publicly available. In certain cases, marginal emissions can be estimated, but challenges exist particularly related to emissions from imported volumes. For example, Pennsylvania-New Jersey-Maryland Interconnection (PJM) and Independent System

[60] ISO-New England. 2023. *FAQs: Locational Marginal Pricing*. https://www.iso-ne.com/participate/support/faq/lmp#:~:text=Locational%20marginal%20pricing%20is%20a,limits%20of%20the%20transmission%20system.
[61] ERCOT (Electric Reliability Council of Texas). 2023. *Market Prices – Real Time Price Reports*. https://www.ercot.com/mktinfo/prices.

Operator - New England's (ISO-NE's) methodology give zero emissions to imports, therefore underestimating marginal emissions rates.[62] Machine learning-based data tools, such as ElectricityMap and WattTime, can help fill in data gaps by estimating emissions from imports, as well as emissions from non-ISO geographic boundaries. These tools have the potential to mistake correlation for causation, which can impact data generation.

While many originating sources (ISOs, regional transmission organizations [RTOs], balancing authorities, etc.) offer some form of publicly available data (e.g., prices, generation, system constraints, emissions), it is often not granular or timely enough to make an equitable comparison. Regarding accessibility, there is an issue with some originating sources or data platforms not being publicly available. Ensuring the harmonization of data and utilizing a centralized public platform would help mitigate these barriers for incrementality or other validation applications. Table 5 below highlights some of the key data points, examples of originating sources, and further details including limitations. The relevance of data sources and availability has been referenced throughout this report, including Part I.

TABLE 5: DATA AVAILABILITY HIGHLIGHTS

Datapoint	Originating Sources	Data Platform	Limitations/Further Details
Hourly LMPs	▪ ISO, RTO, balancing authorities, trading platforms, or index developers	▪ ISO websites ▪ Data service providers such as S&P, Ventyx/ABB[63]	▪ Data service providers typically offer hubs and index reference but range in offering on nodal LMP. ▪ No hourly non-ISO prices; on/off peak with limited availability.
Residual Emissions Data	▪ Green-e®, select suppliers / utilities	▪ Green-e®, select suppliers / utilities websites	▪ Annual factors. ▪ An equivalent to EU's Association of Issuing Bodies (AIB) does not currently exist for the U.S. ▪ Green-e® residual intensities are not all-inclusive; only account for volumes represented by certificates they certify. Annual factors based on latest eGRID dataset. ▪ Additional suppliers / utilities may develop factors not publicly posted. Similar to Green-e®, may not be all-inclusive.
Marginal Emissions Data	▪ ISO websites (PJM and ISO-NE offer marginal emissions data online)	▪ ISO websites ▪ Electricity Map, Singularity, REsurety, and WattTime offer marginal emission	▪ Not all ISOs report this data (MISO does report marginal fuel types and emissions factors, but the rest of the

[62] Resources for the Future. 2022. "*Options for EIA to Publish CO_2 Emissions Rates for Electricity.*" https://media.rff.org/documents/Report_22-08.pdf.
[63] Hitachi Energy. 2022. *Energy Planning & Trading Velocity Suite.* https://library.e.abb.com/public/489e47d9ae12447595fbd7c89204b93f/Velocity-Suite-brochure-9AKK106930A8237.pdf?x-sign=mLPXqpCSUbZRJ3gW+QCKSwWPnt2VJycpFwXiLHkJ+KOPi28mwexZ1gT7BCEPv+8L.

Datapoint	Originating Sources	Data Platform	Limitations/Further Details
	▪ Balancing authorities	data for non-ISO regions ▪ EPA's AVERT tool offers marginal emissions data for various AVERT regions and states[64]	ISOs do not have the data easily available).[65] ▪ ISOs cannot calculate emissions intensity for imports from other grids. Both PJM and ISO-NE list imports to have zero emissions, which results in underreported marginal emissions rates. ▪ Not all balancing authorities are able to produce marginal emissions rate data instantly. ▪ ElectricityMap and WattTime estimate marginal emissions rates though machine learning models that utilize publicly accessible data. Models may mistake correlation for causation. Models can include non-ISO regions and estimate emissions from imports.
Curtailment Data	▪ ISO websites (CAISO, ERCOT, SPP, MISO, and ISO-NE all offer curtailment data online)	▪ ISO websites	▪ Not all ISOs report this data in a timely manner (PJM and NYISO only have 2022 data available online). ▪ Data is difficult to find at a level that is more granular than ISOs.
Certificates	▪ Tracking systems via certificate owners	▪ Green-e® Validation for key criteria ▪ Tracking systems specific to regions (ERCOT, MIRECS, M-RETS, NEPOOL-GIS, NVTREC, NYGATS, PJM-GATS, and WREGIS)[66] ▪ NAR & M-RETS can be used for certificate tracking outside their territory	▪ Certificate tracking is decentralized (vs centralized in the EU), which is also a current barrier to developing comprehensive residual intensity data sets equivalent to the EU's AIB. ▪ Metadata needed for validation (generator location, timestamp) may only be available to certificate owner; aggregated public reports. ▪ A singular unique REC is issued per MWh of energy, and this REC can only be in one tracking system to avoid ownership disputes and double counting.

AIB = Association of Issuing Bodies; CAISO = California Independent System Operator; ERCOT = Electric Reliability Council of Texas; EU = European Union; ISO = Independent System Operator; ISO-NE = Independent System Operator – New England; .LMP = Locational marginal price; M-RETS = Midwest Renewable Energy Tracking System; MIRECS = Michigan Renewable Energy Certification System; MISO = Midcontinent Independent System Operator; MwH = Megawatt hour; NAR = North America Renewables Registry; NEPOOL-GIS = New England Power Pool Generation Information System; NYISO = New York Independent System Operator; PJM = Pennsylvania-New Jersey-Maryland Interconnection; PJM-GATS = Pennsylvania-New Jersey-Maryland Generation Attribute Tracking System; REC = Renewable energy certificate; SPP = Southwest Power Pool; USEPA = Environmental Protection Agency; WREGIS = Western Renewable Energy Generation Information System

[64] USEPA (U.S. Environmental Protection Agency). 2023. *Avoided Emissions and Generation Tool AVERT*. https://www.epa.gov/avert/avoided-emission-rates-generated-avert.
[65] Resources for the Future. 2022. "*Options for EIA to Publish CO_2 Emissions Rates for Electricity*." https://media.rff.org/documents/Report_22-08.pdf.
[66] EPA (U.S. Environmental Protection Agency). 2023. *Renewable Energy Tracking Systems*. https://www.epa.gov/green-power-markets/renewable-energy-tracking-systems.

4. ASSESSMENT OF A STRONG PILLARS-BASED FRAMEWORK

In light of the regional context and implementation considerations discussed above, this final section of the report provides an example of a strong pillars-based framework and assesses it against the design principles introduced at the beginning of the report to illustrate a potential approach for implementation.

The example given below illustrates potential design elements of a strong pillars-based framework, which provides some flexibility to a burgeoning industry while upholding the integrity of the emissions reduction objective.

Example Strong Pillars-Based Framework (underlined elements represent new ideas presented in this report while the rest represent elements in Treasury proposed guidance)

5. **Incrementality:** Clean energy source placed in service no more than 36 months before the electrolyzer claiming the generated clean electricity
   - Can include direct connection, PPAs or equivalent utility program, or hourly matched energy attribute certificates (EACs) from generators that meet the same requirements
   - Can apply the 80/20 rule for renewable facility repowering
   - Can include uprates and resources that would otherwise be curtailed
   - Consider including resources that would otherwise be retired (e.g., nuclear) subject to demonstrated need beyond existing subsidies
   - Consider exceptions for deliverability regions with high renewables penetration (e.g., >90 percent), low grid carbon intensity, and/or states with emissions caps
6. **Temporality**: Clean electricity supply matched on an hourly basis by 2028
   - No legacy (a.k.a. grandfathering) of facilities
   - Consider potential buffer approaches to provide reasonable operational flexibility (e.g., small buffer volume for non-hourly-aligned, unbundled certificates)
7. **Deliverability**: Clean energy source procured from same region as defined by either eGRID boundaries or the *National Transmission Needs Study*
   - Ability to wheel from adjacent regions (e.g., based on transmission capacity rights or LMP differential)
   - Consider periodic updates to boundaries to reflect changing transmission constraints
8. **Calculation Methodology:** The calculation methodology should be Scope 2 attribute-based with electricity supply volumes accounting for transmission / distribution system losses

As introduced at the beginning of the report, the principles against which this example framework are assessed aim to capture the goals of 45V. These principles include:

- **Progress toward economy-wide decarbonization.** Hydrogen is expected to play a key role in achieving this goal, particularly for difficult-to-decarbonize sectors; however, current grid emissions remain a significant contributor to economy-wide emissions. Thus 45V implementation design must consider the cause-and-effect dynamics of the full energy system.

