Benchmarking Methane and Other GHG Emissions

Of Oil & Natural Gas Production in the United States

July 2022

Data Downloads at: www.sustainability.com

CLEAN AIR TASK FORCE

Ceres

Sustainability is the bottom line.

Acknowledgements

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Report Authors: Tom Curry, Luke Hellgren, Pye Russell, Sierra Fraioli

For questions or comments about this report, please contact:
Tom Curry, ERM
Email: tom.curry@erm.com

Data used in this report can also be accessed via an interactive data platform hosted at www.sustainability.com.

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Key Findings

- Of 303 oil and natural gas producers with reported data, the top 100 oil and gas producers by total energy production were responsible for approximately 74% and 77%, respectively, of total reported methane and GHG emissions in 2020. While most top-100 producers are also among the top 100 emitters, production rank does not correspond to emissions rank.
- The methane emissions intensity of natural gas production and the GHG emissions intensity of oil and gas production varies dramatically across producers. Natural gas producers in the highest quartile of methane emissions intensity have an average emissions intensity that is nearly 24 times higher than natural gas producers in the lowest quartile of methane emissions intensity. Oil and gas producers in the highest quartile of GHG emissions intensity have an average emissions intensity that is more than 13 times higher than oil and gas producers in the lowest quartile.
- Pneumatic controllers were the largest source of total reported production-segment methane emissions, making up 62% of total reported methane emissions.
- Fuel combustion equipment, such as engines and heaters, were the largest source of total reported production-segment CO_2 emissions, responsible for 58% of total reported CO_2 emissions.
- In oil-heavy basins, associated gas venting and flaring can be a significant contributor to GHG emissions. In the Williston basin, for example, this source is responsible for 59% of total GHG emissions. In gas-heavy basins, associated gas is limited or non-existent; for example, there was no reported associated gas venting and flaring in the Appalachian basin. Across all basins, associated gas venting and flaring was responsible for 14% of total reported onshore production-segment GHG emissions.
- Methane and GHG intensity declined 29% and 23%, respectively, between 2018 and 2020 due to an increase in natural gas and total hydrocarbon production reported to EPA and a reduction in reported methane and total GHG emissions. However, these trends are not consistent across basins or individual companies and can fluctuate year to year (e.g., increase 2018-2019 and decrease 2019-2020).
- The 2018-2020 decline in methane was driven by a reduction of reported emissions from pneumatic controllers, while associated gas venting and flaring were responsible for the largest decrease in reported CO_2 emissions.

Benchmarking Methane and Other GHG Emissions

Of Oil & Natural Gas Production in the United States

Download detailed data from the 2022 Benchmarking GHG Emissions report at: www.sustainability.com

Oil & Gas Production in the United States

The oil and gas production sector in the United States includes a wide array of companies that produce hydrocarbons from diverse geographies and geological formations. For 2020, companies reported to the U.S. Environmental Protection Agency (EPA) information on over 505 thousand onshore wells which together produced almost 33 trillion cubic feet of natural gas and nearly 3 billion barrels of oil. Onshore oil and gas production reported under EPA's Greenhouse Gas Reporting program declined 3.5% and increased 1.6%, respectively, from 2019 to 2020.

Background

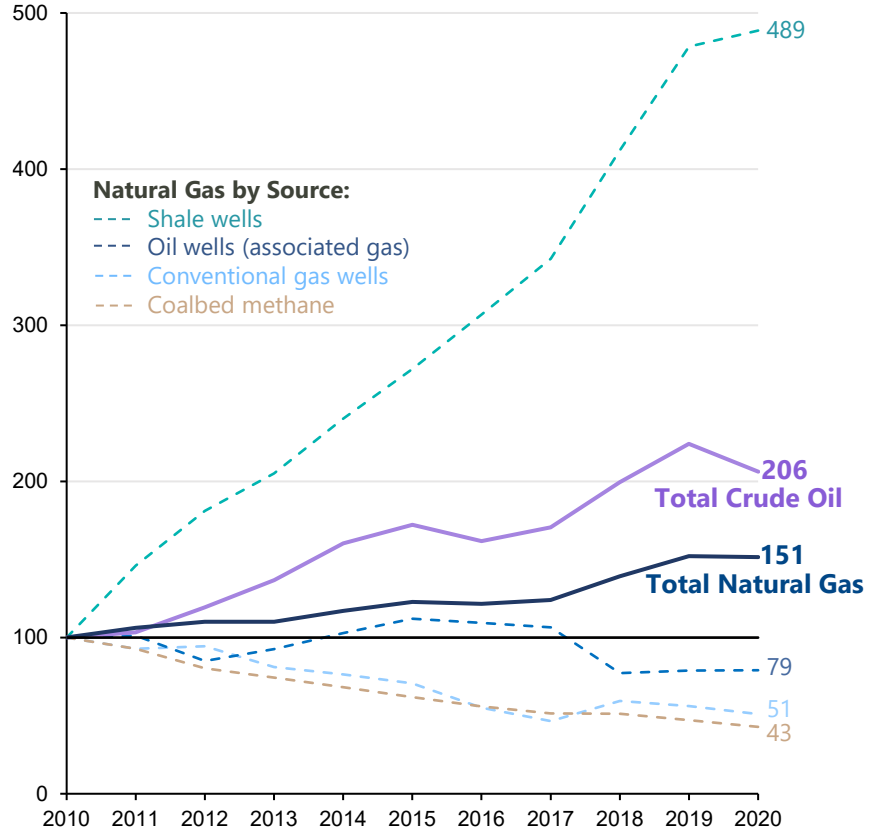
Concern over climate change has brought increased focus on methane and greenhouse gas emissions associated with oil and gas production. These emissions, especially methane, diminish the greenhouse gas benefits of using gas in place of coal for power generation and represent a significant source of climate pollution. In addition, a growing body of research indicates that total methane emissions associated with oil and natural gas production are substantially higher than those reported in official inventories. A wide range of stakeholders, including policymakers, fuel purchasers, environmental organizations, and financial institutions, are interested in better understanding industry-wide and company-specific emissions trends. Oil and gas companies that minimize and most effectively manage their emissions will be best positioned for a low-carbon future.

Stakeholder engagement with the industry—and the industry's ability to benchmark its own performance—has been stymied by a lack of clear and consistently calculated metrics, forcing stakeholders and companies to rely on voluntary metrics reported by companies that are often incomplete or non-comparable. The 2022 Oil & Gas Benchmarking Report is a collaborative effort that uses publicly available data to develop comparable metrics that highlight the GHG performance of onshore oil and gas producers in the U.S. The report uses data reported to EPA under Subpart W of the Greenhouse Gas Reporting Program (GHGRP) and data calculated from assumptions in EPA's annual Greenhouse Gas Inventory (GHG Inventory).* The report focuses on the onshore oil and natural gas production segments and does not include emissions or production from offshore operations, gathering & boosting facilities, or other midstream or downstream segments of the oil and gas supply chains. This report focuses on 2020 production and emissions data and includes production and emissions trends for 2018 to 2020.

Data Year and Company Operations

GHGRP data for the previous calendar year are reported to EPA by March 31 and published by EPA the following October. This report focuses on 2020 data, the most recent year for which data are currently available. It is important to note that current company production and emissions may be significantly different for individual facilities and companies due to operational changes and changes in asset ownership.

U.S. Hydrocarbon Production
(Indexed; 2010 = 100)



* For simplicity, the emissions captured in this report are referred to as "reported emissions"

Introduction and Overview of Oil & Gas Data

Data on U.S. oil and gas production and air emissions are available to the public through several databases maintained by state and federal agencies. Publicly-traded and privately-held oil and gas producers are required to report production and GHG emissions data under EPA's GHGRP for any basin in which their annual GHG emissions exceed 25,000 metric tons of carbon dioxide equivalent (CO_2e). In this report, these data are combined for companies operating in multiple basins and presented such that company-level comparisons can be made across U.S. onshore production operations.

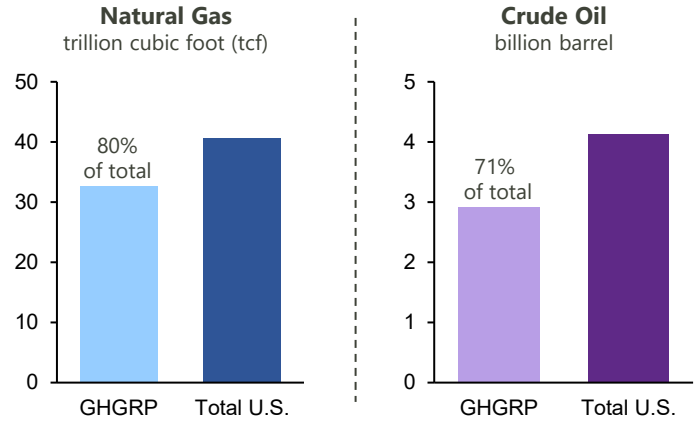
The Oil & Gas Benchmarking Report facilitates the comparison of emissions performance by using reported production and emissions data to calculate methane and GHG emissions intensities and presenting this information and source data in a graphical format that aids in understanding and evaluating the data. The report is intended for a wide audience, including oil and gas industry executives, oil and gas operators, environmental advocates, financial analysts, investors, journalists, and public policymakers.

The methane and GHG emissions included in this report do not capture total emissions from the onshore production segment for several reasons. Most importantly, the GHGRP's methodology relies in part on emission factors that do not properly account for emissions from infrequent, high-emitting occurrences and therefore underestimates emissions from sources covered by the program. In addition, emissions from facilities below the GHGRP reporting threshold are not included. Further, the GHGRP does not require all production segment emission sources (i.e., equipment or processes) to report emissions. As result of these factors, actual emissions from the production segment are higher than the numbers reported to EPA.

Global Warming Potential (GWP)

This report uses GWPs from the Sixth Assessment Report of the Intergovernmental Panel on Climate Change (AR6). The 2021 version of this report used GWPs from the Fifth Assessment Report, which were current at the time of publication. While data for all years in this report and the online data dashboard use AR6 GWPs, the emissions data in this written report cannot be directly compared with the emissions data in the 2021 written report. Note that the CO_2e values in this report also differ from those published in EPA's GHGRP database, as the GHGRP currently uses GWPs from the Fourth Assessment Report.

2020 Hydrocarbon Production
GHGRP vs. Total U.S.[1]



[1] Source: U.S. EIA

Relative Scope of Data Analyzed (2020)

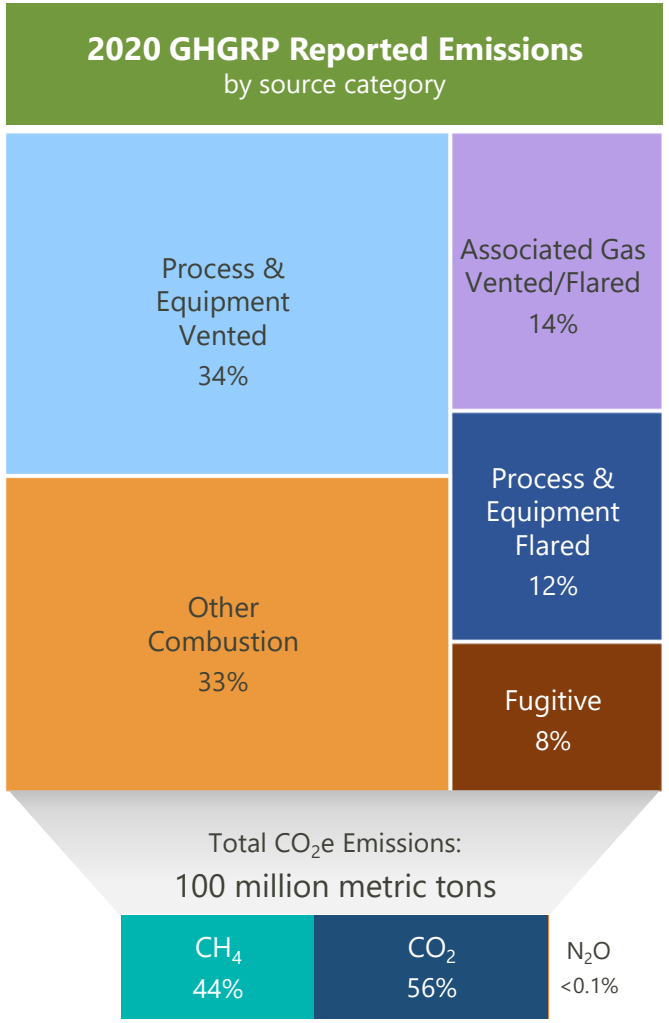
- Onshore oil & gas production reported to the GHGRP represents 71% of total U.S. annual oil production and 80% of total U.S. annual gas production
- Reported onshore production segment methane represents 46% of total methane reported under Subpart W
- Reported onshore production segment CO_2e represents 41% of total CO_2e reported under Subpart W
- Oil and gas production reported to GHGRP as a percent of total U.S. oil and gas production increased 2019-2020

Types of Emissions Associated with Oil & Gas Production

The GHGRP includes reporting on emissions from 17 emission sources (see page 74). In addition, this report attributes emissions associated with six additional sources that are estimated at the national level by EPA in the GHG Inventory, but not included in GHGRP (see page 75). The relative contribution of GHG emissions from oil and gas production can vary widely by both type of gas and emissions source. Factors influencing the relative contribution of emissions include geology, targeted hydrocarbons (e.g., dry gas vs. wet gas), available infrastructure, and company policies and practices.

For purposes of comparison within this report, emission sources are grouped into five categories:

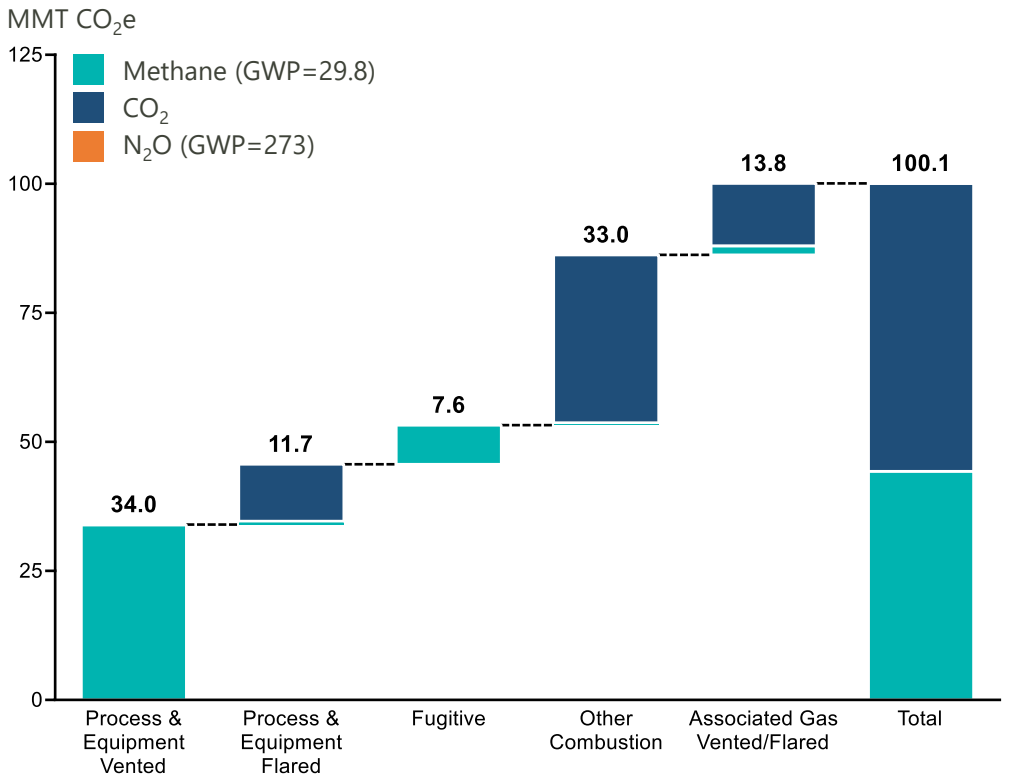
- **Process & Equipment Vented** Vented emissions are intentional releases of natural gas from equipment and processes. Common sources of vented emissions include gas-driven pneumatic devices, compressor seals, tanks, and liquids unloading.
- **Process & Equipment Flared** Flared emissions consist primarily of CO_2 from the combustion of gas that is captured from equipment and processes. Flaring also results in methane emissions from uncombusted gas that escapes through the flare stack.
- **Associated Gas Vented & Flared** Associated gas vented and flared emissions occur at oil wells that do not capture a portion or any of the gas that is produced alongside oil. The gas is directly released to the atmosphere or combusted in a flare rather than captured for sale, on-site use, or reinjection.
- **Fugitive** Fugitive emissions are unintentional releases, or leaks, of natural gas. These emissions are often caused by faulty or worn-out equipment. Sources of fugitive emissions include seals and cracks on equipment such as tanks and piping, and leakage from infrastructure components such as valves and connectors.
- **Other Combustion** Non-flaring combustion is a significant source of CO_2 emissions from oil and gas production. Diesel and natural gas engines used to power equipment and provide electricity represent the largest source of other combustion emissions. Other combustion also includes methane emissions from uncombusted gas.



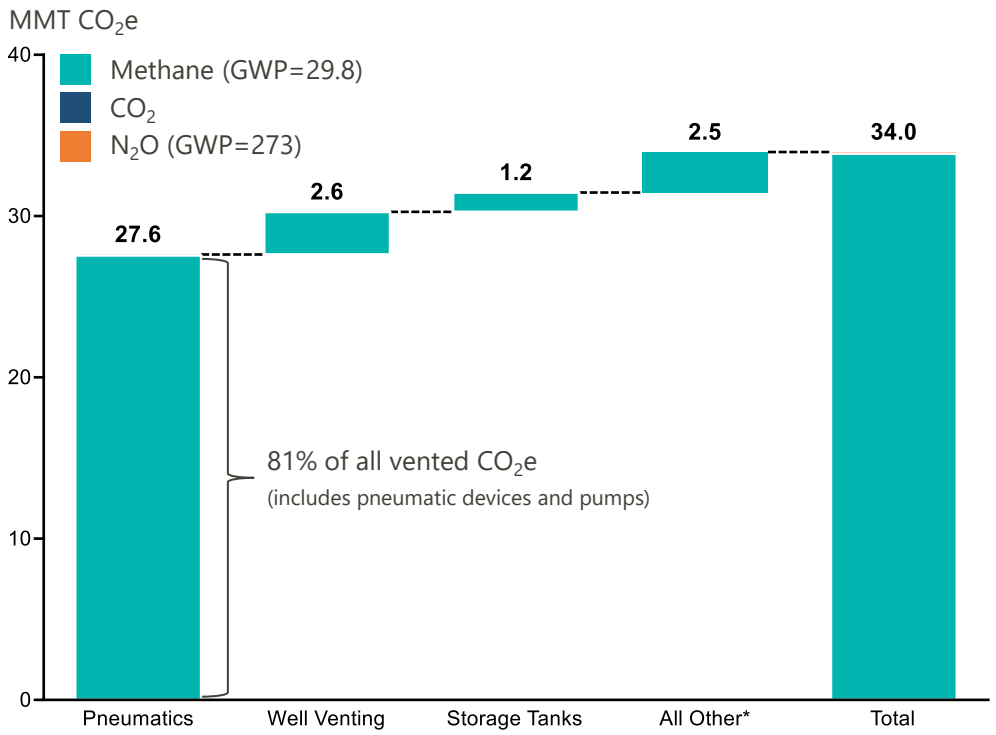
Sources of Methane Emissions

Process & equipment vented and fugitive methane emissions make up approximately 94% and 42% of the total methane and GHG emissions, respectively, reported across all sources included in this report. Pneumatic devices are the largest source of reported methane emissions.

2020 Reported Production Emissions, by Source Category
million metric ton CO_2e (MMT CO_2e)



Process & Equipment Vented Emissions, by Source
million metric ton CO_2e (MMT CO_2e)



* Includes: Centrifugal compressors, Completions/workovers, dehydrators, reciprocating compressors, compressor blowdowns and starts, well drilling, pressure relief valves, well testing, and acid gas removal units

Challenges Associated with Estimating Oil & Gas Emissions

The GHGRP currently represents the most robust and comprehensive inventory of company-level GHG emissions from the oil and gas industry. By applying a uniform emissions calculation methodology across all reporting companies, it creates a dataset that can be used to directly compare company-level data. As noted earlier, the emissions in this report also include sources that are not included in the GHGRP but that can be estimated using emission factors from the GHG Inventory. However, there are important limitations users should keep in mind when reviewing the data:

- **Default emission factors do not represent actual emissions**. The use of emission factors to estimate total emissions relies on the emissions factor being representative of average emissions for a given activity. This approach can be effective where there is robust data on emissions per unit of activity. For example, automobile emissions are routinely and reliably estimated using emission factors despite the fact that emissions from a single vehicle may be different than predicted by an emission factor. With a diversity of emission sources and the presence of low-frequency, high-emission events, the use of emission factors is significantly less reliable in the oil and gas sector, and typically underestimates actual emissions from a number of sources.
- **Emissions from facilities below GHGRP reporting threshold.** Emissions from facilities below the GHGRP's reporting threshold of 25,000 metric tons CO_2e/year are not included in this analysis. Because the GHGRP does not capture facilities responsible for nearly one third of oil production and one quarter of gas production, emissions associated with that portion of oil and gas production activities are not reported to EPA or included in this analysis.
- **Emission source definitions from production and gathering and boosting activities inconsistently applied**. GHGRP requires companies to report emissions from production sources separately from gathering and boosting sources. However, the line between these two activities may be unclear and sometimes overlaps. Thus, companies must decide which section of the GHGRP is appropriate for reporting each source, and the decision is not uniform among all companies. As a result, this analysis, which only looks at production data, may capture emissions from certain equipment for some companies, while not capturing emissions from the same equipment for other companies, depending on how they classify their assets.
- **Emissions from sources not covered by GHGRP.** Companies are not required to report emissions from certain equipment and processes. Estimated emissions from some of these sources are included in this analysis by applying GHG Inventory emission factors to GHGRP reported activity data, as described in the Appendix.
- **Emission reduction activities not included.** Many producers implement work practices to reduce emissions and, in some cases, separately report these reductions to EPA through voluntary programs. However, unless the practices result in the use of a lower emissions factor or changes in activity data, these reductions are not incorporated into reported GHGRP data and are not accounted for in this analysis.
- **Abandoned infrastructure not included.** Research has highlighted that abandoned oil and gas wells are a significant source of methane emissions. These sources are not reported under the GHGRP and represent another source of the industry's GHG emissions that are not accounted for in this report. As a result, if companies are responsible for significant amounts of abandoned infrastructure, emissions from that infrastructure will not be captured in this report.
- **EPA flags on GHGRP data.** EPA may include a flag on company data to indicate that some of its verification requirements have not been met. Reports can be flagged because the facility has not provided an acceptable explanation for the potential error identified in their report, has not submitted a revised report to correct the potential error, or has submitted a revised report that does not resolve the error or contains new potential errors. However, EPA does not specify the specific reason for flagging individual facilities, and these flags are not considered in the current analysis.

Understanding Differences between Top-Down and Bottom-Up Inventories

The development of unconventional oil and gas resources in the U.S. and concern about the impacts of greenhouse gas emissions have driven research to better understand and quantify methane emissions from oil and gas infrastructure. Methane emissions are generally estimated using two approaches: "bottom-up" estimates that quantify and then sum emissions at the equipment level and "top-down" estimates derived from atmospheric emissions measurements across an entire facility or region. Research on methane emissions using top-down approaches, including aerial flyovers and satellite imaging, has consistently found higher emissions from oil and gas equipment than are estimated using bottom-up, emission factor-based inventories.

Even when emission factors and activity assumptions have been updated using in-field measurements, studies with top-down inventories that measure emissions from one or more sites at various scales (e.g., single well pad to entire production basin) consistently record higher emissions than comparable bottom-up inventories.

Researchers have repeatedly found that a major driver of this mismatch is a relatively small number of sources with high-emitting, abnormal process conditions. These emission events have random spatial and temporal distributions and have proven to be difficult to account for using equipment-level emission factors.

While the accuracy of bottom-up estimates varies across companies and regions, top-down studies have found that inventories such as EPA's GHGRP and GHG Inventory underestimate total methane emissions from the oil and gas industry.

Top-down inventories are critical because they better quantify the amount of methane emitted to the atmosphere. Understanding these emissions provides for an improved understanding of the industry's climate impact. Top-down observations can also allow operators to quickly detect and repair faulty equipment that might otherwise go undetected, as well as identify potential emissions sources and implement practices to prevent leaks before they occur.

The primary analysis and benchmarking in this report uses the GHGRP data because it provides the only comprehensive data set that captures the majority of U.S. oil and gas production and applies a consistent methodology that allows for direct comparison of company performance.

Permian Basin Top-Down and Bottom-Up Case Study

The Permian basin, which spans parts of New Mexico and Texas, became the largest U.S. hydrocarbon production basin in 2020 and has been the focus of research on methane emissions in recent years. The table below shows estimated methane leakage rates as a percent of total natural gas production from several recent top-down Permian studies. **For comparison, the GHGRP data implies that oil and gas methane emissions are equal to 0.61% of methane produced in the Permian. At the national level, the GHGRP data implies a leak rate of 0.51%***

Note that these leak rates are not directly comparable to the production-segment NGSI methane intensity metric used in this report:

1. They represent total methane emissions from oil and gas equipment divided by total methane produced
2. They capture methane emissions from production through transmission compression

Study**	Leak Rate	Measurement Year(s)
Chen et al.	9.4%	2018-2020
Lyon et al.	1.9% - 3.3%	2020
Schneising et al.	3.7%	2018-2019
Zhang et al.	3.7%	2018-2019

*Leak rate calculated as total methane emissions divided by methane production. Includes Subpart W methane emissions for onshore production, gathering & boosting, processing, transmission compression, and underground storage facilities located in the Permian basin, as well as Subpart C methane emissions for Permian processing, transmission compression, and underground storage facilities. Applies average calculated GHGRP Permian produced gas methane content of 70.2% and EPA produced gas average methane content of 78.8% for national level.
**See page 80 for complete study citations.

The comparison of GHGRP and top-down study data shows that estimated Permian leak rates in top-down studies are 3.1 to 15.4 times higher than leak rates derived from emissions and production data reported under GHGRP. The primary drivers of the observed gap are GHGRP emission factors that do not reflect actual emissions for all sources and the absence of emissions from high-emitting abnormal process conditions.

Leak rates derived from regional top-down measurements provide a snapshot of emissions performance for an area. However, these regional estimates do not isolate company performance. Some companies within a region will have leak rates below the regional performance and others will have leak rates above the regional performance. While a growing number of technology providers offer companies proprietary estimates of company-level leak rates and EDF has launched a regional monitoring initiative focused on the Permian, there are no public datasets that provide a national view into company-level performance using top-down measurements.

In addition to there being differences in methane emissions intensities derived from top-down and bottom-up estimates, there are also meaningful differences in intensities associated with EPA's two bottom-up programs, the GHGRP and GHG Inventory. The GHG Inventory's implied national methane leak rate of 1.15% is more than double that of the GHGRP's of 0.51% for the same industry boundaries (onshore production through transmission compression).

Top-Down Uncertainty

When considering top-down estimates, it is important to understand levels of uncertainty associated with different measurement technologies and to understand how emissions or leak rates from observed sites are extrapolated across unobserved sites and broader geographic areas.

Expectations for Direct Measurement of Methane Emissions

Understanding of methane emissions will continue to improve with additional research and as companies deploy a growing number of diverse technologies that can detect and quantify emissions. In the future, data from top-down direct measurement could potentially be used in programs such as the GHGRP, providing a broader data set with improved estimates of facility- and company-level methane emissions.

Leading oil and gas companies are committing to direct measurement of methane emissions independently and through initiatives such as the Oil & Gas Methane Partnership 2.0 (OGMP 2.0) and Project Astra. Stakeholders are also working to establish processes to reconcile emissions calculated by different approaches, including GTI's Veritas initiative and OGMP 2.0's guidance on reconciling source-level bottom-up inventories with site-level top-down inventories. These efforts will increase the accuracy of methane emission estimates at the facility, company, regional, and national level.

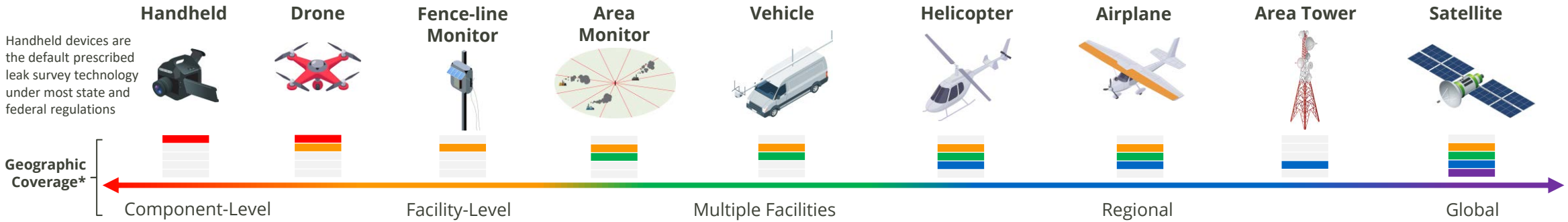
Advanced technologies do not directly measure methane emission rates. Instead, they use measurements of methane concentrations in combination with environmental conditions (e.g., wind speed and direction), and algorithms to estimate leak rates.

Different technologies have different minimum detection limits, use different approaches to calculate leak rates, and may be best suited for different types of equipment and operating conditions.

Industry groups and stakeholders are working to demonstrate the effectiveness of technologies and establish "equivalency" between various approaches to determine which technologies, practices, and survey frequencies achieve equivalent emissions reductions. Efforts such as the testing performed at Colorado State University's Methane Emissions Technology Evaluation Center (METEC), help validate quantification results and allow for comparison of different technologies and work practices.

Methane detection and quantification technologies can be deployed at a wide range of scales. The geographic scope of these technologies can vary from individual pieces of equipment to entire production basins. Stakeholders are evaluating the frequency at which surveys should be conducted for each technology to maximize the efficiency of methane emission reduction strategies.

Advanced Emission Detection and Quantification Platforms



*Geographic coverage of platforms is for illustrative purposes. Coverage of individual technologies and emissions detection resolution varies across platforms.

Using Public Data to Compare Producer Performance

Despite the challenges of estimating emissions from oil and gas sources, the application of a uniform emissions calculation methodology across the industry allows for direct comparison of company-level data. Normalizing these emissions by reported production data allows for calculation of emissions intensities that can be used to directly compare company methane and GHG emissions performance per unit of energy produced. While intensity metrics provide a straightforward way to compare the performance of operators of different sizes, it is important to note that absolute emissions can increase even as emissions intensity declines. Users are encouraged to consider total GHG emissions as well as emissions intensity when reviewing company data.

This report uses two emissions intensity metrics to compare producer performance. The first is the Edison Electric Institute and American Gas Association Natural Gas Sustainability Initiative (NGSI) protocol for calculating methane emissions intensity. This approach focuses on the natural gas value chain and calculates intensity as methane emissions assigned to natural gas on an energy basis divided by the total methane content of produced natural gas. This metric provides insight to investors and gas purchasers interested in evaluating the methane performance of the natural gas value chain separate from the oil value chain. The NGSI methane emissions intensity is expressed as a percent (%).*

The second metric, total GHG emissions intensity, is calculated as total production-segment GHG emissions in kilograms of carbon dioxide equivalent (CO_2e) divided by total hydrocarbon production in barrel of oil equivalent (BOE). The GHG emissions intensity is expressed as kilograms CO_2e per BOE.

*The NGSI methane emissions intensity metric is different than a methane leak rate calculated as total methane divided by total produced gas as it allocates emissions between oil production and natural gas production on a produced energy basis, and uses the emissions attributed to natural gas to calculate intensity as a percentage of total methane content of the produced natural gas. It does not include emissions assigned to oil production. Additional details on the NGSI metric are available on EEI's website.

NGSI Methane Emissions Intensity

$$\frac{CH_4 \text{ Emissions (MT)} * \text{Gas Ratio}}{\text{Produced Gas (mcf)} * \text{Methane Content} * (0.0192 \text{ MT/mcf})}$$

where:

Gas Ratio = Energy content of produced gas / Energy content of total hydrocarbons
Methane Content = Molar fraction of methane in produced gas

Greenhouse Gas Emissions Intensity

$$\frac{CH_4 \text{ Emissions (kg } CO_2e) + CO_2 \text{ Emissions (kg } CO_2e) + N_2O \text{ Emissions (kg } CO_2e)}{\text{Produced Gas (BOE)} + \text{Oil Sales (BOE)}}$$

where:

CO_2e = CO_2-equivalent of gases adjusted by GWP
Produced Gas (BOE) + Oil Sales (BOE) = Hydrocarbons as barrel oil equivalent

Note that the NGSI methane intensities in this report may differ slightly from those calculated by companies due to assumptions made in this analysis and its use of publicly reported data

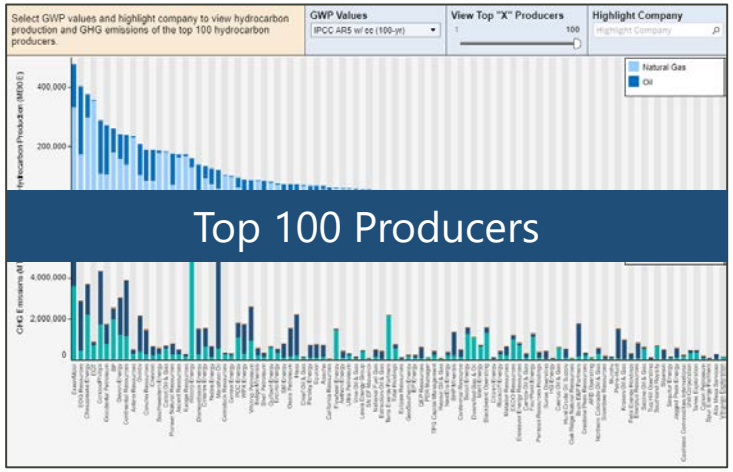
Benchmarking Analytical Resources

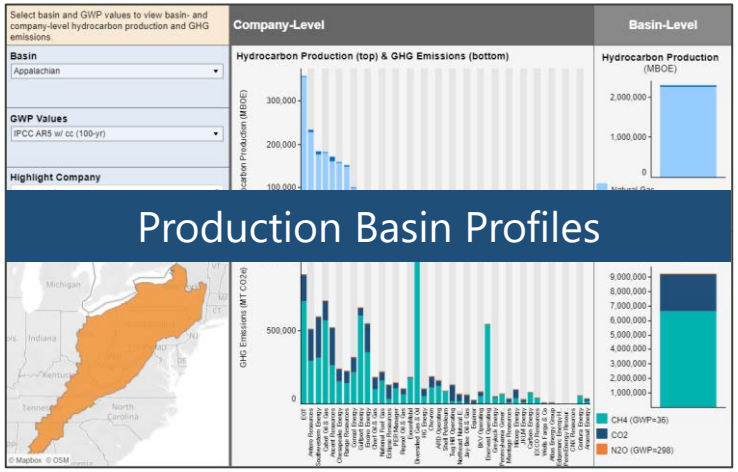
The Oil & Gas Benchmarking Report includes a series of interactive, web-based dashboards to further visualize GHG emissions from oil and gas producers and production basins in the United States. These tools provide insight into how company- and basin-level emissions and emissions intensity vary as well as information on the types of sources that contribute to GHG emissions.