- **Efficient investment of capital and taxpayer funds.** As with all tax program design and implementation, 45V should be held to high standards regarding efficient use of taxpayer funds and incentives for capital investment.
- **Equitable outcomes across disparate regional conditions.** The U.S. contains a diverse landscape of resources, demand, and regulatory and market structures, which make the design and implementation of the 45V framework inherently challenging. Treasury's design and implementation should plan to manage these differences over the life of the tax credit, but also in the context of the broader clean hydrogen market while acknowledging the influence they will have on the long-term viability of regional hydrogen pathways.
- **Durability.** The 45V tax credit will eventually sunset. A robust design and implementation will lay the foundation for robust value chains that endure past the expiration of the tax credit.
- **Workability.** Successful 45V design and implementation will provide workable solutions for the various actors in the hydrogen value chain and will also account for foundational considerations such as data availability.

4.1 ASSESSMENT FINDINGS

As evidenced by the number of considerations discussed in Parts I and II of this report, the implementation of the 45V tax credit presents many potential challenges and benefits. It is important to understand the balance of risks and benefits to shape guidance so it manages the risks while maximizing the benefits. Towards this end, this section conducts a "Strengths, Weaknesses, Opportunities, Threats" or SWOT analysis of the three-pillars framework example given above to categorize the potential outcomes of the requirements and properly weigh them against each other.

4.1.1 OVERARCHING ASSESSMENT

This pillars-based framework example's elements reinforce and enhance the efficacy of each other. Incrementality underpins temporality and deliverability; without incrementality measures, it will be challenging for temporality and deliverability measures to deliver the intended emission reductions within the grid based on the mechanics of how grids must balance in real time. This illustrates the importance of framework synergy and the necessity of all three pillars supporting each other.

While this synergy is a strength of the three pillars, it also reveals the weakness of variations. For example, with a weakened incrementality measure, deliverability and temporality are not sufficient to safeguard against emissions increases. In the case of no incrementality combined with lax temporality or deliverability, electrolysis production would likely lead to notable net increases in grid emissions, contravening the requirements and goals of 45V.

Some of the challenges that come with a strong three-pillars framework can be mitigated or managed in the short term with expanded eligibility and flexibility options, while others present opportunity and incentive to support longer term goals. This combination of expanded flexibility options and continuing incentives is an opportunity to leverage local resources to enable and support the development of a range of hydrogen pathways, while setting precedent which allows for broader progress across the energy sector. Leveraging local resources in this manner also works toward the secondary goal of efficient investment. By taking advantage of regional factors, the framework could facilitate the foundation of robust value chains which endure past the expiration of the tax credit.

4.1.2 INCREMENTALITY ASSESSMENT

Incrementality is critical in supporting the other two pillars. Without incrementality requirements and new low-carbon generation added to the grid, temporality and deliverability alone cannot avoid increased emissions.[67] Furthermore, strong incrementality requirements carry the opportunity for increased and efficient development and deployment of renewables within the grid. This is a strong positive externality which connects the development of resource capacity and deployment of low-carbon generation sources with the deployment of low-carbon hydrogen, tying together the establishment of the low-carbon hydrogen economy with the increased penetration of renewables in the grid. Incrementality is, therefore, a strong driving force behind the ability of electrolysis production to support continued grid decarbonization.

Physical and operative aspects of the grid may present challenges to strong incrementality requirements and require parallel efforts toward improvement, even if only near term. The primary challenge to incrementality is transmission, mostly due to regulatory bottlenecks within the interconnect process, or the physical need for expansion to enable generation to connect to demand areas. While the IRA and the Bipartisan Infrastructure Law both provide significant funding for transmission build-out, incrementality requirements may be an opportunity to drive further advocacy support for finding solutions to debottleneck transmission permitting, particularly if a material number of hydrogen producers rely on grid-connected electricity to optimize their supply portfolio and utilization. Reform could aim to streamline and shorten timelines for permitting energy projects and transmission, resulting in a more effective grid with increased transmission capacity and reduced interconnection queues. Increased transmission capacity and reduction of transmission constraints between regions could also allow for expansion of deliverability boundaries.

Although the EU guidelines for production of clean hydrogen institute a phase-in of full incrementality in 2028, this should be a minimum standard for incrementality. The EU possesses a more rigorous emissions regulatory framework than the U.S. and therefore is not necessarily an appropriate comparison for justification of incrementality phasing considerations.

[67] Energy Innovation Policy & Technology LLC. 2023. "*Smart Design of 45V Hydrogen Production Tax Credit Will Reduce Emissions and Grow the Industry*." https://energyinnovation.org/publication/smart-design-of-45v-hydrogen-production-tax-credit-will-reduce-emissions-and-grow-the-industry/.

4.1.3 EXPANDED INCREMENTALITY OPTIONS

Although incrementality has the benefit of motivating the deployment of new low-carbon generation sources within the grid, there may be a need to include resources that would not otherwise be available to the grid, especially in regions with low renewable resource quality, high existing baseload low-carbon generation, and regions with both characteristics. For this reason, expanded incrementality options will achieve the principle of equity in the context of disparate regional factors, while retaining the emissions integrity of the overall framework.

New nuclear and hydropower installations typically represent significant and costly infrastructure projects with considerable permitting requiring extended project timelines. As such, it is unlikely these types of new generation facilities will become significant electricity supply options for hydrogen project investments within the lifespan of the 45V credit. Some regions with limited or poor solar and onshore wind resource quality but access to existing nuclear or substantial hydropower along with sizable sources of potential demand would benefit from a low-carbon hydrogen market to decarbonize local industry and other end-uses. There is an opportunity to include these regions and their baseload generation within the early wave of 45V-aided low-carbon hydrogen production, but doing so requires examining various expanded concepts or options of incrementality.

These options could allow for incrementality in the form of demonstrated need in the face of threat of closure beyond other federal and state subsidies (for example, the 45U tax credit for existing nuclear under the IRA and the Civil Nuclear Tax Credit) given that retaining at-risk generation or avoiding retirement is no different from a new project entering the market from a net impact perspective. This could allow nuclear installations in threat of retirement to access additional demand market options. Adhering to strict standards for repowering, such as the 80/20 rule previously used by the Internal Revenue Service, could allow some participation of legacy facilities (e.g., wind farms) while maintaining strong incrementality. Expanded incrementality options could also encompass certain regions with conditions which render incrementality less material from an emissions impact perspective. This could include deliverability regions with high levels of grid decarbonization, either by intensity rate and/or renewables percentage, or effective and enforceable state emissions caps. Expanded incrementality options offer the opportunity to extend accessibility to the 45V tax credit to regions that could greatly benefit from the decarbonization that electrolysis production could provide.

4.1.4 TEMPORALITY ASSESSMENT

The potential cost impacts of a strong temporality requirement, specifically hourly matching, has been the topic of much discussion with varying views on the magnitude of this impact. The actual net cost effect is dependent upon location and even project-specific factors, but may be balanced by reduced market exposure through higher alignment of supply and demand. Wind and solar are variable by nature, and introducing a limited volume buffer can enable some operational flexibility to mitigate supply variability while still maintaining the overall integrity of an hourly temporality requirement. There are many resources available to EAC buyers, including those already providing 24/7 zero-carbon supply management services. While these options may be more prevalent for those located in competitive versus regulated markets, utilities are continually expanding their green tariff offerings and temporality may be an opportunity to structure supply options that better meet the emissions tracking and reporting needs of end-users.

The temporality pillar presents an opportunity for grid modernization and adaptation to increasing penetration of variable renewable sources of generation in the grid. Independent of the 45V tax credit and the deployment of electrolysis production, there is expected to be a large expansion in the amount of renewable generation attached to the grid throughout the U.S. driven by declining technology costs, IRA tax credits, and state policies. Renewable generation sources like wind and solar come with novel challenges for the grid compared to traditional fossil fuels because their generation output is inherently tied to variable inputs such as wind speed and sunlight, which fluctuate day to day and hour to hour. There is some degree of adaptation required by the grid to optimize certain processes around the variable nature of these renewables. Phasing in hourly matching could allow operators, producers, and tracking systems time to scale hourly certificate systems, as well as adapt and plan for the degree of costs and operations associated with hourly matching. Energy tracking providers suggest hourly certificates can be made available nationwide in a relatively short time frame (within 12 to 18 months). Through requiring strong temporality measures in the form of hourly matching, 45V guidelines could incentivize and create demand support for optimal grid solutions and system-wide investments, including efficient deployment of energy generation tax credits. This includes other forms of grid management solutions by highlighting time periods of low renewable generation as well as periods of high renewable generation, which can encourage more efficient use of potential curtailment volumes. Strong temporality requirements could also indirectly help the continued evolution of the use and application of market-based mechanisms in the electricity market and robust emissions accounting through improved data management, such as development of centralized certificate tracking and residual emissions reference resources.