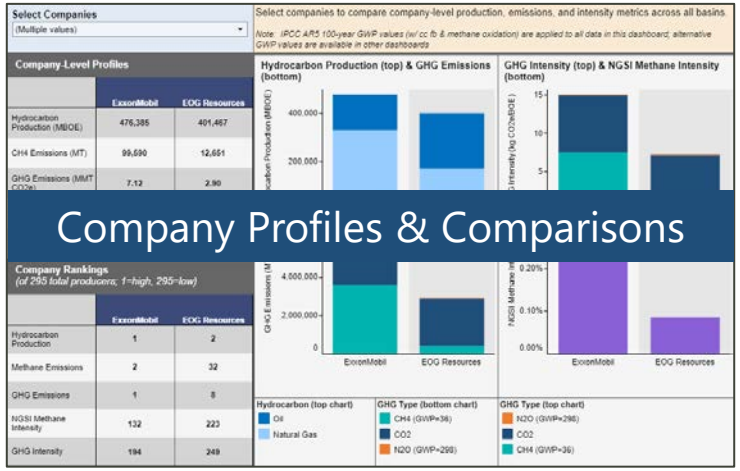
The online resources include data for all companies and basins in the GHGRP database, including those not highlighted in this report. Data dashboards include:

- **Top 100 Producers:** Oil & gas production, source-specific emissions, and emissions intensities of the top 100 hydrocarbon producers with additional company rankings of other key metrics
- **Production Basin Profiles:** Production, detailed emissions, and emissions intensities by basin and companies that operate within selected basins
- **Company Profiles & Comparisons:** Production, detailed emissions, and emissions intensities at a company and basin level with the ability to select and directly compare companies

These tools are available at http://www.sustainability.com/.



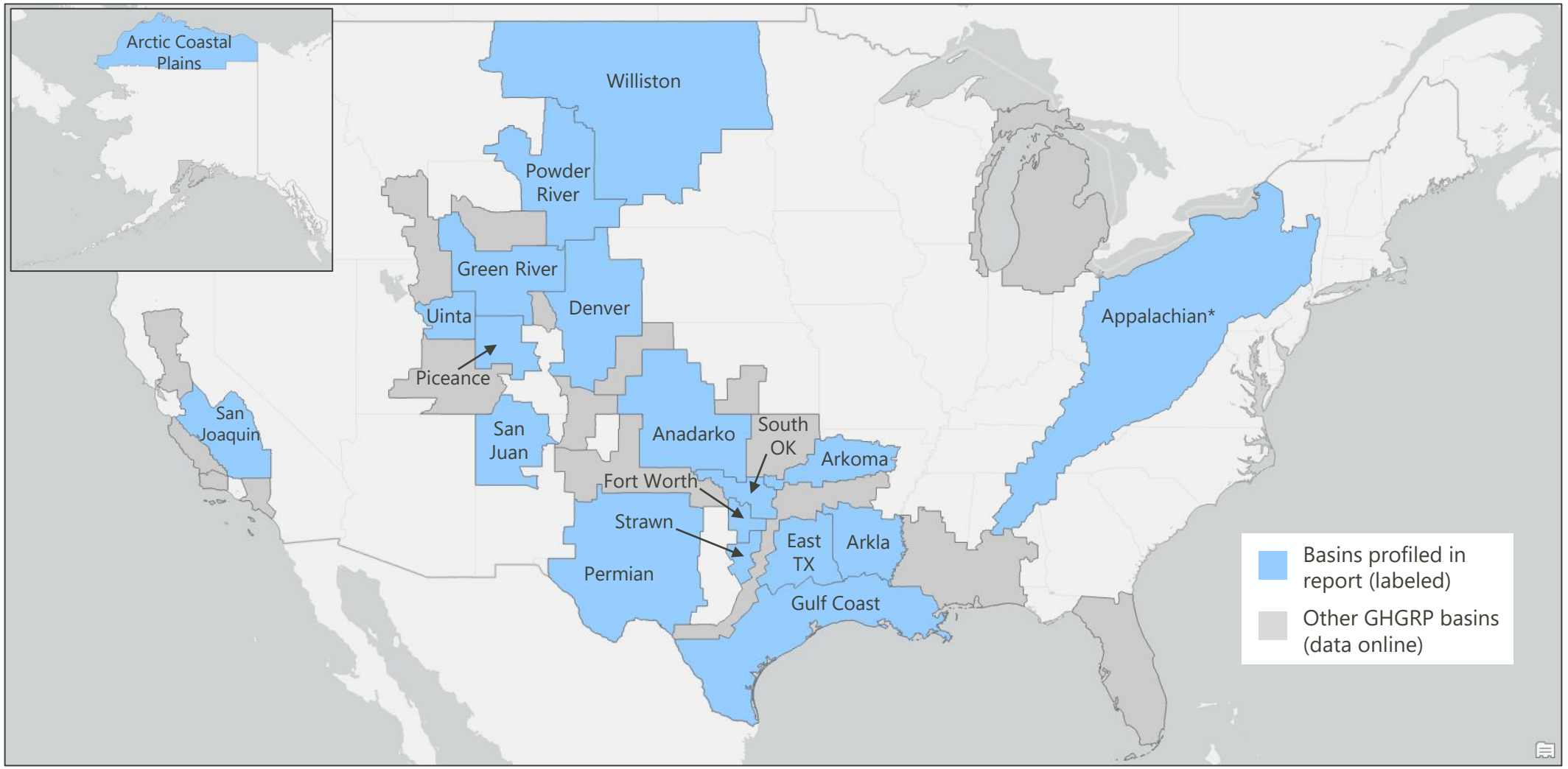




Basin-Level Summary Data

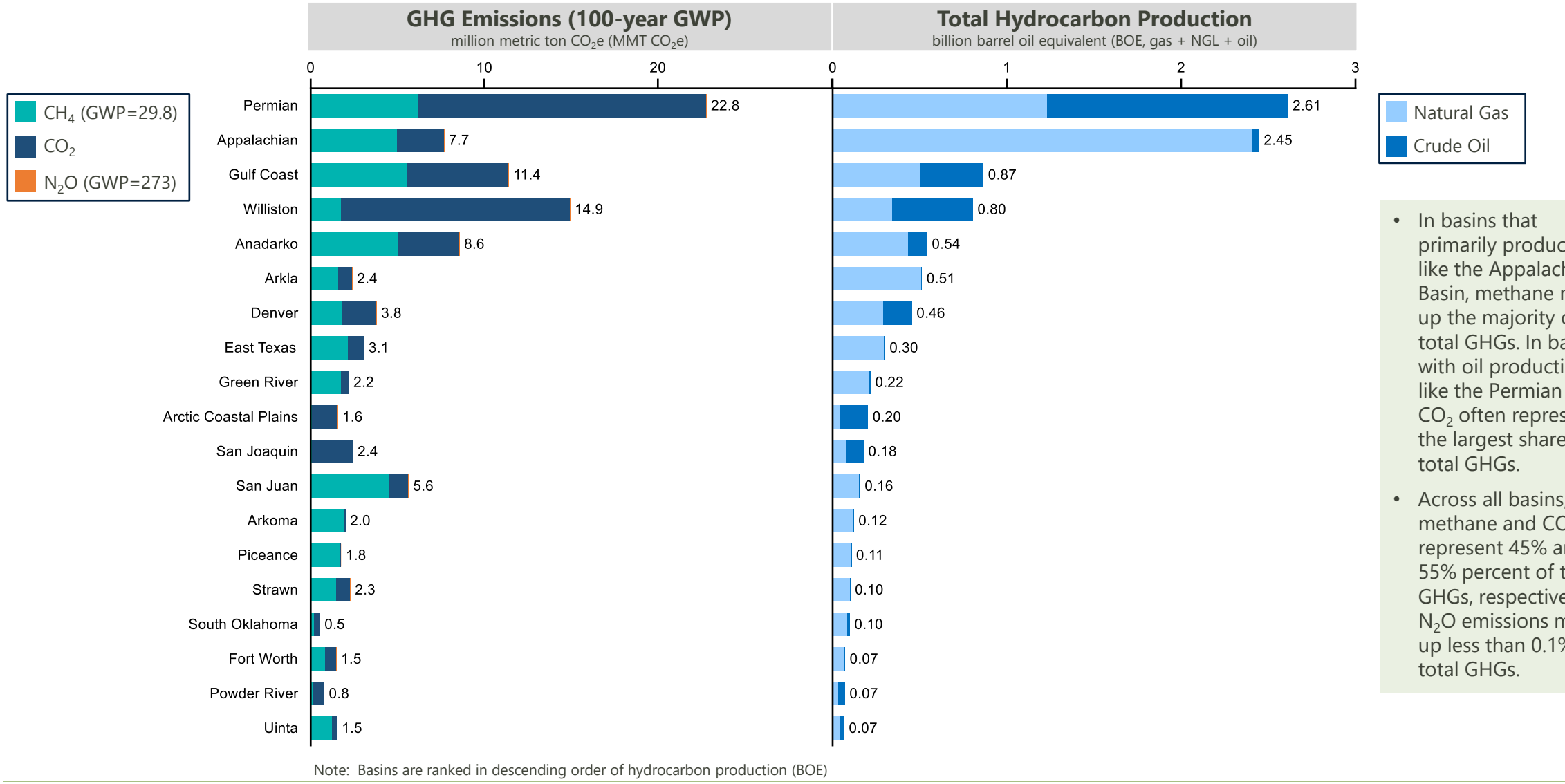
This section provides data on hydrocarbon production, GHG emissions, emissions intensity, and sources of emissions for the 19 largest hydrocarbon production basins in the U.S. by 2020 production volume. Together these basins represent 98.9% and 99.4% of total 2020 natural gas and oil production, respectively, in the EPA data.

GHGRP Basins



* GHGRP data contain two distinct Appalachian basins (160 & 160A). This analysis combines data reported across both basins and presents them as a single basin.
Note: Basin boundaries defined by geologic provinces published by the American Association of Petroleum Geologists; data provided by U.S. EPA.

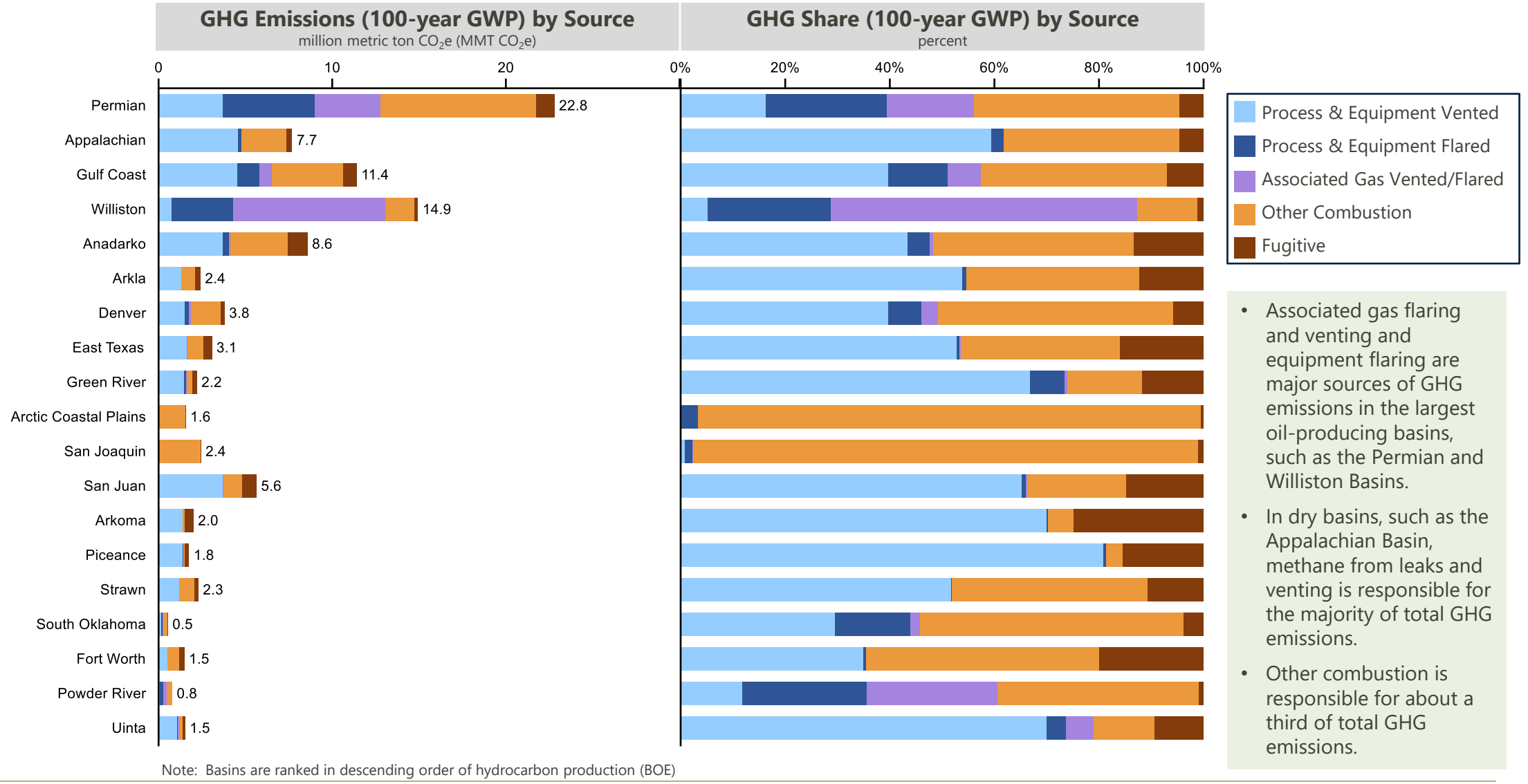
GHGRP Basin Production & Emissions



- In basins that primarily produce gas, like the Appalachian Basin, methane makes up the majority of total GHGs. In basins with oil production, like the Permian Basin, CO_2 often represents the largest share of total GHGs.
- Across all basins, methane and CO_2 represent 45% and 55% percent of total GHGs, respectively. N_2O emissions make up less than 0.1% of total GHGs.

Note: Basins are ranked in descending order of hydrocarbon production (BOE)

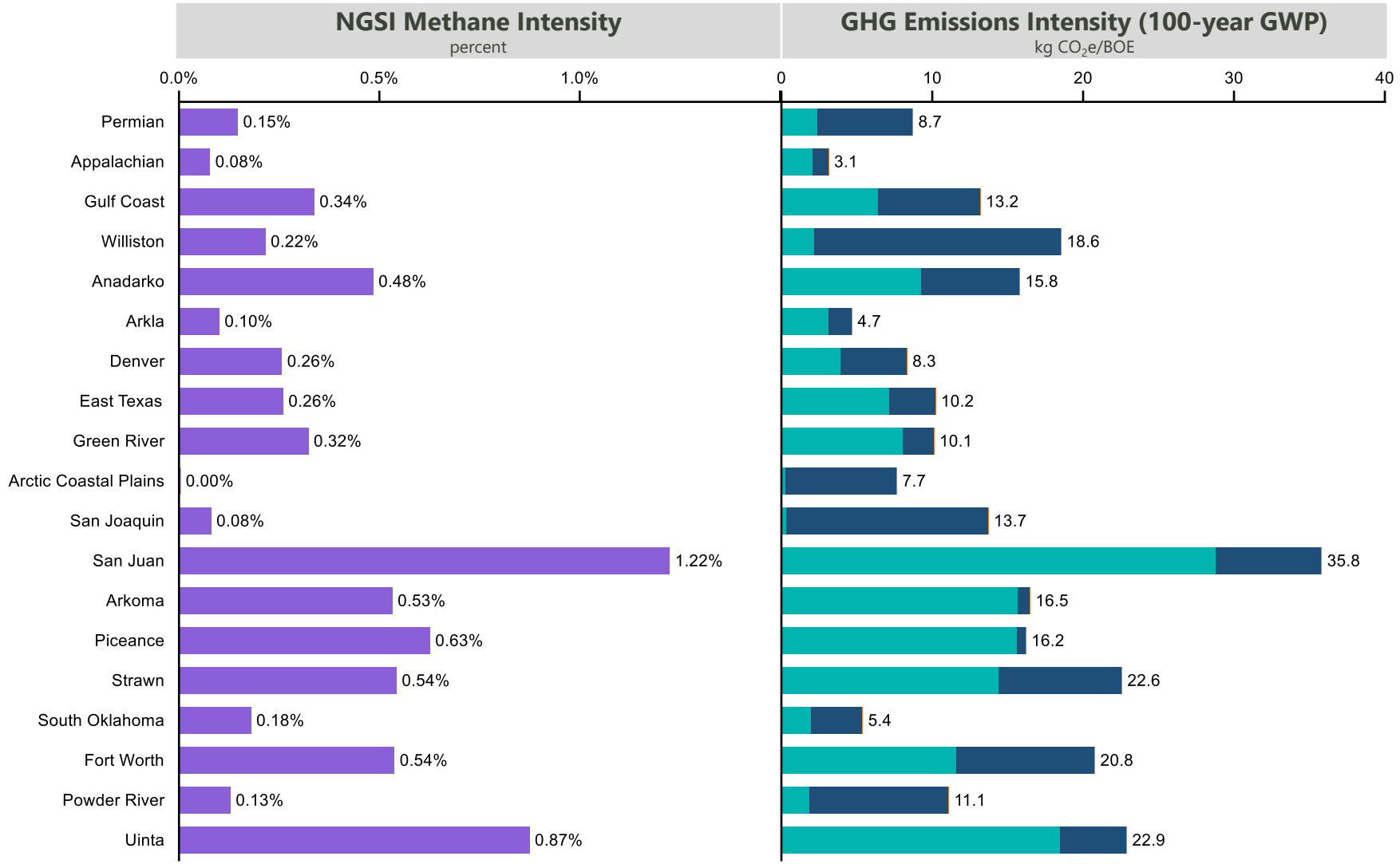
GHGRP Basin Emissions by Source



Note: Basins are ranked in descending order of hydrocarbon production (BOE)

- Associated gas flaring and venting and equipment flaring are major sources of GHG emissions in the largest oil-producing basins, such as the Permian and Williston Basins.
- In dry basins, such as the Appalachian Basin, methane from leaks and venting is responsible for the majority of total GHG emissions.
- Other combustion is responsible for about a third of total GHG emissions.

GHGRP Basin Methane & GHG Intensity



- Methane and GHG emissions intensities vary substantially across basins.
- Ranking in methane intensity does not always correspond to the same GHG intensity rank, reflecting the higher contribution of CO_2 to total emissions in some basins.
- Differences in emissions intensities can be driven by operator practices, type of hydrocarbon production, and infrastructure age.

Note: Basins are ranked in descending order of hydrocarbon production (BOE)

2018-2020 Trends Analysis

Year-over-year changes in emissions, production, and intensities are driven by a variety of factors. These factors can result in both increases and decreases to company- , basin-, and national-level metrics. The reasons for changes may not be able to be determined by analysis of the GHGRP data alone, and company-specific trends often need additional narrative and context to explain the causes of annual variability. This report presents national trends as well as basin trends for the four largest hydrocarbon producing basins. Data for all other basins and individual companies are available in the online dashboards.

The factors driving annual trends fall into several categories:

Operational Changes. Operational changes reflect tangible changes captured within the GHGRP methodology and include updates to technologies, practices, and activities. These could include deployment of new systems and strategies to mitigate emissions, such as conversion to non-venting pneumatic controllers or installation of gas capture systems (e.g., vapor recovery units) on sources that previously vented emissions. Operational changes also include increases and decreases in hydrocarbon production, which could be the result of multiple factors (e.g., new well completions, recompletions, natural production declines). Activity can also reduce emissions from certain sources while increasing emissions from other sources. For example, the build-out of gas gathering infrastructure in oil-rich basins may reduce emissions from associated gas venting and flaring, but increase emissions from compression equipment at production facilities.*

Structural Changes. Structural changes include acquisitions, divestments, and mergers that affect company size. These types of changes can lead to significant year-over-year variation in production and emissions at the company level as production and emissions shift from one company to another. Total production and emissions as measured at the basin or national level are not affected by structural changes, unless such changes result in assets moving from GHGRP reporters to non-reporters, or vice versa. It is important to note that due to the lag in data disclosure, the most recently available company data (i.e., 2020) may not reflect current asset ownership.

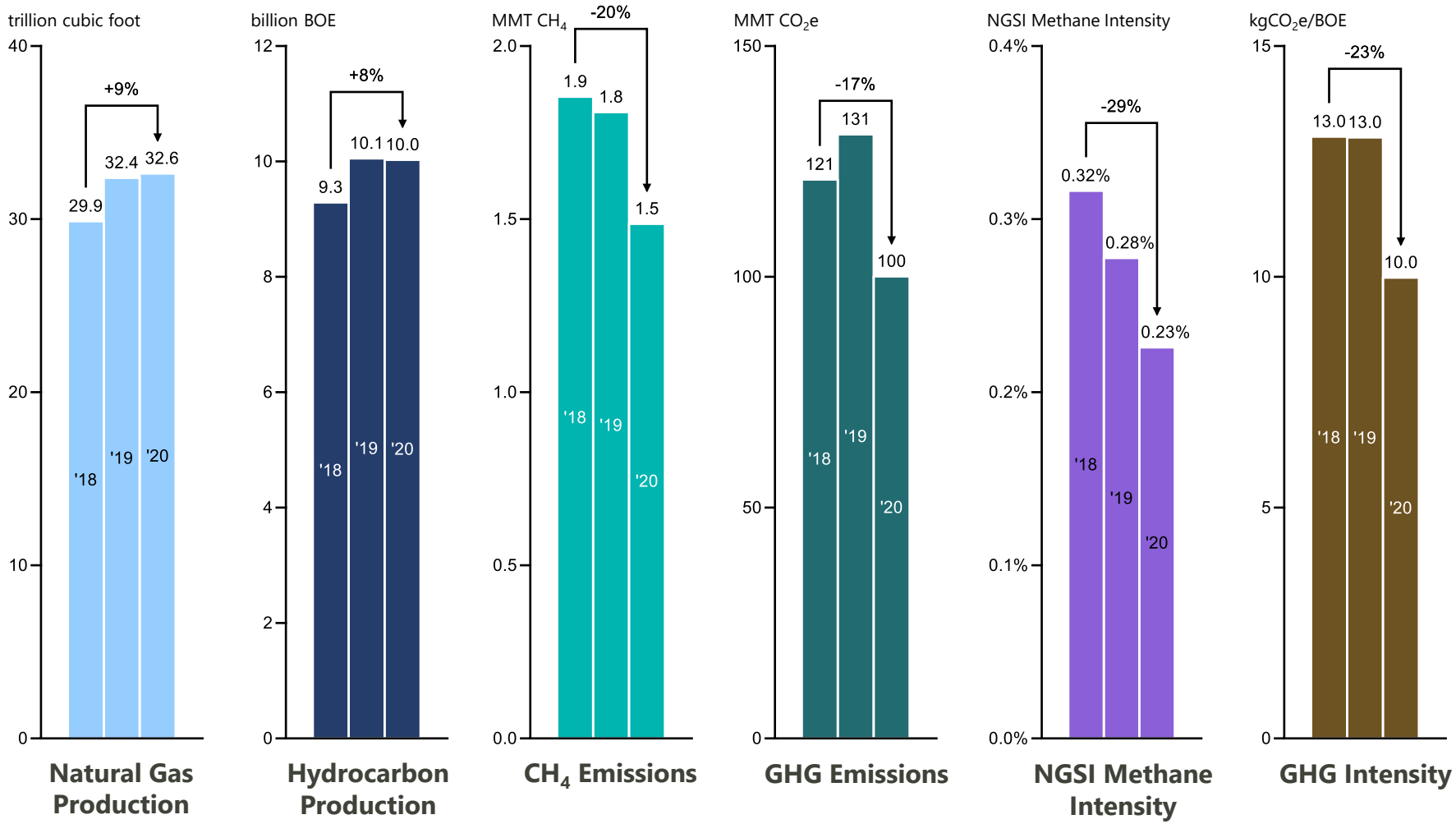
Methodological Changes. Methodological changes are changes to the way companies estimate emissions within the GHGRP's prescribed calculation methodologies. For example, several approaches use equipment operating hours as an input to the emissions calculation equation. Different interpretations of how to apply the operating hour factor can lead to inconsistency across companies, while inconsistent application of the factor year-over-year results in fluctuating emissions within a company or facility. These types of changes are the result of changes to the methodology used to calculate emissions rather than operational changes. Changes in emissions identified as resulting from methodological revisions must be carefully scrutinized.

Boundary Changes. Boundary changes are related to the GHGRP's annual reporting threshold of 25,000 metric tons CO_2e. As facilities exceed or fall below this threshold, they will be captured or dropped from the EPA dataset. For example, a facility that began operations in 2019 and ramped up production in 2020 may be included in the 2020 data but not the 2019 data.

*Note that the build out of natural gas gathering equipment can also shift emissions from the production segment to the gathering & boosting segment, depending on how these assets are categorized by operators. This report only analyzes the onshore production segment and does not capture data from gathering & boosting facilities.

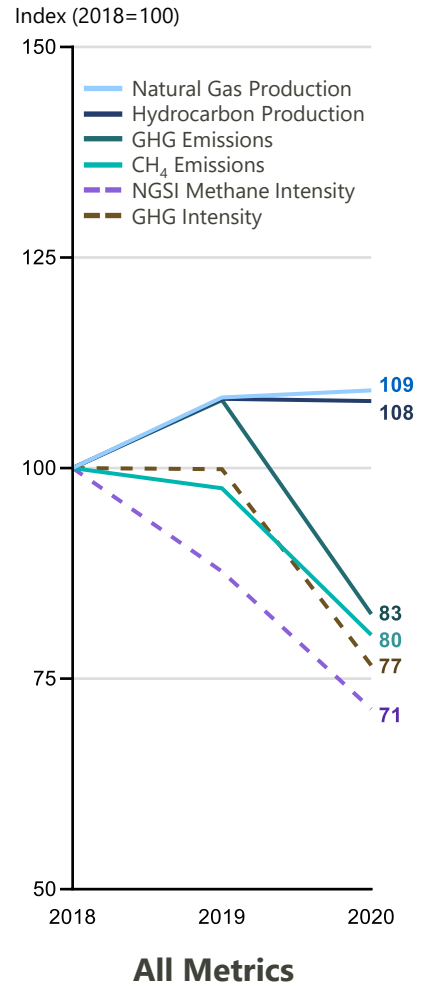
2018-2020 Trends Analysis: Production & Emission Metrics

GHGRP Data Trends, 2018-2020

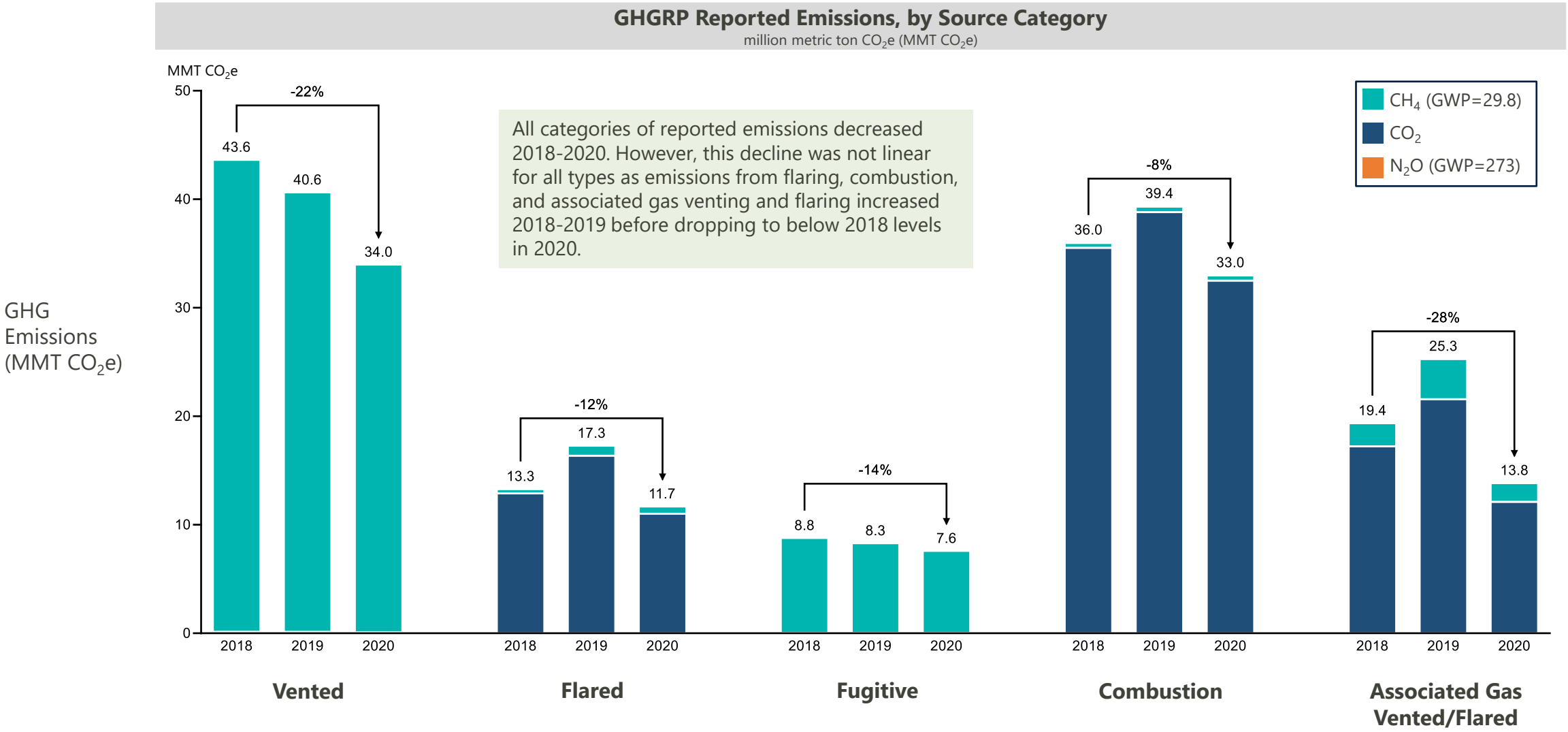


Combined Data Metrics

Indexed; 2018 = 100



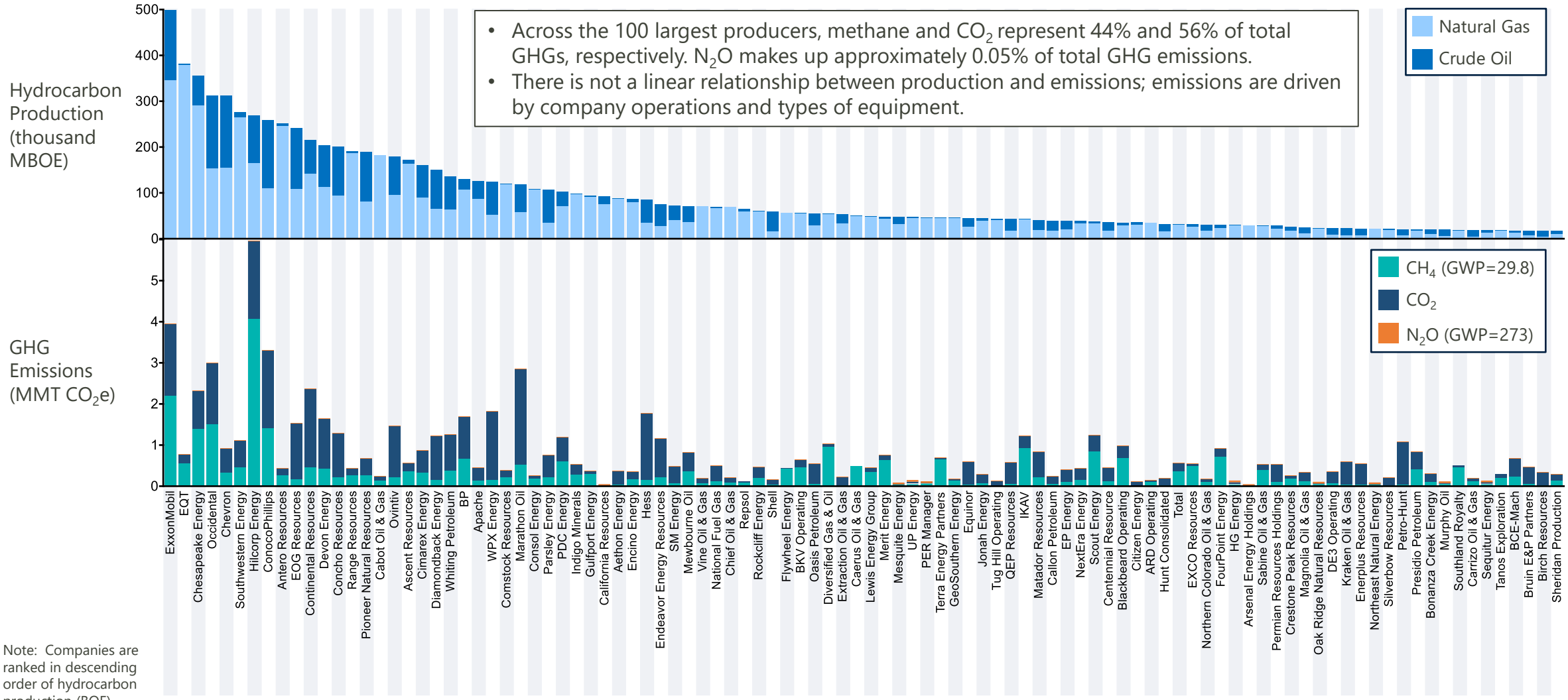
2018-2020 Trends Analysis: Emission Sources



Company-Level Summary Data

This section summarizes data on hydrocarbon production, GHG emissions, emissions intensity, and sources of emissions for the 100 largest hydrocarbon producers in the U.S. Additional graphics show the relative distribution of hydrocarbon production, GHG emissions, and methane and GHG emissions intensities across the 100 largest producers. Detailed tables list the data and associated rankings for the primary metrics included in this analysis for each of the 100 companies.

Hydrocarbon Production & Emissions (100-year GWP)

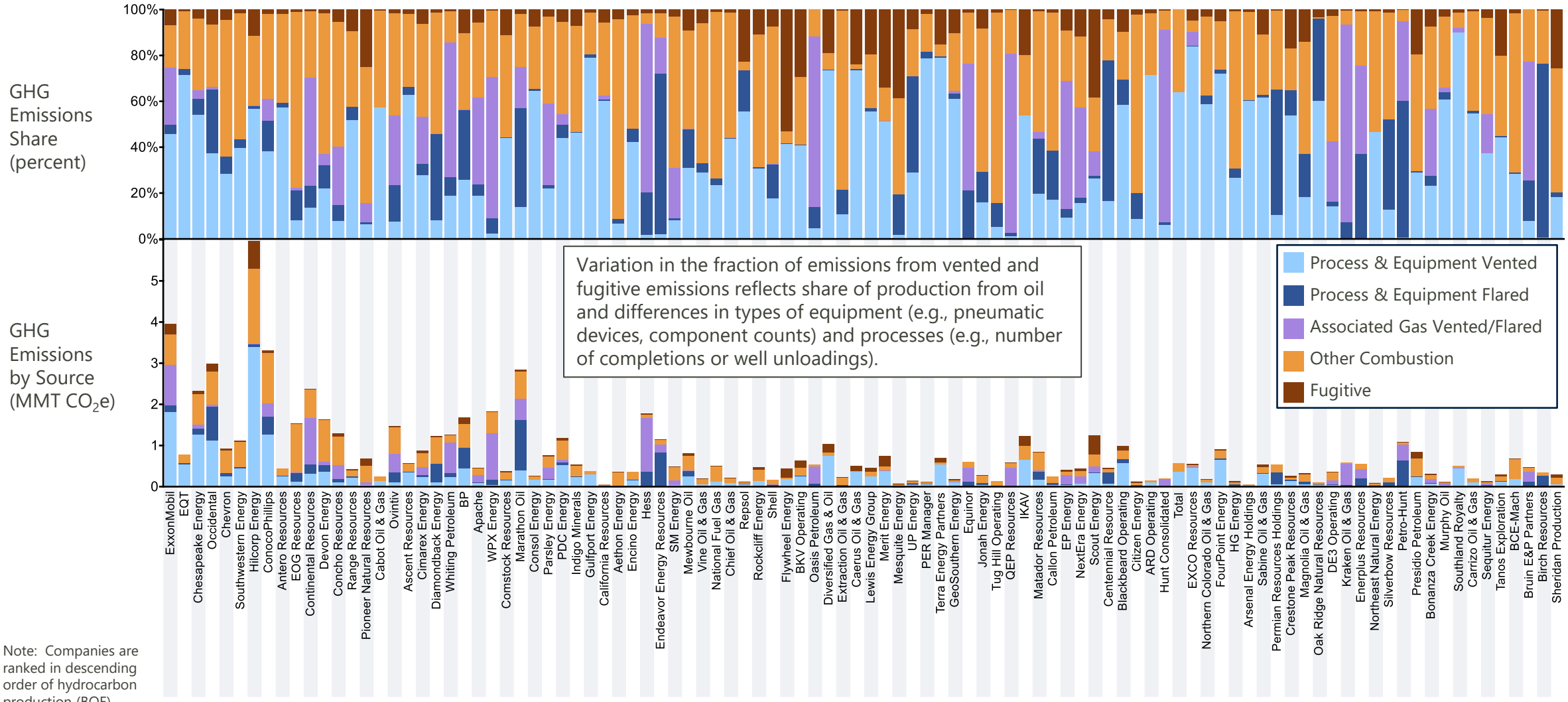


Note: Companies are ranked in descending order of hydrocarbon production (BOE)