4.1.5 DELIVERABILITY ASSESSMENT

The interaction the deliverability and particularly temporality pillars have with regionality is a notable strength of the three-pillar framework. By requiring that low-carbon electricity for electrolysis production be both local and matched, deliverability and temporality drive the focus on leveraging local resources for the establishment of regional low-carbon hydrogen economies; this supports the DOE’s goals for hydrogen strategy, which underscores the development of regional networks of low-carbon hydrogen production. A focus on regional solutions could help establish value chains that remain robust past tax credit expiration. It also presents the opportunity to advance a diverse set of decarbonization solutions, as each region will develop and deploy a toolkit tailored to the region’s specific available resources, whether high-quality low-carbon generation or abundant gas and sequestration. However, although the interaction of the pillars and regionality present the opportunity to establish robust value chains and diversified decarbonization solutions, it also means that some regions may not be positioned to be first movers on electrolysis production, particularly wind- and solar-based electrolysis; there is a spectrum of how material each pillar and specific guideline will be for each region. However, there are also a variety of avenues which regions can follow to establish low-carbon hydrogen markets. The electrolysis production pathway may be more advantageous for some regions once development of hydrogen markets and technology costs decline to the point where electrolysis production becomes more economically feasible for these second-stage adoption regions.

4.1.6 WORKABILITY ASSESSMENT: MARKET STRUCTURES AND DATA AVAILABILITY

Another interaction of regionality and the pillar guidelines could become evident at the grid operator level, as ISOs and non-ISOs have varying market structures and data availability that could affect implementation of 45V guidance and the deployment of electrolysis production. This is likely to be a challenge at some level under any system of book-and-claim accounting (i.e., regardless of whether a three-pillar framework is adopted or not). Although it could be a challenge to ensure that all regions are easily able to participate in electrolysis production deployment regardless of grid operator, the three-pillar framework also contains the opportunity to advance capabilities across all grid operation styles, and promotes convergence of methodologies and data availability between grid operators. This in turn provides additional transparency to all market participants, increasing the robustness of the evolution of voluntary and compliance markets and applications. The tax credit could be an incentive to build uniform data sets and calculation methodologies across the nation, which would increase transparency across grid regions. This would serve to strengthen grid operations through increased data availability and increased development and uptake of best practices for calculating grid-related emissions, to support both hydrogen and other grid-connected decarbonization efforts.

5. CONCLUSION

The 45V guidance presents the significant opportunity to shape the low-carbon hydrogen economy in the U.S. from its earliest stages. With strong requirements for all three pillars, there will be no need to transition from an initial state of non-optimized emissions reductions to a truly low-carbon hydrogen economy. Strong requirements will also build confidence, public support, and provide a defensible decarbonization stance to electrolysis producers and end-users of low-carbon hydrogen; this includes increased alignment with (and possible exceedance of) international market requirements such as the EU. If 45V's goal is to facilitate the establishment of a strong low-carbon hydrogen economy, it is reasonable to prioritize the establishment of low-carbon value chains in this novel industry through early commitments to low-carbon processes; shaping the guidance framework and incorporating the pillars in a way that leads to strong decarbonization principles is an opportunity to do just this.

Furthermore, 45V guidelines will provide guidance and serve as a precedent for future tax credits, policies, or regulations to reference. For example, USEPA's May 2023 proposed rule for limiting GHG emissions from natural gas electric generating units under Section 111 of the Clean Air Act contained a definition of "low-GHG" hydrogen that aligns with the lowest tier available under 45V. In this manner, the 45V PTC could be expected to continue to support future hydrogen-related decarbonization initiatives and other regulations relating to low-carbon production that are grid-connected, even after the expiration of the tax credit itself, setting a strong precedent and an opportunity to influence these future measures.

APPENDIX A MAP REFERENCES

FIGURE A 1: DOE *NATIONAL TRANSMISSION NEEDS STUDY* GEOGRAPHIC REGIONS

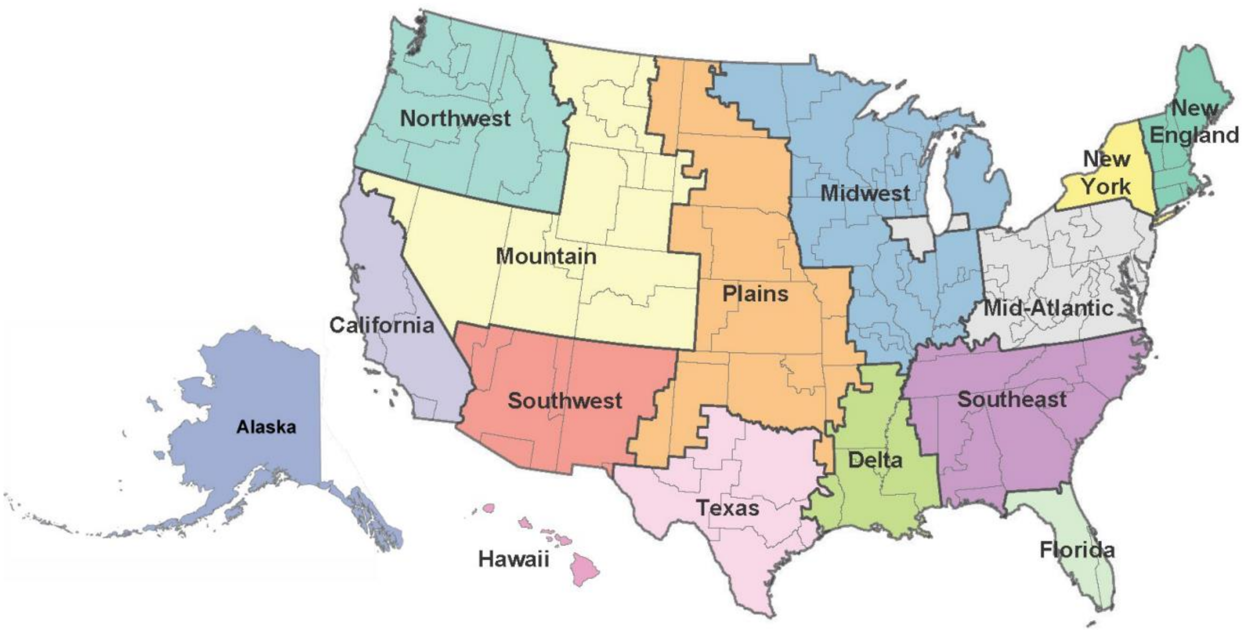


FIGURE A 2: CAMBIUM MODEL REGIONS MAP

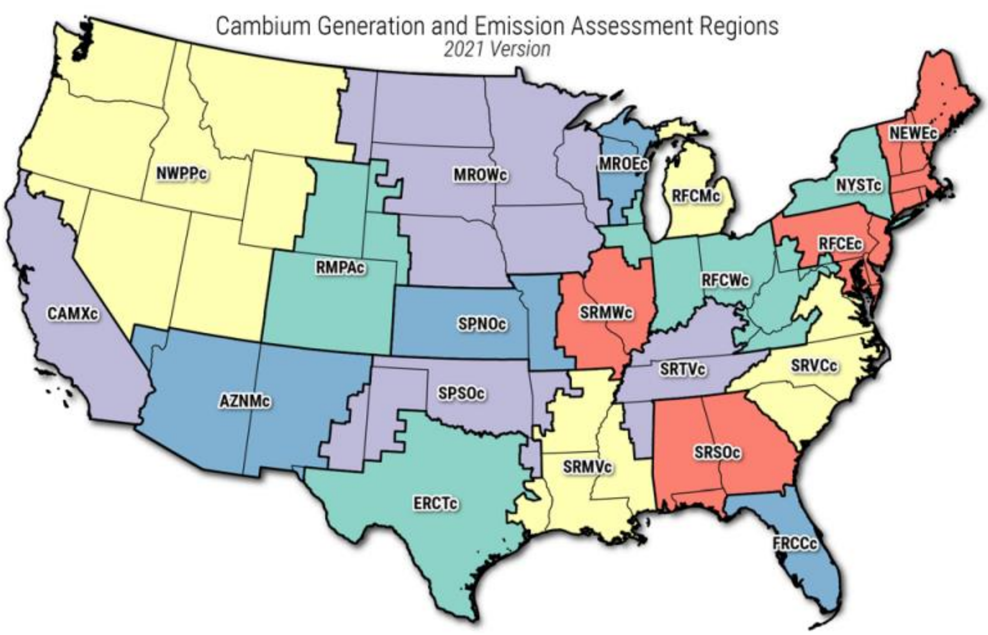
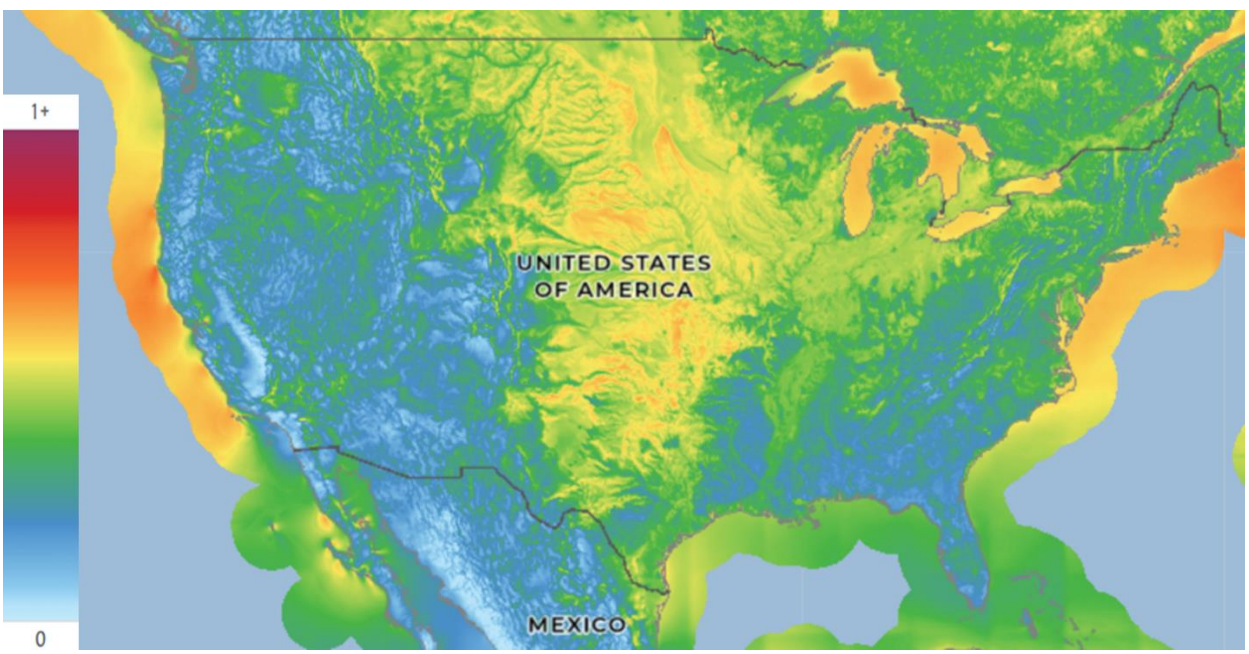