Note: Reflects unpublished data submitted by ExxonMobil, Occidental, Apache, and Tanos Exploration currently under EPA review. Presidio Petroleum reflects assets purchased in 2019 that were allocated to Apache in current EPA data; IKAV reflects assets purchased in 2020 that were allocated to BP in current EPA data

Top 100 Hydrocarbon Producers

GHG Emissions by Source (100-year GWP)



Note: Companies are ranked in descending order of hydrocarbon production (BOE)

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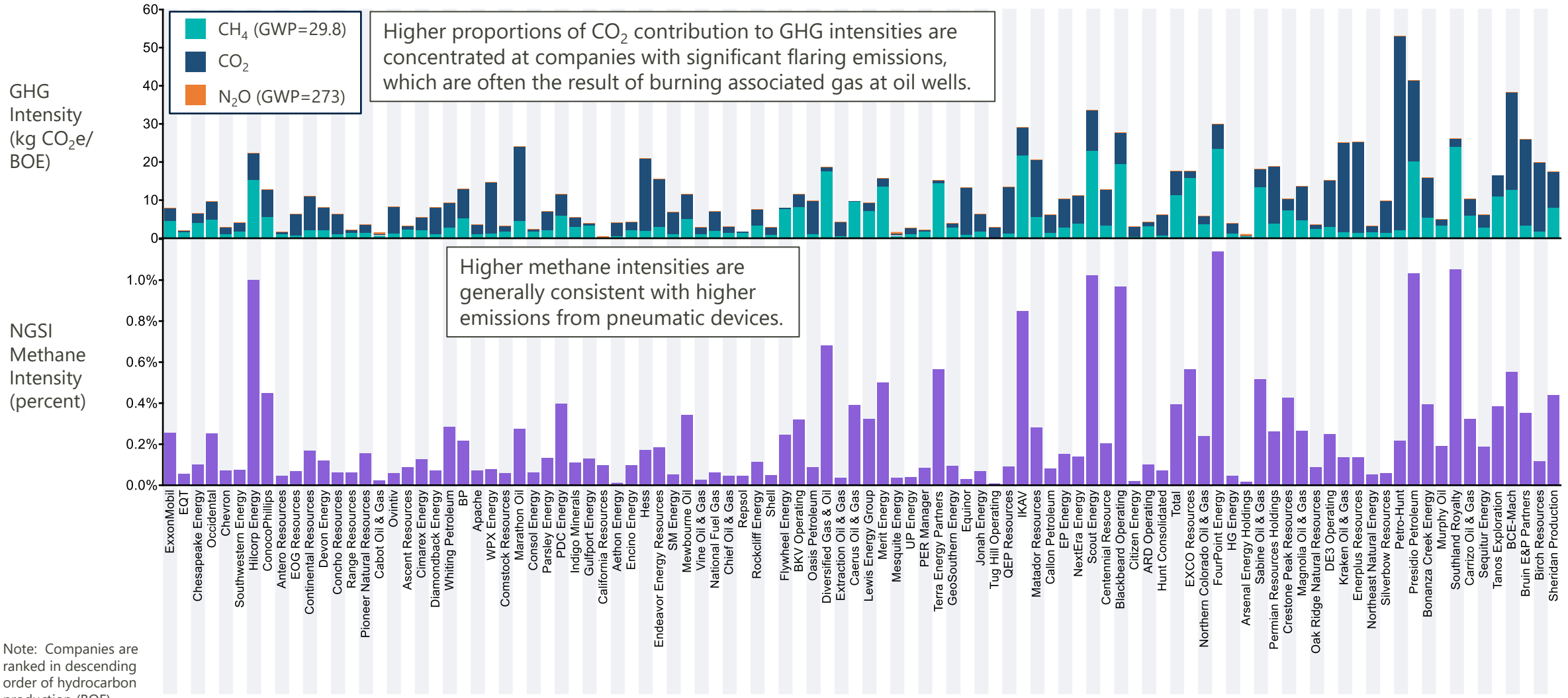
Top 100 Hydrocarbon Producers

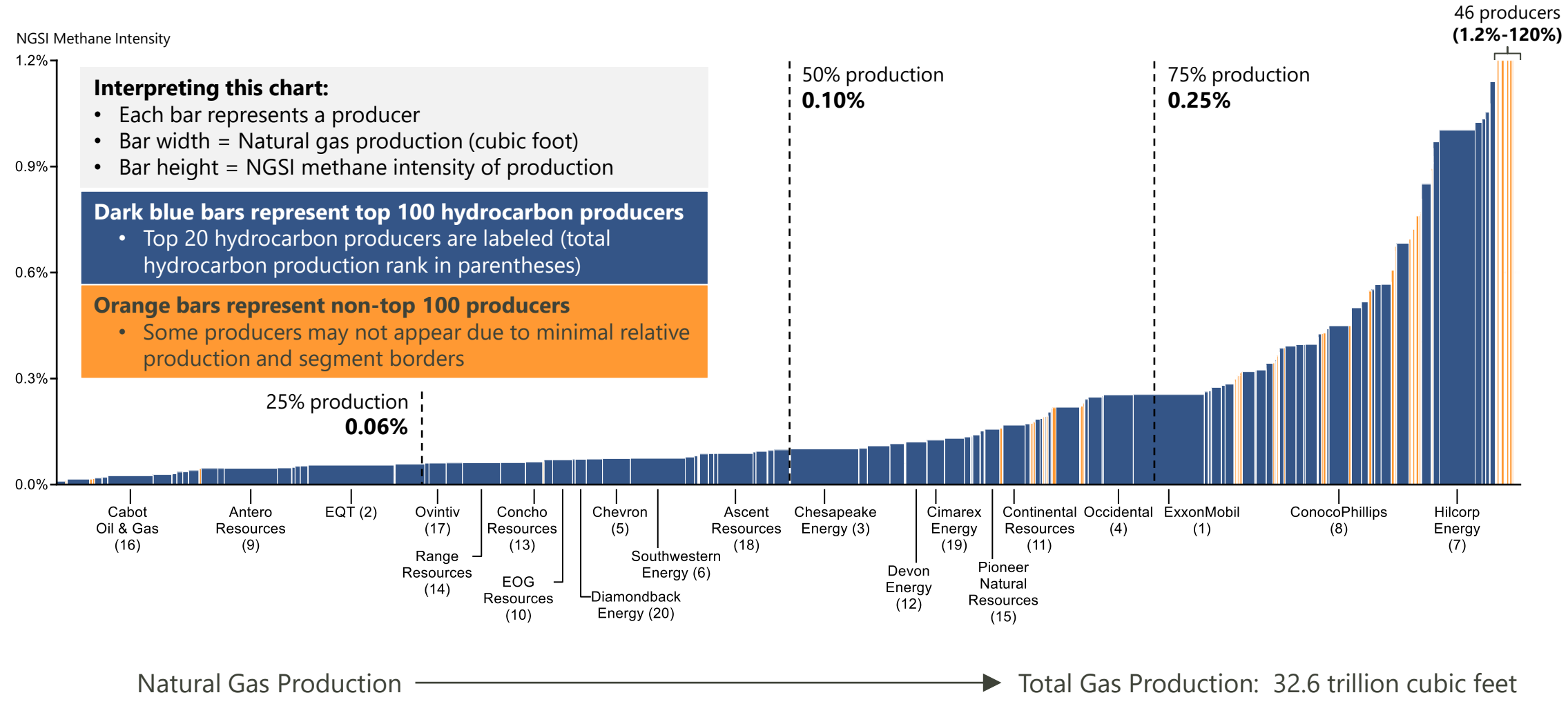
Methane & GHG Intensity (100-year GWP)



Note: Companies are ranked in descending order of hydrocarbon production (BOE)

Note: Reflects unpublished data submitted by ExxonMobil, Occidental, Apache, and Tanos Exploration currently under EPA review. Presidio Petroleum reflects assets purchased in 2019 that were allocated to Apache in current EPA data; IKAV reflects assets purchased in 2020 that were allocated to BP in current EPA data

Total GHGRP Natural Gas Production, by Methane Intensity



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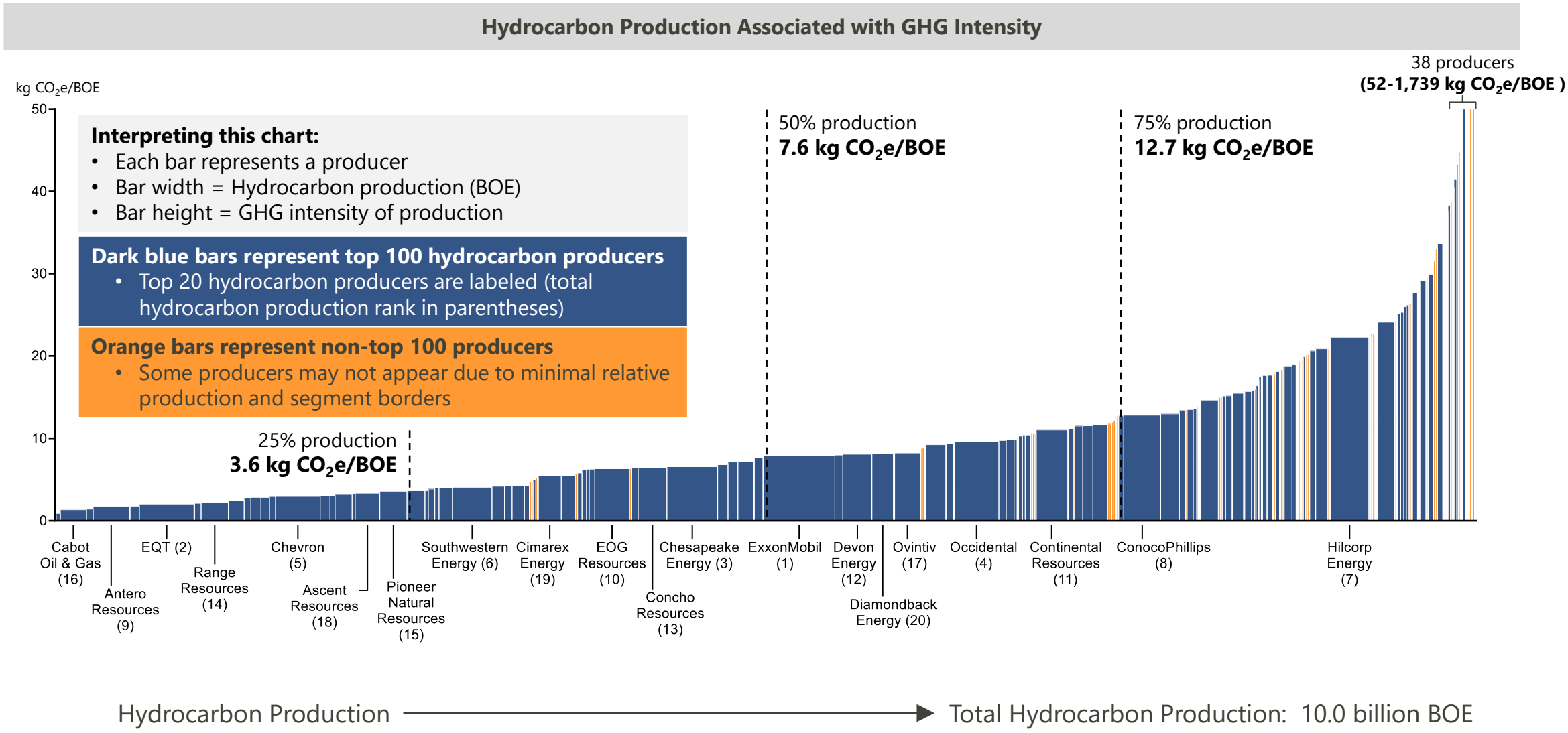
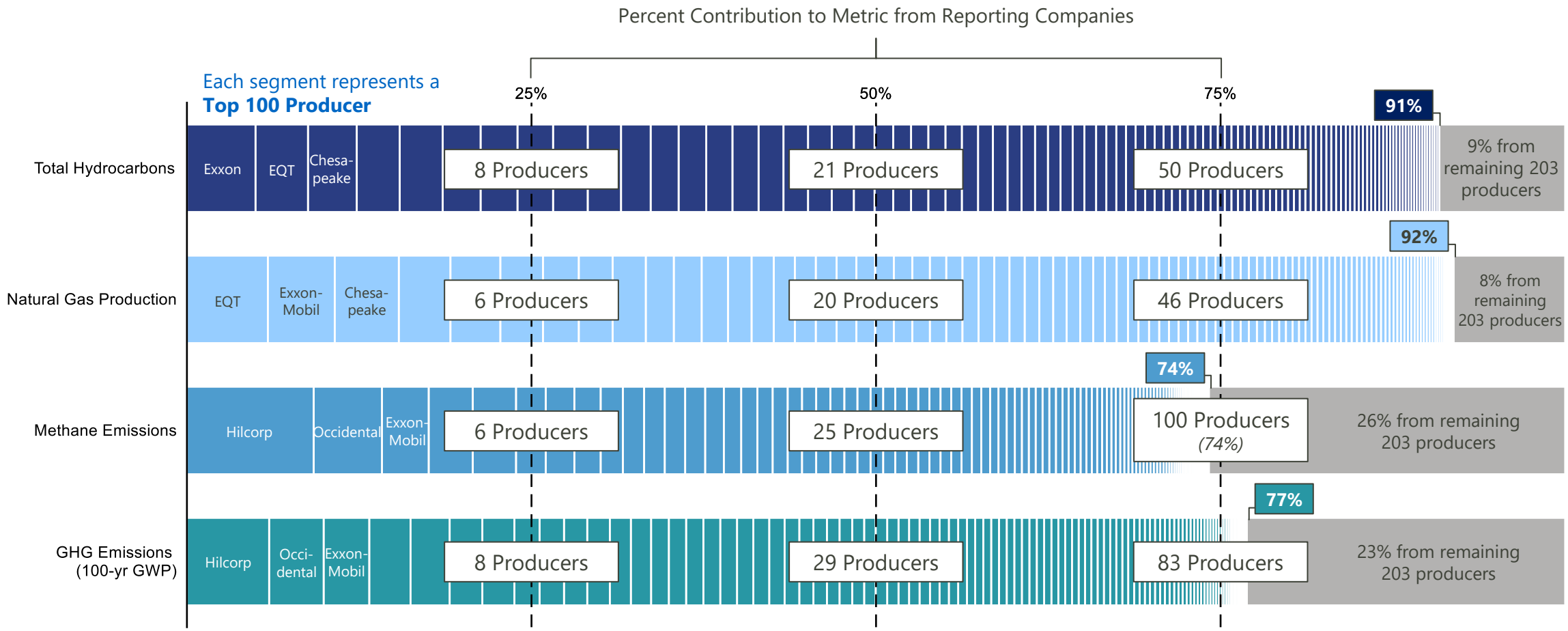
Total GHGRP Hydrocarbon Production, by GHG Intensity



Note: Reflects unpublished data submitted by ExxonMobil, Occidental, Apache, and Tanos Exploration currently under EPA review. Presidio Petroleum reflects assets purchased in 2019 that were allocated to Apache in current EPA data; IKAV reflects assets purchased in 2020 that were allocated to BP in current EPA data

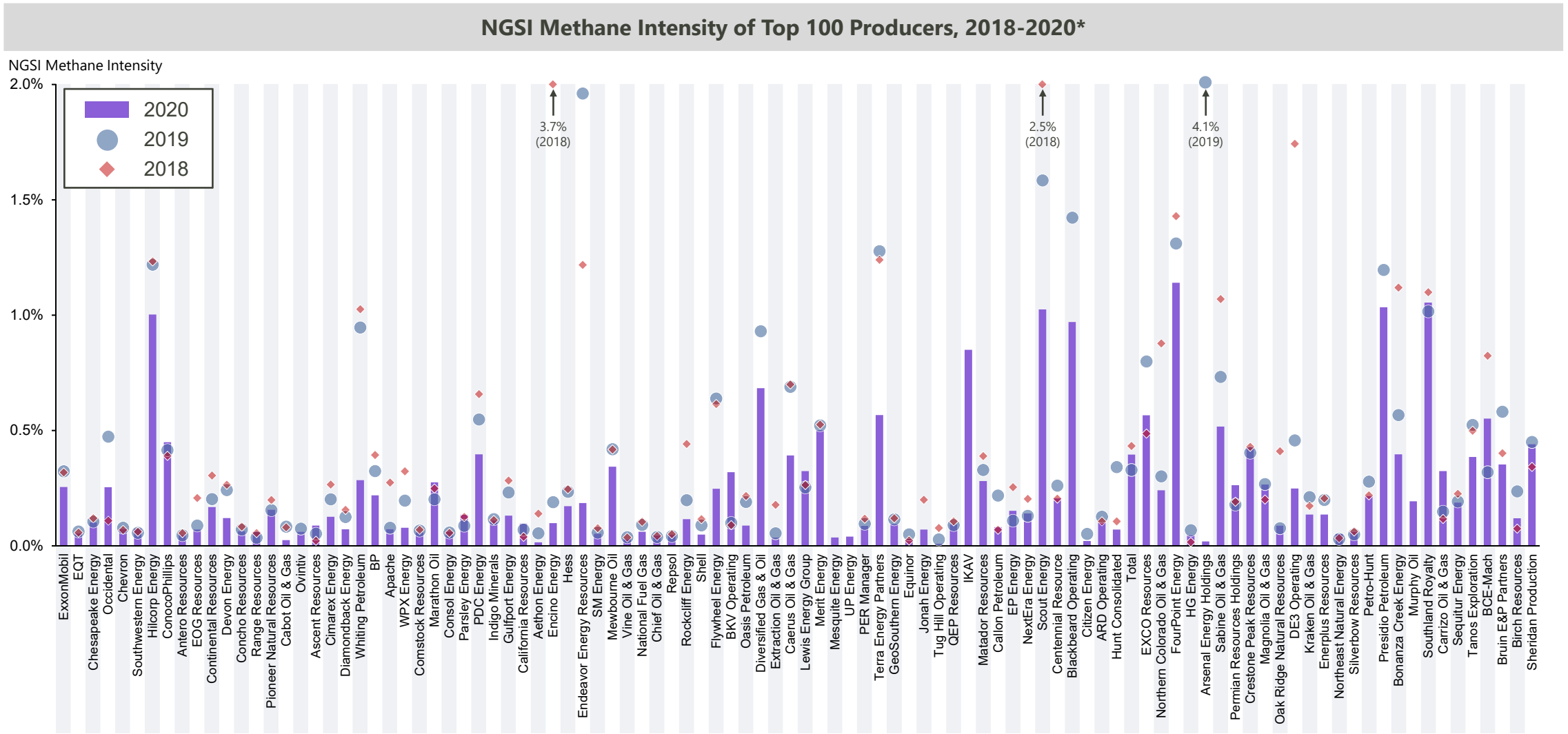
GHGRP Hydrocarbon Production & Emission Contributions



Hydrocarbon production and absolute GHG emissions reported to EPA are highly concentrated among a small number of companies. 25% of total reported hydrocarbons produced and GHG emitted are by eight companies. However, the 203 companies that fall outside the top 100 are responsible for 23% of reported GHG emissions but only 9% of total hydrocarbon production.

Note: Reflects unpublished data submitted by ExxonMobil, Occidental, Apache, and Tanos Exploration currently under EPA review. Presidio Petroleum reflects assets purchased in 2019 that were allocated to Apache in current EPA data; IKAV reflects assets purchased in 2020 that were allocated to BP in current EPA data

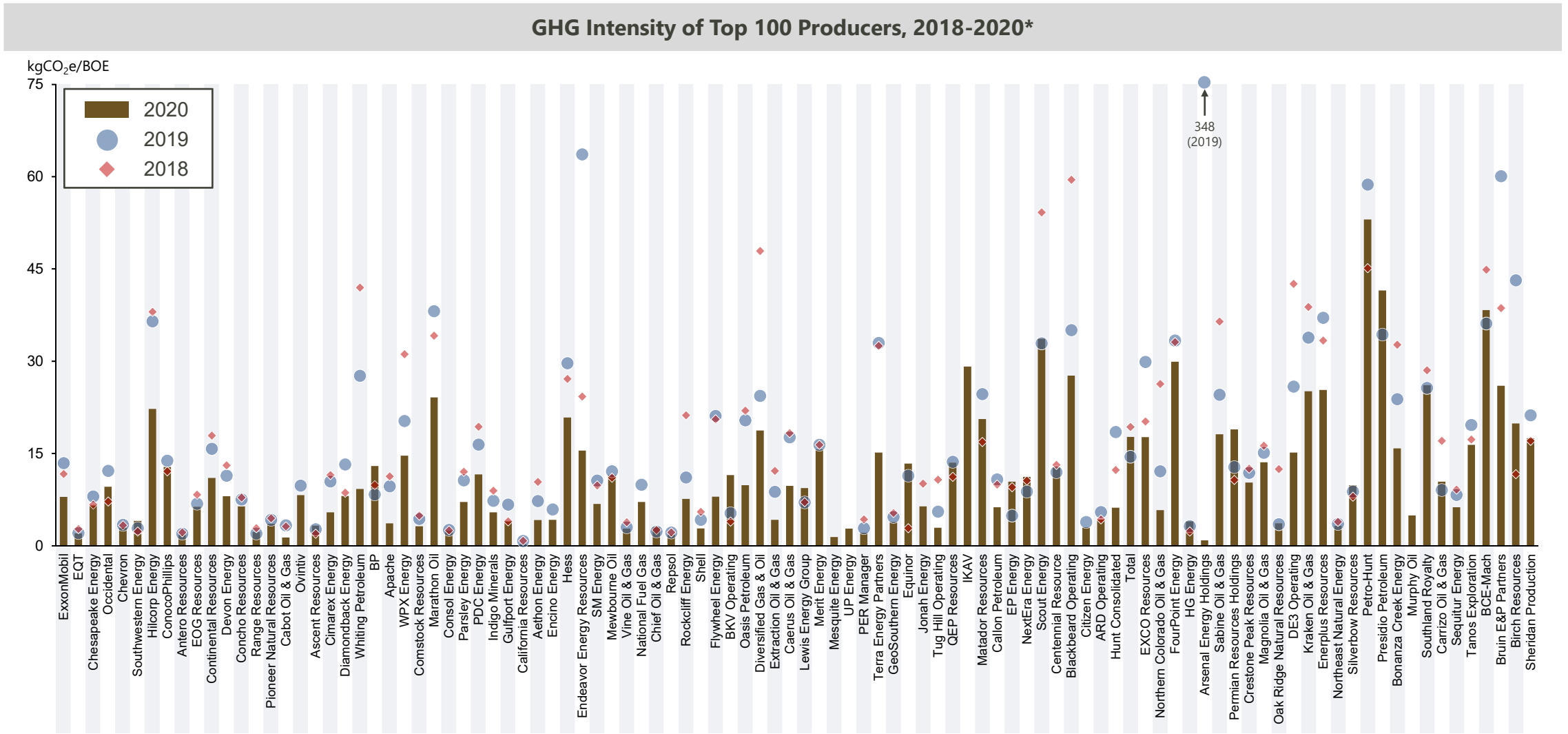
2018-2020 Trends Analysis: Change in Methane Intensity, by Top 100 Producer



*8 of the top 100 producers in 2020 were not in the EPA database for all three years and may not have data for 2018 and/or 2019.

Note: Reflects unpublished data submitted by ExxonMobil, Occidental, Apache, and Tanos Exploration currently under EPA review. Presidio Petroleum reflects assets purchased in 2019 that were allocated to Apache in current EPA data; IKAV reflects assets purchased in 2020 that were allocated to BP in current EPA data

2018-2020 Trends Analysis: Change in GHG Intensity, by Top 100 Producer



*8 of the top 100 producers in 2020 were not in the EPA database for all three years and may not have data for 2018 and/or 2019.

Note: Reflects unpublished data submitted by ExxonMobil, Occidental, Apache, and Tanos Exploration currently under EPA review. Presidio Petroleum reflects assets purchased in 2019 that were allocated to Apache in current EPA data; IKAV reflects assets purchased in 2020 that were allocated to BP in current EPA data

Emissions & Emissions Intensities of the Top 100 Producers

		Production		Emissions		Intensity		Metric Rank (among top 100 producers)				
								1=highest, 100= lowest				
Rank	Company	Total MBOE	Gas (bcf)	MT CH4	MT GHG	NGSI Intensity	GHG Intensity	Gas (bcf)	CH4 Emissions	GHG Emissions	NGSI Intensity	GHG Intensity
1	ExxonMobil	498,732	1,583	73,642	3,959,748	0.25%	7.94	2	2	2	32	54
2	EQT	382,031	1,916	18,758	772,056	0.05%	2.02	1	15	31	83	94
3	Chesapeake Energy	355,098	1,517	46,674	2,327,588	0.10%	6.55	3	5	7	58	59
4	Occidental	312,249	660	50,372	2,991,288	0.25%	9.58	11	3	4	33	47
5	Chevron	312,196	623	11,167	917,739	0.07%	2.94	12	32	25	70	86
6	Southwestern Energy	276,331	1,223	15,480	1,111,093	0.07%	4.02	4	19	21	69	74
7	Hilcorp Energy	268,351	800	136,708	5,968,674	1.00%	22.24	8	1	1	5	13
8	ConocoPhillips	258,722	442	47,480	3,312,777	0.45%	12.80	20	4	3	14	34
9	Antero Resources	252,247	1,182	8,876	441,269	0.05%	1.75	5	37	59	88	96
10	EOG Resources	242,181	444	5,833	1,529,272	0.07%	6.31	19	50	12	74	62
11	Continental Resources	215,629	493	15,122	2,375,577	0.17%	11.02	17	22	6	44	40
12	Devon Energy	203,274	467	14,111	1,640,523	0.12%	8.07	18	23	11	53	52
13	Concho Resources	201,220	382	7,149	1,289,346	0.06%	6.41	25	44	14	76	60
14	Range Resources	190,379	849	8,802	427,713	0.06%	2.25	7	38	61	78	92
15	Pioneer Natural Resources	189,884	329	9,039	676,667	0.16%	3.56	30	36	36	45	80
16	Cabot Oil & Gas	181,484	1,008	4,705	242,364	0.02%	1.34	6	56	77	96	98
17	Ovintiv	178,700	383	7,331	1,469,122	0.06%	8.22	24	43	13	80	50
18	Ascent Resources	172,545	786	12,370	564,672	0.09%	3.27	9	28	41	63	81
19	Cimarex Energy	160,648	388	11,167	872,278	0.13%	5.43	23	33	27	52	68
20	Diamondback Energy	150,545	249	5,192	1,220,240	0.07%	8.11	38	53	18	72	51
21	Whiting Petroleum	135,743	197	12,405	1,253,494	0.28%	9.23	47	27	15	27	49
22	BP	130,075	525	22,273	1,686,140	0.22%	12.96	14	11	10	37	33
23	Apache	125,441	360	4,411	455,778	0.07%	3.63	28	58	55	71	79
24	WPX Energy	124,557	201	4,852	1,823,556	0.08%	14.64	46	54	8	68	29
25	Comstock Resources	119,251	663	7,060	379,793	0.06%	3.18	10	45	63	82	83
26	Marathon Oil	118,032	220	17,506	2,845,901	0.27%	24.11	43	16	5	29	12
27	Consol Energy	107,667	558	6,316	260,887	0.06%	2.42	13	48	75	77	91
28	Parsley Energy	106,711	138	7,413	760,751	0.13%	7.13	61	41	32	50	56
29	PDC Energy	102,086	268	20,084	1,184,307	0.40%	11.60	36	14	19	17	36
30	Indigo Minerals	97,757	499	9,548	530,916	0.11%	5.43	15	35	47	56	67
31	Gulfport Energy	93,943	439	10,093	372,985	0.13%	3.97	21	34	64	51	75
32	California Resources	91,910	138	598	26,210	0.10%	0.29	62	97	99	60	100
33	Aethon Energy	87,659	497	1,407	366,012	0.02%	4.18	16	86	65	99	73
34	Encino Energy	85,943	346	5,752	361,262	0.10%	4.20	29	51	66	59	71

Note: Reflects unpublished data submitted by ExxonMobil, Occidental, and Apache that are currently under EPA review

Emissions & Emissions Intensities of the Top 100 Producers

		Production		Emissions		Intensity		Metric Rank (among top 100 producers)				
								1=highest, 100= lowest				
Rank	Company	Total MBOE	Gas (bcf)	MT CH4	MT GHG	NGSI Intensity	GHG Intensity	Gas (bcf)	CH4 Emissions	GHG Emissions	NGSI Intensity	GHG Intensity
35	Hess	85,107	111	5,295	1,775,985	0.17%	20.87	71	52	9	43	14
36	Endeavor Energy Resources	74,507	108	7,366	1,152,789	0.18%	15.47	72	42	20	42	26
37	SM Energy	71,922	169	2,209	489,035	0.05%	6.80	52	74	52	84	58
38	Mew bourne Oil	70,834	152	11,914	815,974	0.34%	11.52	57	30	30	23	37
39	Vine Oil & Gas	70,365	416	2,138	196,828	0.03%	2.80	22	75	83	95	89
40	National Fuel Gas	69,610	361	4,210	495,883	0.06%	7.12	27	60	50	79	57
41	Chief Oil & Gas	68,588	371	3,149	206,161	0.05%	3.01	26	69	80	90	85
42	Repsol	65,097	319	3,026	115,059	0.05%	1.77	31	70	91	87	95
43	Rockcliff Energy	60,632	319	6,577	462,440	0.12%	7.63	32	47	53	55	55
44	Shell	59,243	70	1,460	167,376	0.05%	2.83	84	84	86	86	88
45	Flyw heel Energy	55,668	310	14,107	443,785	0.25%	7.97	33	24	58	35	53
46	BKV Operating	55,597	277	15,190	638,963	0.32%	11.49	35	21	37	26	38
47	Oasis Petroleum	55,428	91	1,782	545,846	0.09%	9.85	75	80	45	64	45
48	Diversified Gas & Oil	54,742	277	32,052	1,026,024	0.68%	18.74	34	6	23	8	18
49	Extraction Oil & Gas	52,764	129	984	221,688	0.04%	4.20	64	94	78	93	72
50	Caerus Oil & Gas	50,853	241	16,190	495,648	0.39%	9.75	39	18	51	20	46
51	Lew is Energy Group	48,503	217	11,507	454,365	0.32%	9.37	44	31	56	24	48
52	Merit Energy	47,806	225	21,571	749,934	0.50%	15.69	42	13	33	13	25
53	Mesquite Energy	47,484	128	950	67,142	0.04%	1.41	65	95	98	92	97
54	UP Energy	46,963	231	1,688	129,992	0.04%	2.77	40	82	88	91	90
55	PER Manager	46,281	195	2,647	97,971	0.09%	2.12	48	71	94	66	93
56	Terra Energy Partners	45,885	227	22,006	695,648	0.57%	15.16	41	12	34	9	27
57	GeoSouthern Energy	45,733	250	4,271	175,774	0.09%	3.84	37	59	85	61	77
58	Equinor	44,723	113	1,104	597,686	0.03%	13.36	70	89	38	94	32
59	Jonah Energy	44,305	193	2,589	283,208	0.07%	6.39	49	72	73	75	61
60	Tug Hill Operating	42,872	191	303	125,577	0.01%	2.93	50	100	89	100	87
61	QEP Resources	42,507	64	1,777	573,469	0.09%	13.49	87	81	40	62	31
62	IKAV	42,244	216	30,794	1,231,142	0.85%	29.14	45	7	17	7	6
63	Matador Resources	40,628	83	7,486	837,249	0.28%	20.61	77	40	29	28	15
64	Callon Petroleum	39,144	75	1,785	244,911	0.08%	6.26	81	79	76	67	63
65	EP Energy	38,459	82	3,475	400,331	0.15%	10.41	78	67	62	46	41
66	NextEra Energy	38,262	160	4,829	428,364	0.14%	11.20	54	55	60	47	39
67	Scout Energy	37,072	152	28,407	1,247,710	1.02%	33.66	56	8	16	4	4

Note: IKAV reflects assets purchased in 2020 that were allocated to BP in current EPA data

Emissions & Emissions Intensities of the Top 100 Producers

		Production		Emissions		Intensity		Metric Rank (among top 100 producers)				
								1=highest, 100= lowest				
Rank	Company	Total MBOE	Gas (bcf)	MT CH4	MT GHG	NGSI Intensity	GHG Intensity	Gas (bcf)	CH4 Emissions	GHG Emissions	NGSI Intensity	GHG Intensity
68	Centennial Resource	35,634	68	3,983	453,262	0.20%	12.72	85	61	57	39	35
69	Blackbeard Operating	35,270	136	22,910	975,561	0.97%	27.66	63	10	24	6	7
70	Citizen Energy	35,134	125	428	105,823	0.02%	3.01	66	99	93	97	84
71	ARD Operating	34,886	190	3,635	147,743	0.10%	4.24	51	65	87	57	70
72	Hunt Consolidated	32,030	55	785	197,838	0.07%	6.18	88	96	82	73	65
73	Total	31,916	169	12,108	564,268	0.40%	17.68	53	29	42	19	20
74	EXCO Resources	31,028	140	16,407	547,536	0.57%	17.65	60	17	44	10	21
75	Northern Colorado Oil & Gas	30,631	71	3,715	177,322	0.24%	5.79	83	64	84	36	66
76	FourPoint Energy	30,608	115	23,940	915,904	1.14%	29.92	68	9	26	1	5
77	HG Energy	29,323	141	1,068	116,373	0.05%	3.97	59	90	90	89	76
78	Arsenal Energy Holdings	29,236	157	533	25,778	0.02%	0.88	55	98	100	98	99
79	Sabine Oil & Gas	29,140	145	13,033	528,146	0.52%	18.12	58	26	48	12	19
80	Permian Resources Holdings	28,441	82	3,594	538,088	0.26%	18.92	79	66	46	31	17
81	Crestone Peak Resources	25,624	72	6,276	263,370	0.43%	10.28	82	49	74	16	43
82	Magnolia Oil & Gas	24,594	53	3,791	333,623	0.27%	13.56	89	62	69	30	30
83	Oak Ridge Natural Resources	23,421	114	1,834	85,142	0.09%	3.64	69	78	96	65	78
84	DE3 Operating	23,405	32	2,271	354,349	0.25%	15.14	93	73	67	34	28
85	Kraken Oil & Gas	23,403	26	1,164	587,883	0.14%	25.12	94	87	39	49	11
86	Enerplus Resources	21,738	23	1,013	550,318	0.14%	25.32	98	91	43	48	10
87	Northeast Natural Energy	21,322	115	1,106	69,460	0.05%	3.26	67	88	97	85	82
88	Silverbow Resources	21,198	91	994	208,780	0.06%	9.85	74	93	79	81	44
89	Petro-Hunt	20,232	25	1,427	1,073,459	0.22%	53.06	95	85	22	38	1
90	Presidio Petroleum	20,196	78	13,666	838,003	1.03%	41.49	80	25	28	3	2
91	Bonanza Creek Energy	19,636	36	3,472	311,059	0.40%	15.84	92	68	70	18	24
92	Murphy Oil	19,403	24	2,073	96,038	0.19%	4.95	97	76	95	40	69
93	Southland Royalty	19,115	84	15,322	499,612	1.05%	26.14	76	20	49	2	8
94	Carrizo Oil & Gas	19,058	22	3,736	198,330	0.32%	10.41	99	63	81	25	42
95	Sequitur Energy	18,379	51	1,681	114,889	0.19%	6.25	90	83	92	41	64
96	Tanos Exploration	18,255	96	6,630	299,321	0.39%	16.40	73	46	71	21	23
97	BCE-Mach	17,785	65	7,529	681,319	0.55%	38.31	86	39	35	11	3
98	Bruin E&P Partners	17,698	24	1,897	460,226	0.35%	26.00	96	77	54	22	9
99	Birch Resources	17,187	21	1,002	341,749	0.12%	19.88	100	92	68	54	16
100	Sheridan Production	16,810	48	4,431	293,959	0.44%	17.49	91	57	72	15	22