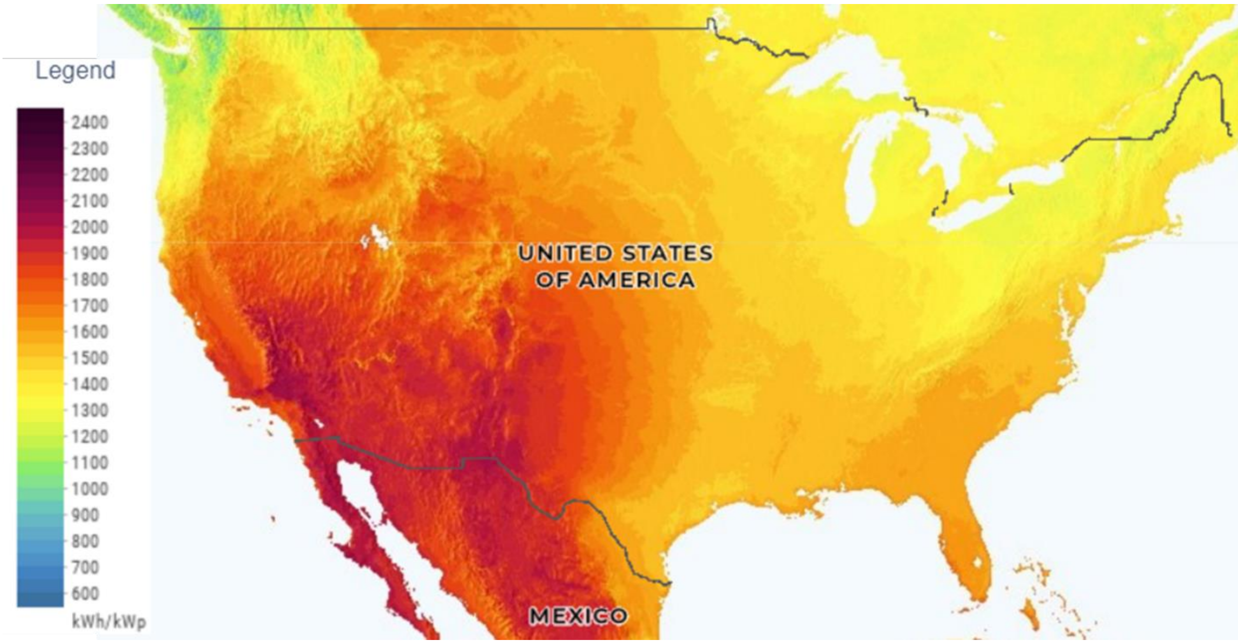
FIGURE A 3: EGRID SUBREGIONS

FIGURE A 4: WIND RESOURCE BY ANNUAL CAPACITY FACTORS[68]



[68] Global Wind Atlas 3.0 by the Technical University of Denmark (DTU), "IEC Class II capacity factor energy wind layer", August 2023, https://globalwindatlas.info

FIGURE A 5: SOLAR RESOURCE BY ANNUAL CAPACITY FACTORS[69]

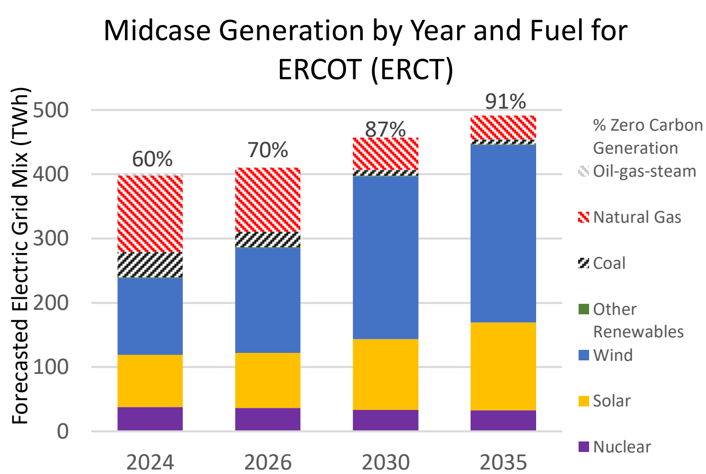


[69] Global Solar Atlas 2.0, "Photovoltaic power output of a fixed-axis system measured in kWh/kWp, which is reflective of annual capacity factors.", August 2023, https://globalsolaratlas.info

APPENDIX B REGIONAL SUMMARIES

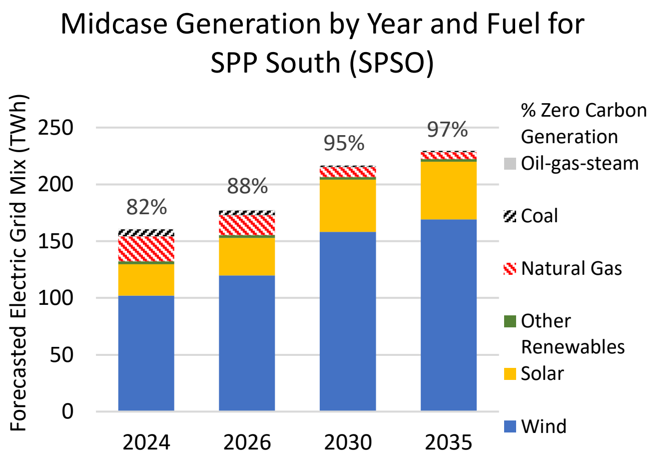
The sections below provide a high-level overview of hydrogen supply and demand considerations for various regions within the U.S. which could influence whether a region is poised to be an early stage focused region for clean hydrogen and specifically for electrolysis. Overview descriptions are drawn from the DOE National Clean Hydrogen Strategy and Roadmap, DOE's H2IQ webinars, and Carbon Solutions' The Landscape of Clean Hydrogen report.[70,71] Accompanying each Section is a summary of the modeled generation mix projections by fuel type for a representative area based on the NREL Cambium Midcase Scenario for the U.S. electricity market. A map of the model regions is represented by Figure A1 in Appendix A. References to renewables as a percentage of the grid mix include biomass, geothermal, hydro, solar, onshore wind, and offshore wind. Percentages of zero-carbon generation include nuclear. The Midcase scenario uses central estimates for inputs such as technology costs, fuel prices, demand growth, and the IRA's clean electricity PTC and ITC are assumed not to phase out. A full description of each scenario can be found in the Cambium 2022 Scenario Descriptions and Documentation.[72] Additional generation projections for additional Cambium modeled regions are in Appendix C.

Texas benefits from both substantial wind and solar potential and has the largest amount of renewable energy projected in NREL's Midcase with around 413 terawatt hours of renewable generation by 2035 or 80 percent of the generation mix as illustrated below (note renewables are a subset of zero carbon generation). Texas also has several viable options for near-term demand. Proximity to the Gulf Coast opens access to heavy industry end-uses including oil refining and processing, as well as ammonia, methanol, metallic ore, and low-carbon steel production. The Gulf of Mexico and the Mississippi River provide both inland domestic and international shipping options, supporting a wider range of low-carbon hydrogen end-uses. The combination and proximity of industrial demand and high-quality wind and solar make Texas a strong candidate for early adoption of low-carbon hydrogen production. Additionally, the majority of current U.S. hydrogen production is concentrated around the Gulf, facilitating low-carbon hydrogen uptake through existing hydrogen infrastructure and easy substitution into value chains.

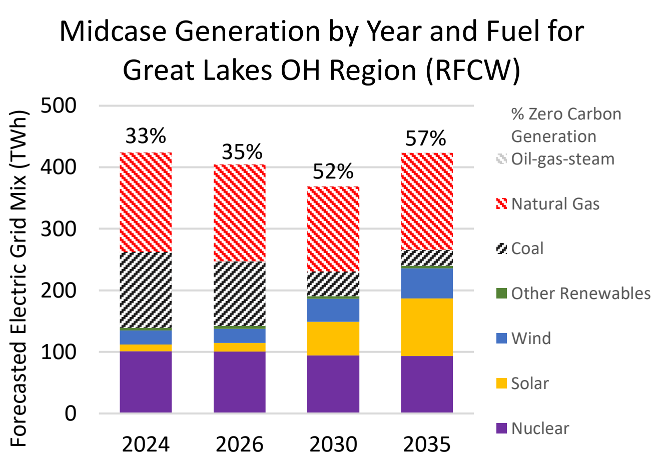


[70] DOE (U.S. Department of Energy), "National Clean Hydrogen Strategy and Roadmap," June 2023, https://www.hydrogen.energy.gov/pdfs/us-national-clean-hydrogen-strategy-roadmap.pdf
[71] DOE (U.S. Department of Energy), "DOE Update on Hydrogen Shot, RFI Results, and Summary of Hydrogen Provisions in the Bipartisan Infrastructure Law," https://www.energy.gov/sites/default/files/2021-12/h2iq-12082021.pdf
[72] Gagnon, Pieter, Brady Cowiestoll, and Marty Schwarz. "Cambium 2022 Scenario Descriptions and Documentation. Golden, CO: National Renewable Energy Laboratory", NREL/TP-6A40-84916, 2023, https://www.nrel.gov/docs/fy23osti/84916.pdf.

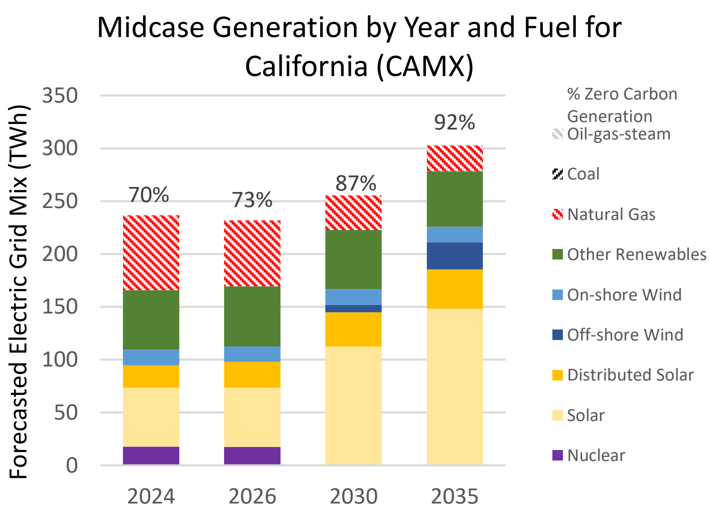
The Greater Plains have considerable potential for low-carbon generation in onshore wind and solar. The largest areas of high-quality onshore wind in the U.S. occupy a corridor which covers the entirety of the Central Plains, stretching from the Dakotas in the north all the way south into West Texas. These ample wind resources are complemented by significant solar resources, particularly to the west. Some areas of this region may reach over 90 percent generation mix from renewables in 2030 and 2035 as reflected here for SPP South. Low-carbon hydrogen production in the Greater Plains could also feed into regional sources of demand. For example, the Greater Plains already produce large amounts of ammonia-based fertilizers for regional agricultural demands, making low-carbon ammonia and ammonium nitrate a major near-term market for low-carbon hydrogen in the region. Refineries in the region could also decarbonize by using low-carbon hydrogen as a feedstock, providing another ready source of demand.



The Great Lakes region boasts a significant demand opportunity in the steel-making industry, for which low-carbon hydrogen represents a ready replacement for natural gas as both a heat source and chemical catalyst. The majority of the steel-making industry in the U.S. is concentrated around the Great Lakes region, along with ample cement and ammonia production among other metal, ore, and chemicals industries. While the Great Lakes enjoys industrial demand for low-carbon hydrogen, concentrated to the north and east, the quality of renewable resources in the region varies with greater solar and wind resources westward. Some regions may only reach 18 percent renewables in 2035, while others may reach 83 percent. Increased transmission connectivity and corresponding expansion of deliverability boundaries could address this and allow low-carbon wind-generated electricity to supply electrolyzers located near steel or chemicals plants. Nuclear power is also a material contributor to the generation mix across the region. The chart to the left displays the Great Lakes Ohio region or RFC West as an example of this diverse region.

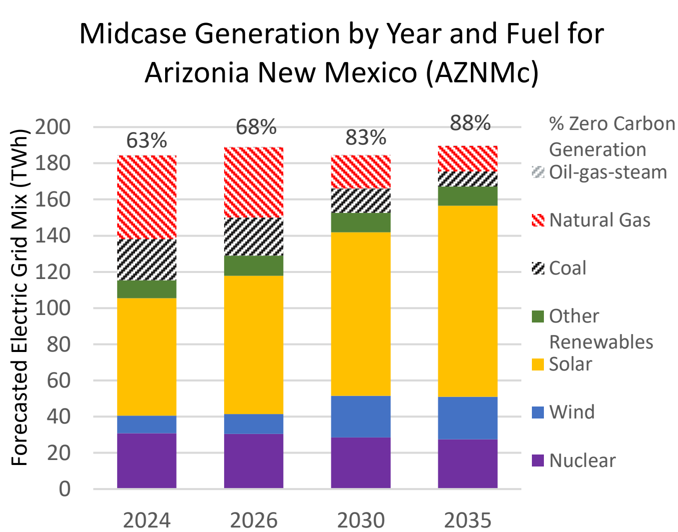


California has potential for large amounts of solar, supplemented by onshore and potential for increased offshore wind. Note, nuclear power in California is modeled to be zero by 2030 in this scenario. Renewable energy generation reaches just below 80 percent in 2030 and 2035, with the majority being from solar as reflected in the graph below. Northern and Southern California may need to deploy alternative strategies for electrolytic production deployment. While Southern California has quality solar and onshore wind potential, the region will have to consider access to water as a potentially restricting factor. Hourly temporality considerations may also impact Southern California if there is a strong reliance on solar. California has a large potential for quality renewables as well as proximate markets of demand.

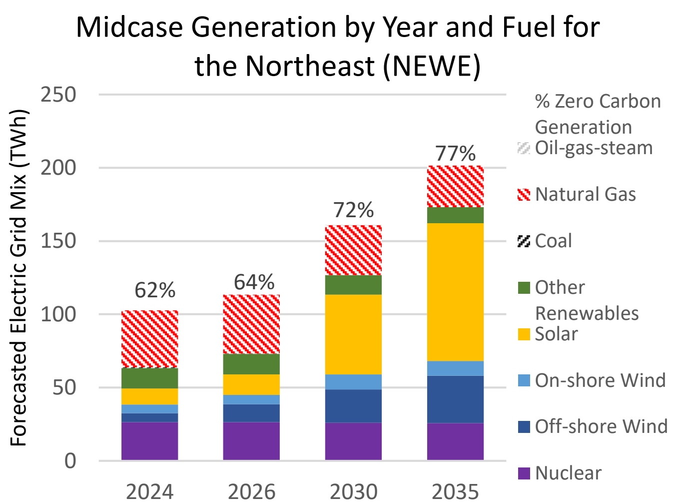


California could find demand markets in refining and ammonia and is well-positioned to explore the use of hydrogen in fueling, as all current U.S. hydrogen refueling stations are in the state. California already invests in research and development of transportation and refueling infrastructure for hydrogen fuel cell vehicles to reach the state's carbon neutrality goals. This includes medium- and heavy-duty vehicles for the purpose of decarbonizing shipping and transportation. California could also find sources of demand in ports through both Pacific shipping with low-carbon hydrogen based marine fuels and use of low-carbon hydrogen for port site activities.