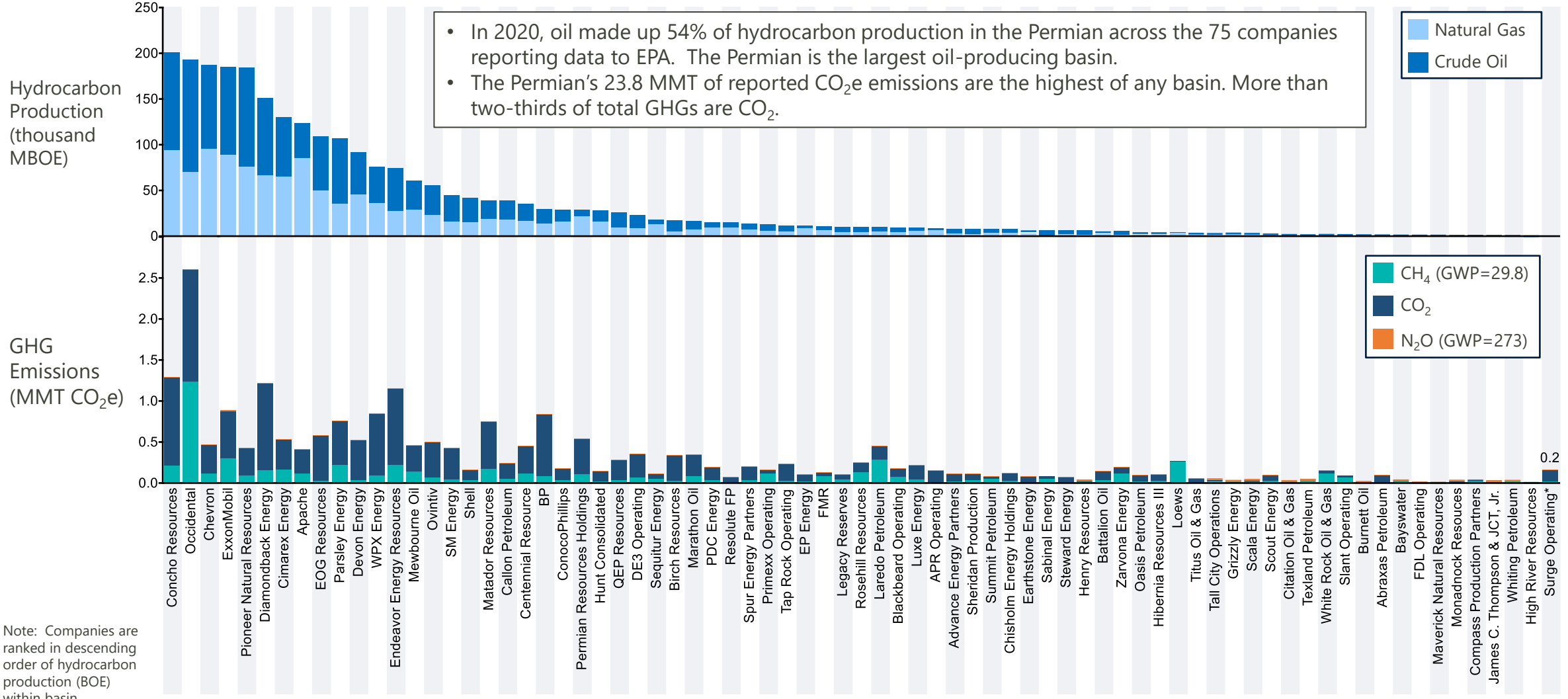
Note: Reflects unpublished data submitted by Tanos Exploration currently under EPA review; Presidio Petroleum reflects assets purchased in 2019 that were allocated to Apache in current EPA data

Company- & Basin-Level Summary Data

This section summarizes company-level data on hydrocarbon production, GHG emissions, emissions intensity, and sources of emissions for each of the following basins: Permian, Appalachian, Gulf Coast, and Williston. Additional data show the distribution of methane and GHG emissions intensities by volume in each basin.

Hydrocarbon Production & Emissions (100-year GWP)

- In 2020, oil made up 54% of hydrocarbon production in the Permian across the 75 companies reporting data to EPA. The Permian is the largest oil-producing basin.
- The Permian's 23.8 MMT of reported CO_2e emissions are the highest of any basin. More than two-thirds of total GHGs are CO_2.

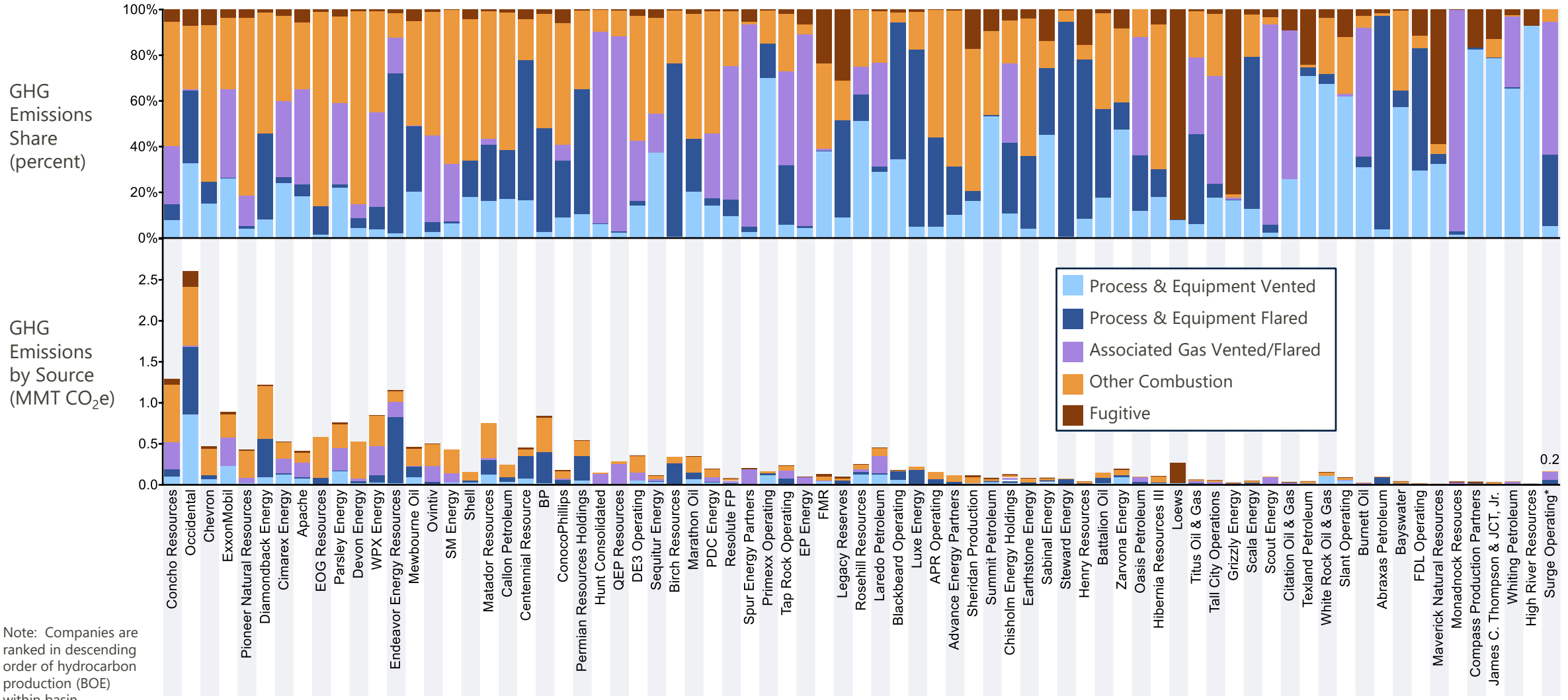


Note: Companies are ranked in descending order of hydrocarbon production (BOE) within basin

* Surge Operating did not report any hydrocarbon production but did report GHG emissions

Note: Reflects unpublished data submitted by ExxonMobil, Occidental, and Apache that are currently under EPA review

GHG Emissions by Source (100-year GWP)



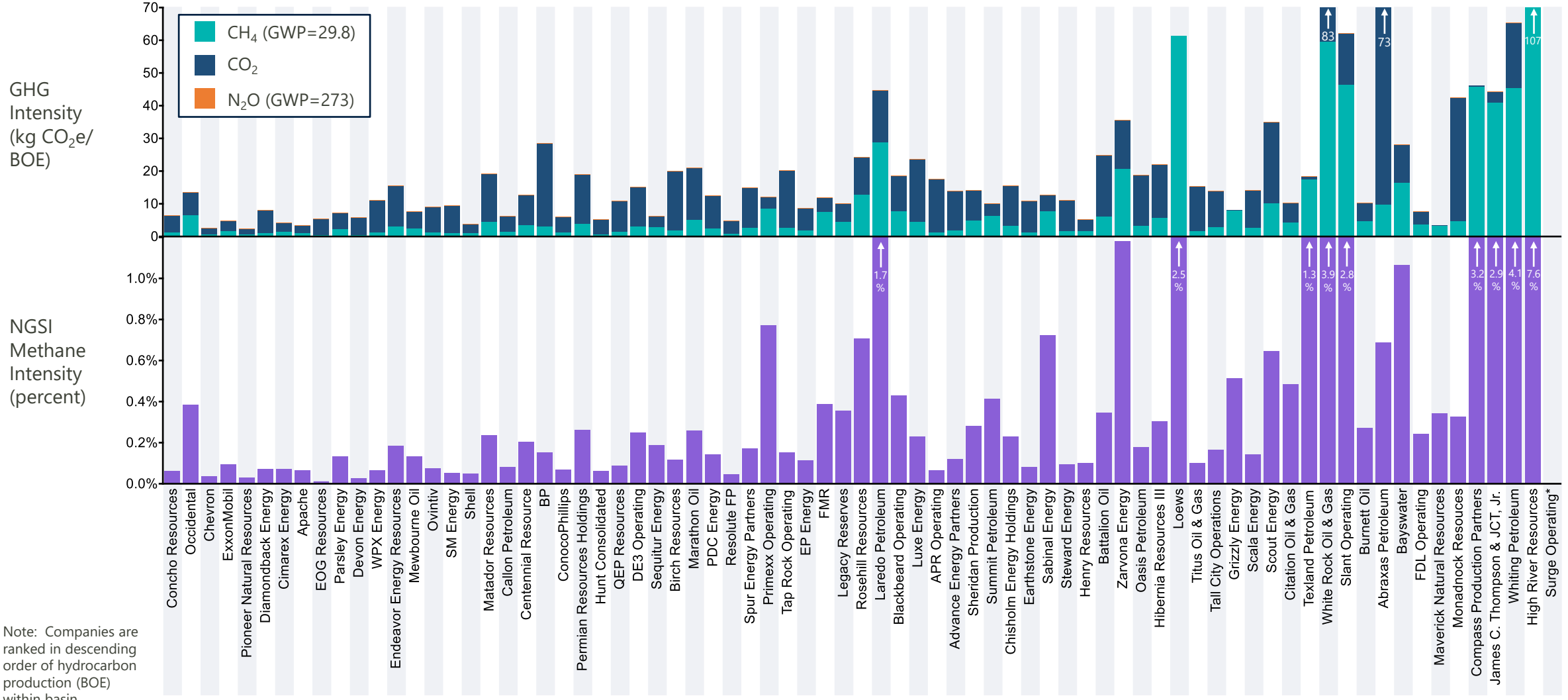
Note: Companies are ranked in descending order of hydrocarbon production (BOE) within basin

* Surge Operating did not report any hydrocarbon production but did report GHG emissions

Note: Reflects unpublished data submitted by ExxonMobil, Occidental, and Apache that are currently under EPA review

Permian Basin Producers

Methane & GHG Intensity (100-year GWP)

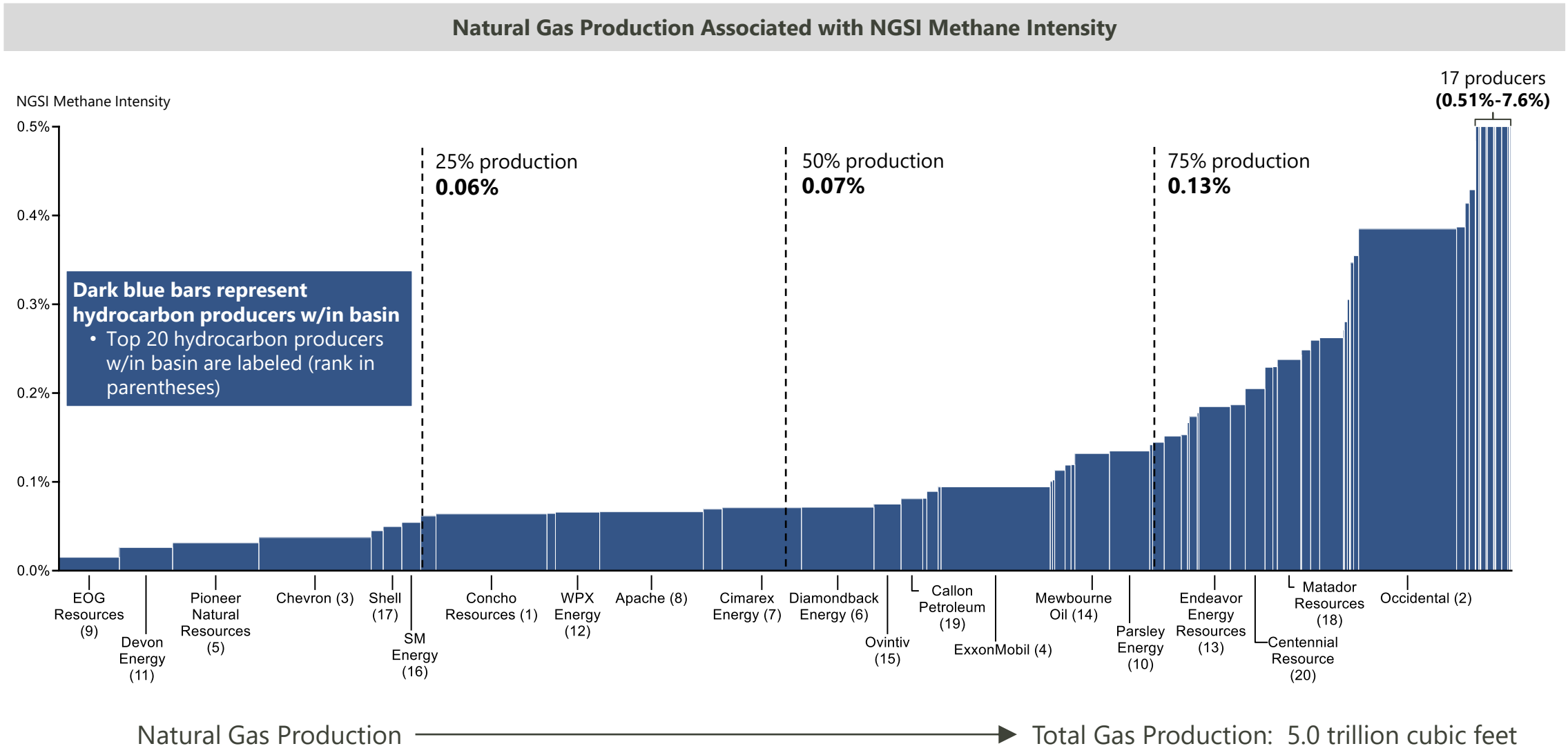


Note: Companies are ranked in descending order of hydrocarbon production (BOE) within basin

* Surge Operating did not report any hydrocarbon production but did report GHG emissions

Permian Basin Producers

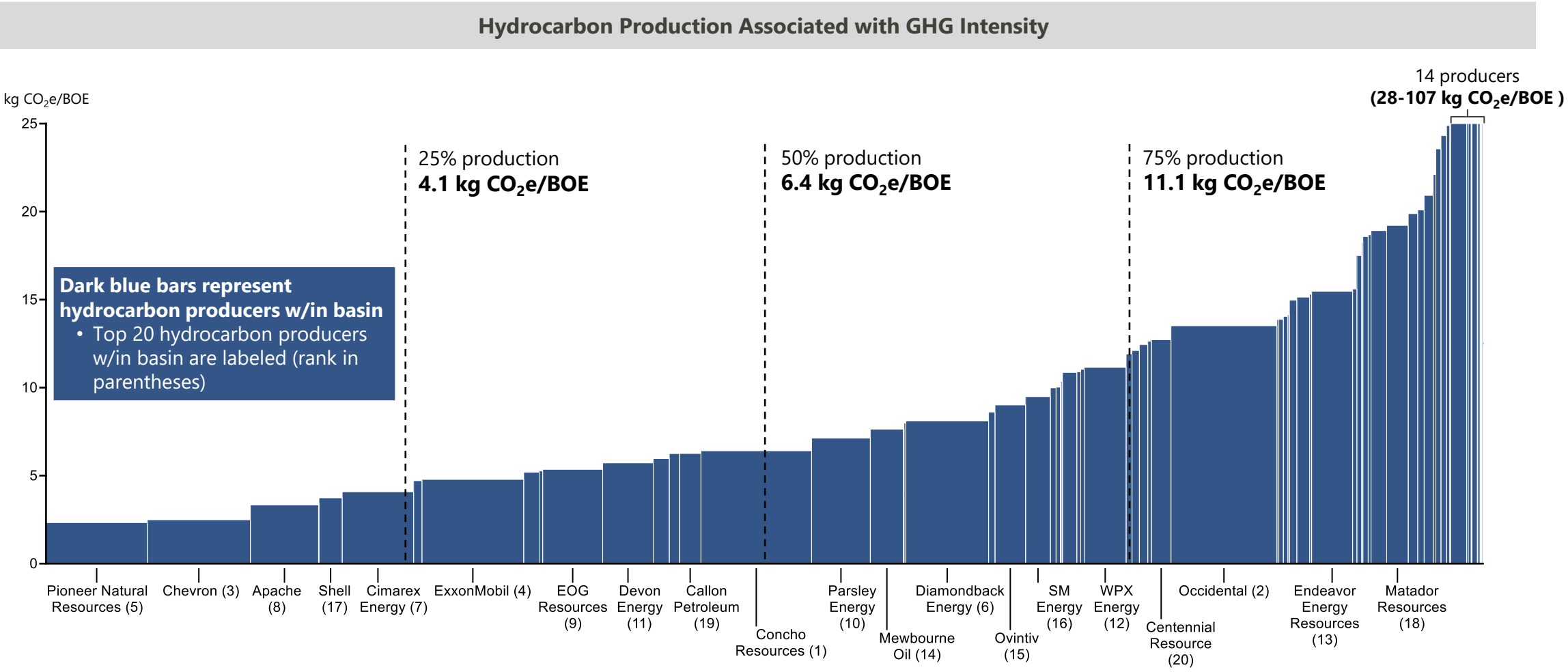
Total GHGRP Natural Gas Production, by Methane Intensity