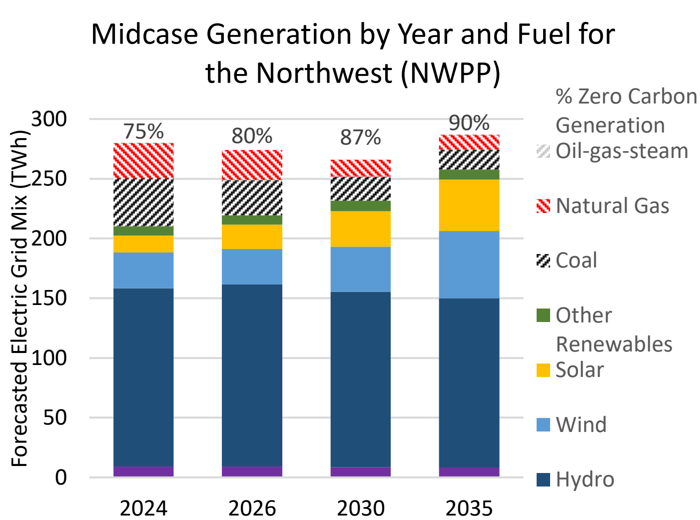
The Southwest has substantial potential for solar generation, some of the highest quality in the country, along with quality wind potential to the east. A high dependence on solar will make the temporality measures of 45V guidance particularly material for the Southwest. Securing sufficient sources of demand will also be important for low-carbon hydrogen production in the Southwest, as there is less clustered industry in this region than there is elsewhere in the country. The DOE and Carbon Solutions suggest interacting with neighboring hydrogen markets in California and Texas to establish demand for Southwest-generated low-carbon hydrogen. Demand could flow from hydrogen fueling stations on heavy freight routes into California, or from exporting hydrogen to California for other end-uses. Although the Southwest will have ample low-carbon electricity, low-carbon hydrogen producers must also secure water for electrolysis. Water security may be a key issue for the viability and sustainability of electrolysis in this region.



The Northeast does not possess particularly high-quality onshore wind or solar potential when compared to other regions. However, there is large potential for offshore wind generation in the region, which could provide low-carbon electricity for electrolysis deployment that would benefit from its higher capacity factors. The graph below displays the New England region, a representative electric mix for the Northeast. Nuclear is also a key component to the electricity mix. Existing hydropower in other parts of the region could also be used to support low-carbon hydrogen production but is contingent upon similar incrementality considerations as nuclear. The broader Northeast has several avenues for demand. The region hosts industrial end-uses where low-carbon hydrogen could decarbonize industrial processes such as cement, pulp and paper, chemical production, and refining, although industrial demand is smaller in the Northeast compared to other regions in the U.S. The Northeast also possesses a large share of national medium- and heavy-duty vehicle traffic, particularly along heavily trafficked roads like Interstate 95, presenting an opportunity for demand in transportation and shipping.



The Northwest possesses some potential for wind generation, but the highest quality resource in this region is hydropower which has ranged from 55 to 78 percent of the annual generation for Washington and Oregon over the last five years.[73] Low-carbon hydrogen production in the region therefore may be heavily influenced by guidelines surrounding 45V eligibility relating to existing hydropower and/or state emissions caps. The Northwest has comparatively little presence of near-term hydrogen-related industries, although there is some extant refining industry around Seattle. Therefore, the region must secure sources of demand which could include decarbonization in shipping and fuels, particularly through ports.



[73] U.S. EIA, "Electricity Data Browser, Washington, Oregon, Net generation all sectors, All fuels, Conventional hydroelectric, Annual, 2018-2022", April 2023, https://www.eia.gov/electricity/data/browser/.

SCENARIO CONSIDERATIONS

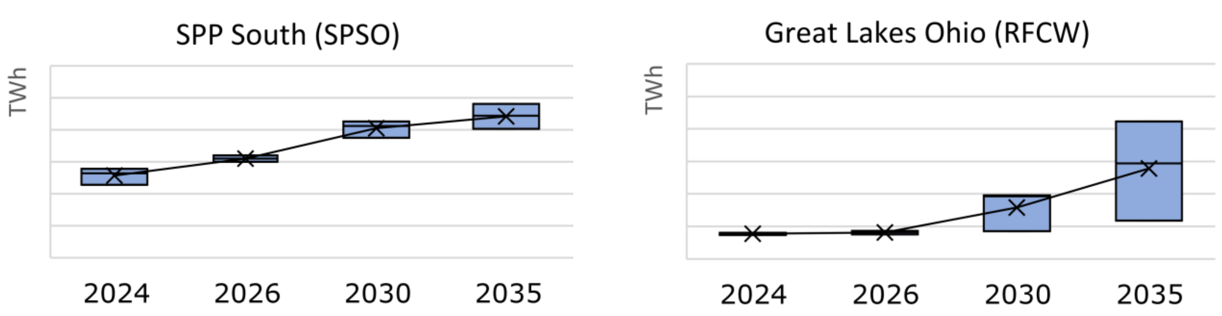
Many factors can influence the pace and magnitude of renewable electricity growth, primarily driven by wind and solar, and therefore the potential for clean electricity supply for electrolysis. The Midcase represented in the prior Section is just one scenario. Regions which demonstrate consistent growth under a range of scenarios are typically those with quality resources which reflect more robust economics for those generation sources. As the resource quality decreases or other resources in the region prove to be more robust economically, the renewable growth potential has a wider range under varying scenarios. Regions which demonstrate consistently minimal growth under a range of scenarios reflect low potential for wind and solar growth and are unlikely to be regions focused on electrolysis for hydrogen unless supplied by existing nuclear or sustainable hydro. This variation on potential low-carbon electricity supply, specifically wind and solar, provides necessary additional context for evaluating the regional characteristics which could differentiate early movers from marginal or later movers in electrolysis and therefore help to prioritize areas of focus for potential impacts from framework guidelines.

NREL's Cambium 2022 data sets contain a range of modeled projections for the U.S. electric sector. To demonstrate the variability in renewables growth, the renewables generation in years 2024, 2030, and 2035 were compared across three different scenarios. The High Renewable Cost case uses the same set of base assumptions as the Midcase, but where renewable energy and battery costs are assumed to be high. The High Electrification case has the same set of base assumptions as the Midcase scenario but where a higher demand growth is assumed to represent higher rates of electrification than the base assumption. A full description of each scenario can be found in the Cambium 2022 Scenario Descriptions and Documentation.[74] These three scenarios were selected to represent a range of renewable generation projections.

A general theme across the majority of NREL regions is that the High Electrification case projected the largest amount of renewable energy generation, and the High Renewable Cost case projected the smallest. Regions with low variability across scenarios demonstrate a potentially higher confidence level in the zero-carbon generation projections. SPP South is an example of a region with robust renewable growth projections as seen on Figure B1. Large variation ranges have potential for renewable growth but need more conditions to be met to reach the higher levels forecasted, with a range of variables impacting magnitude of growth. The Great Lakes Ohio area as represented by RFC West is an example of a region with a higher level of variability demonstrated across the selected scenarios as seen on Figure B1. Scenario comparisons for additional Cambium modeled regions are in Appendix C.

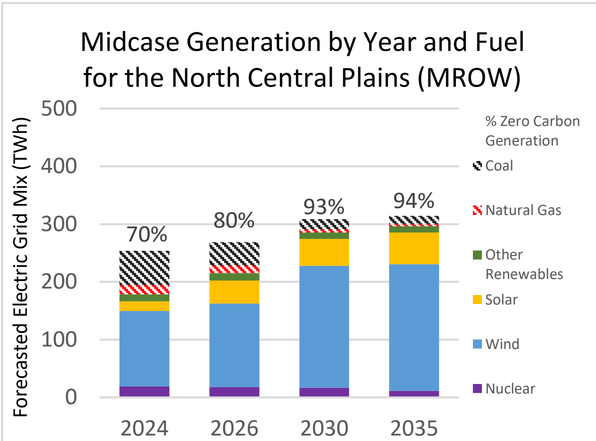
[74] Gagnon, Pieter, Brady Cowiestoll, and Marty Schwarz. "Cambium 2022 Scenario Descriptions and Documentation. Golden, CO: National Renewable Energy Laboratory", NREL/TP-6A40-84916, 2023, https://www.nrel.gov/docs/fy23osti/84916.pdf.

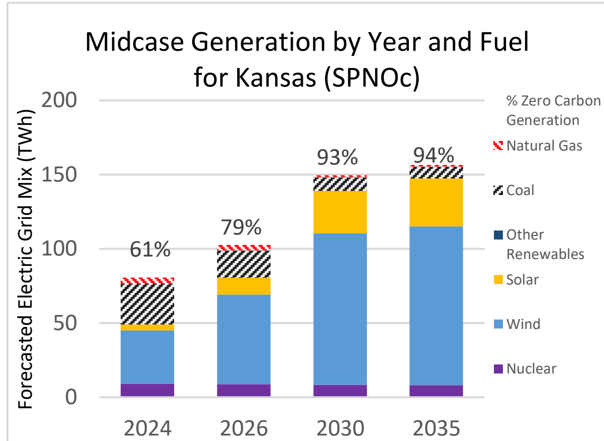
FIGURE B 1: SCENARIO RANGE PROJECTIONS FOR RENEWABLE GROWTH IN SPP SOUTH (SPSO) AND GREAT LAKES OHIO (RFC WEST)

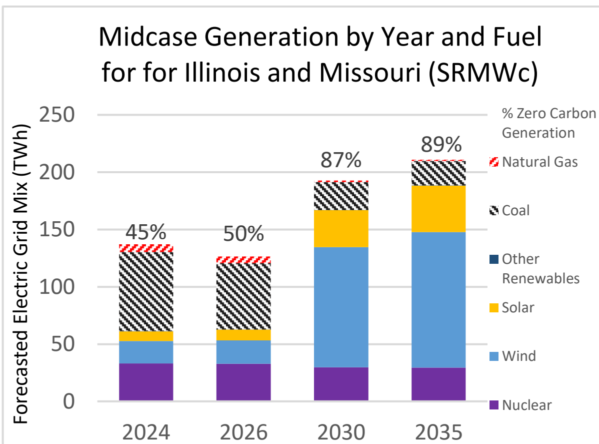


APPENDIX C ADDITIONAL CAMBIUM FORECASTED DATA

FIGURE C 1: MIDCASE GENERATION BY YEAR AND FUEL FOR SELECT REGIONS


Midcase Generation by Year and Fuel
for the North Central Plains (MROW)
Forecasted Electric Grid Mix (TWh)
500
400
300
200
100
0
70%
80%
93%
94%
2024
2026
2030
2035
% Zero Carbon Generation
Coal
Natural Gas
Other Renewables
Solar
Wind
Nuclear


Midcase Generation by Year and Fuel
for Kansas (SPNOc)
Forecasted Electric Grid Mix (TWh)
200
150
100
50
0
61%
79%
93%
94%
2024
2026
2030
2035
% Zero Carbon Generation
Natural Gas
Coal
Other Renewables
Solar
Wind
Nuclear


Midcase Generation by Year and Fuel
for for Illinois and Missouri (SRMWc)
Forecasted Electric Grid Mix (TWh)
250
200
150
100
50
0
45%
50%
87%
89%
2024
2026
2030
2035
% Zero Carbon Generation
Natural Gas
Coal
Other Renewables
Solar
Wind
Nuclear

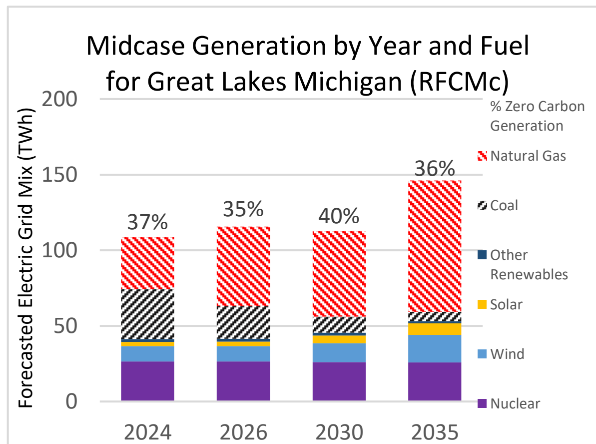
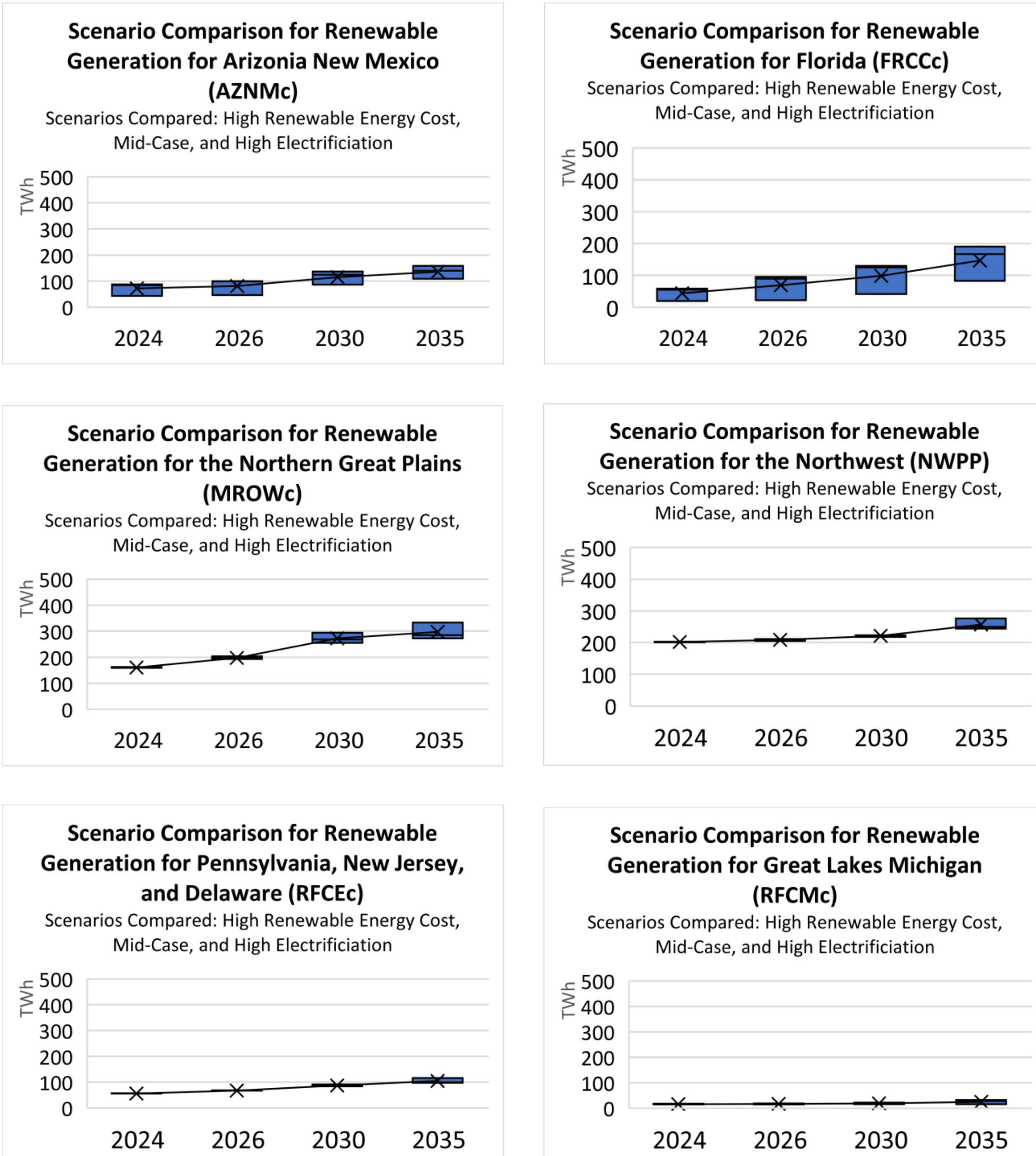
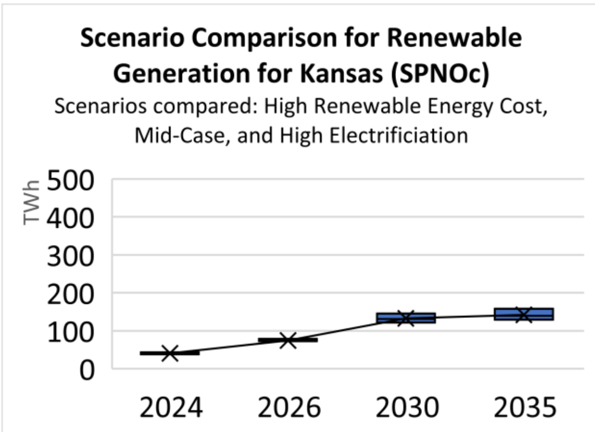
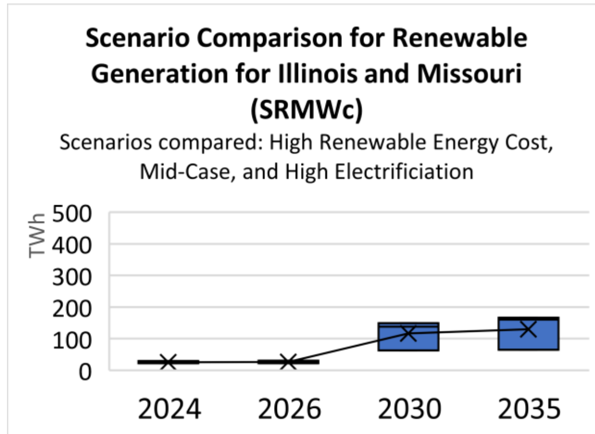
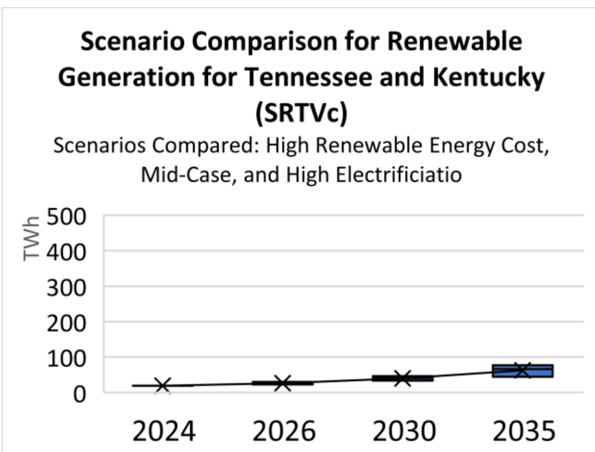

Midcase Generation by Year and Fuel
for Great Lakes Michigan (RFCMc)
Forecasted Electric Grid Mix (TWh)
200
150
100
50
0
37%
35%
40%
36%
2024
2026
2030
2035
% Zero Carbon Generation
Natural Gas
Coal
Other Renewables
Solar
Wind
Nuclear

FIGURE C 2: CAMBIUM SCENARIO COMPARISONS FOR RENEWABLE GENERATION




Scenario Comparison for Renewable Generation for Kansas (SPNOc)
Scenarios compared: High Renewable Energy Cost, Mid-Case, and High Electrificiation
TWh
500
400
300
200
100
0
2024
2026
2030
2035


Scenario Comparison for Renewable Generation for Illinois and Missouri (SRMWc)
Scenarios compared: High Renewable Energy Cost, Mid-Case, and High Electrificiation
TWh
500
400
300
200
100
0
2024
2026
2030
2035


Scenario Comparison for Renewable Generation for Tennessee and Kentucky (SRTVc)
Scenarios Compared: High Renewable Energy Cost, Mid-Case, and High Electrificiatio
TWh
500
400
300
200
100
0
2024
2026
2030
2035

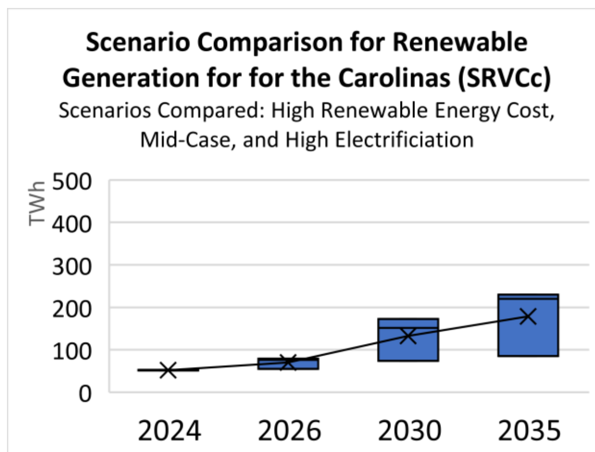
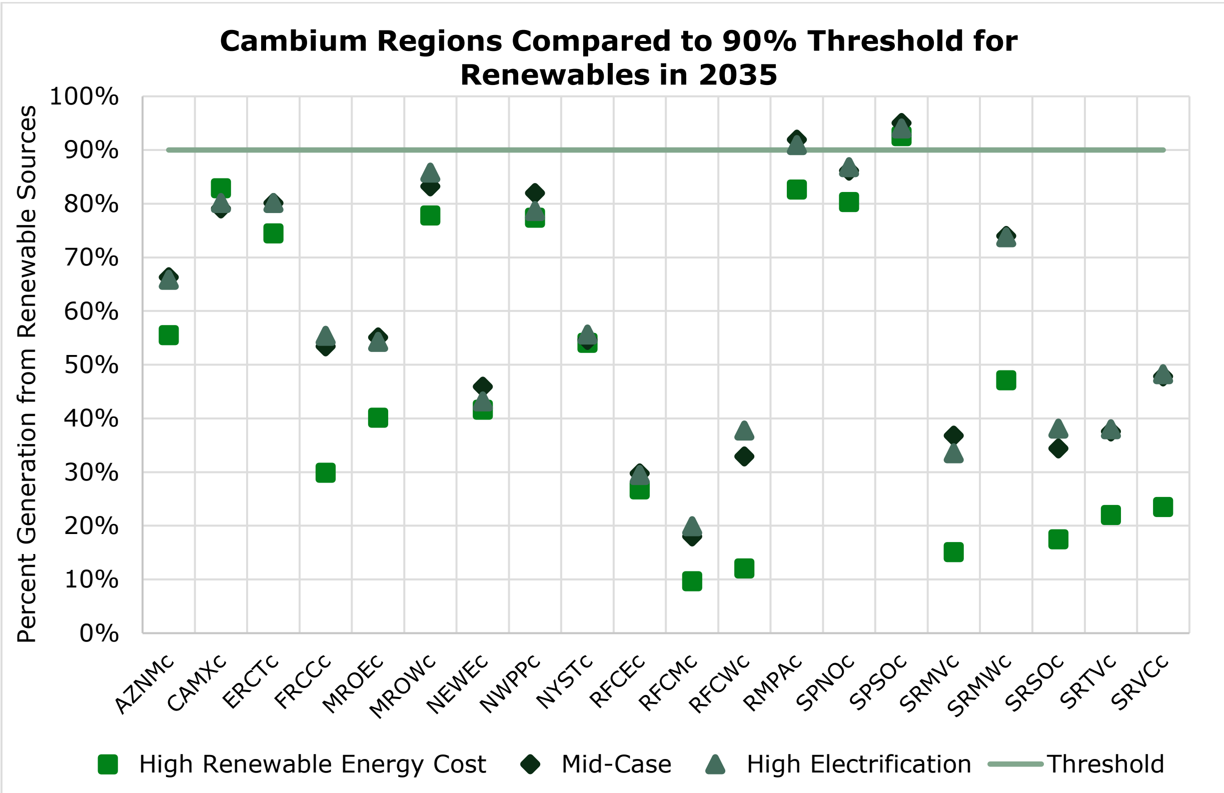
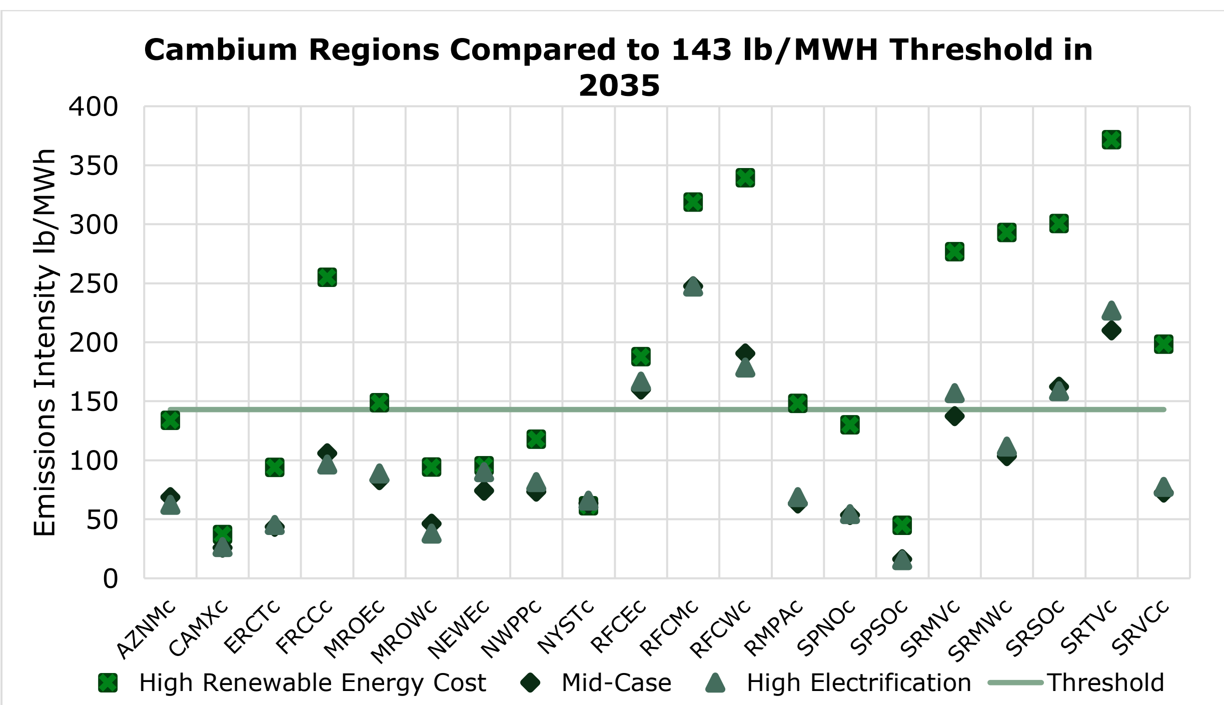

Scenario Comparison for Renewable Generation for for the Carolinas (SRVCc)
Scenarios Compared: High Renewable Energy Cost, Mid-Case, and High Electrificiation
TWh
500
400
300
200
100
0
2024
2026
2030
2035

FIGURE C 3: CAMBIUM REGIONAL RENEWABLES PERCENTAGES AND GRID INTENSITIES BY SCENARIO VERSUS EXAMPLE THRESHOLDS IN 2035





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