Note: Reflects unpublished data submitted by ExxonMobil, Occidental, and Apache that are currently under EPA review

Permian Basin Producers

Total GHGRP Hydrocarbon Production, by GHG Intensity

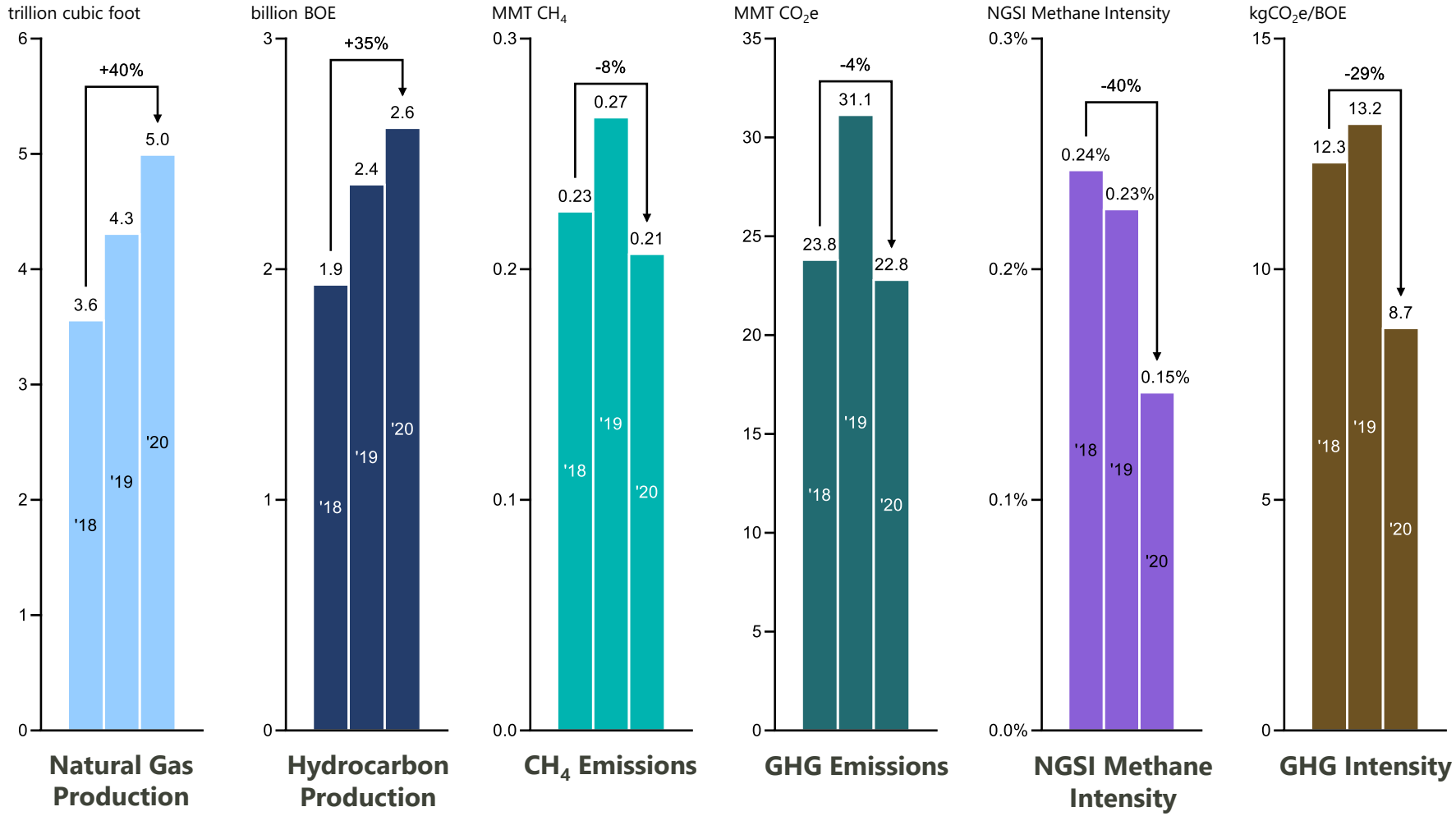


Permian Basin Producers

2018-2020 Trends Analysis: Production & Emission Metrics

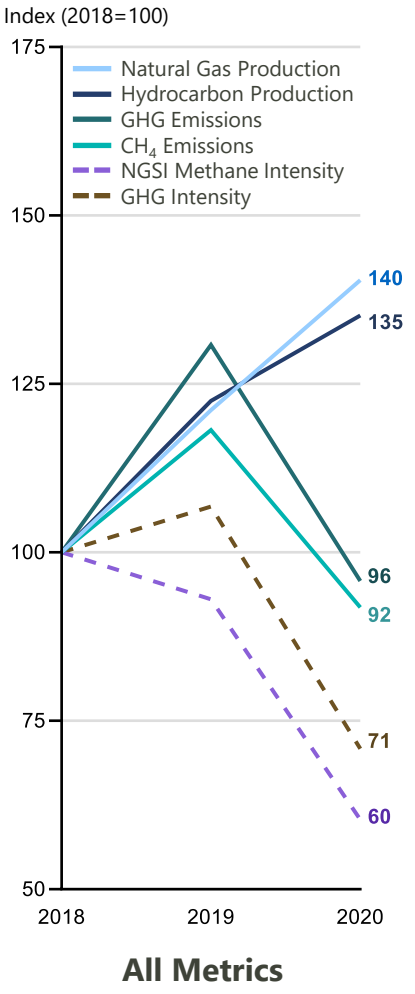
GHGRP Data Trends, 2018-2020

Permian Basin



Combined Data Metrics

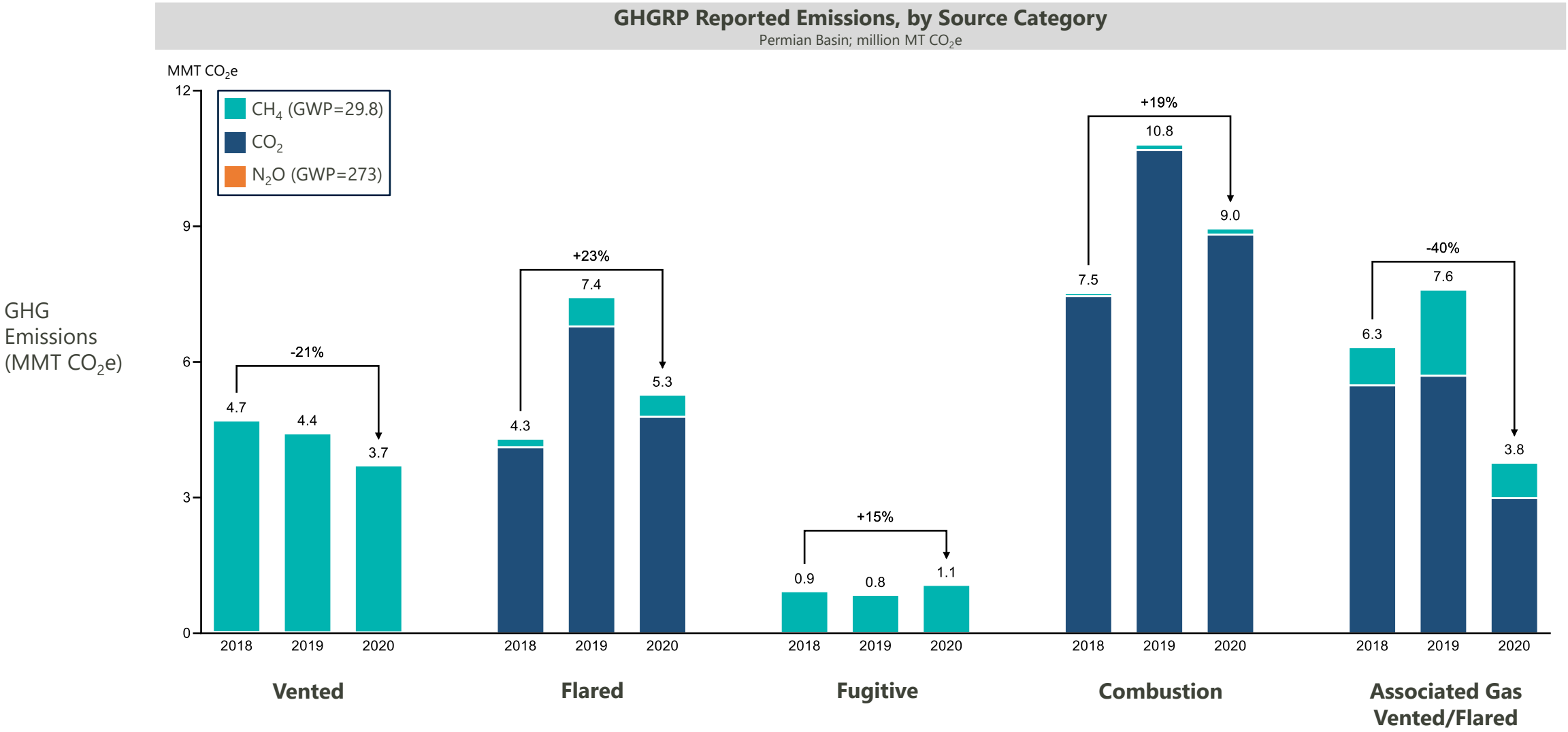
Indexed; 2018 = 100



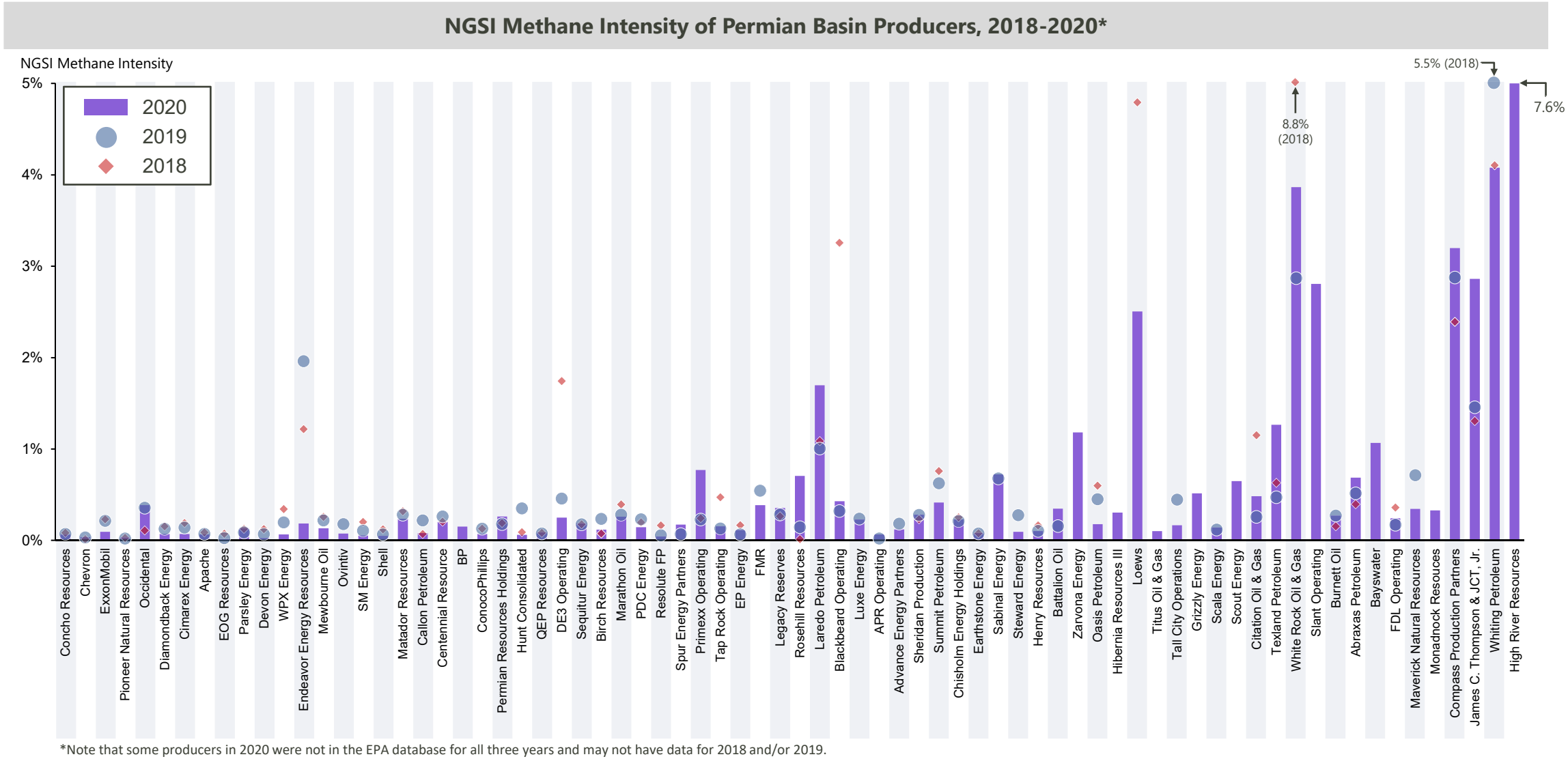
Note: Reflects unpublished data submitted by ExxonMobil, Occidental, and Apache that are currently under EPA review

Permian Basin Producers

2018-2020 Trends Analysis: Emission Sources



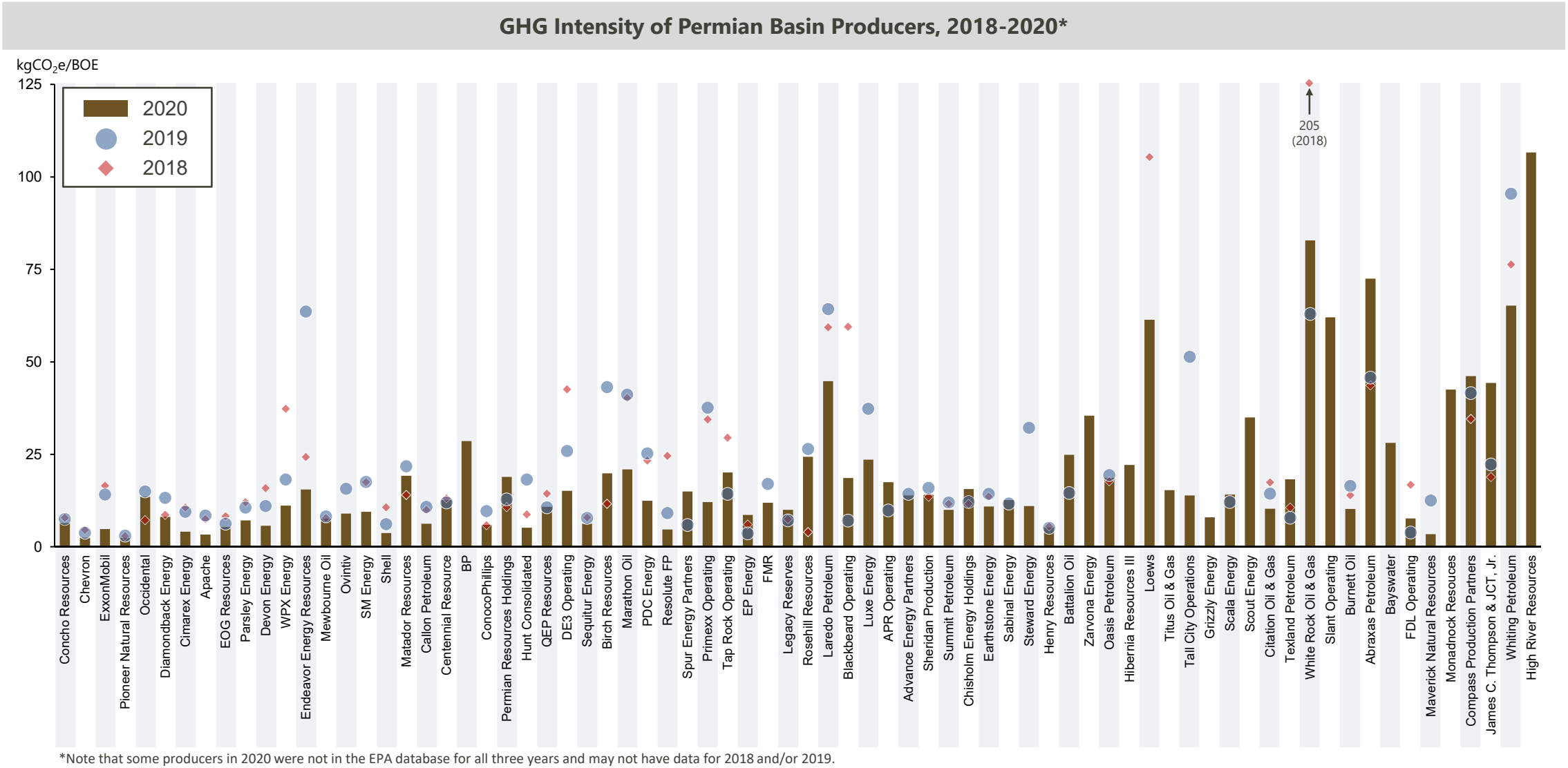
2018-2020 Trends Analysis: Change in Methane Intensity, by Top 100 Producer



*Note that some producers in 2020 were not in the EPA database for all three years and may not have data for 2018 and/or 2019.

Note: Reflects unpublished data submitted by ExxonMobil, Occidental, and Apache that are currently under EPA review

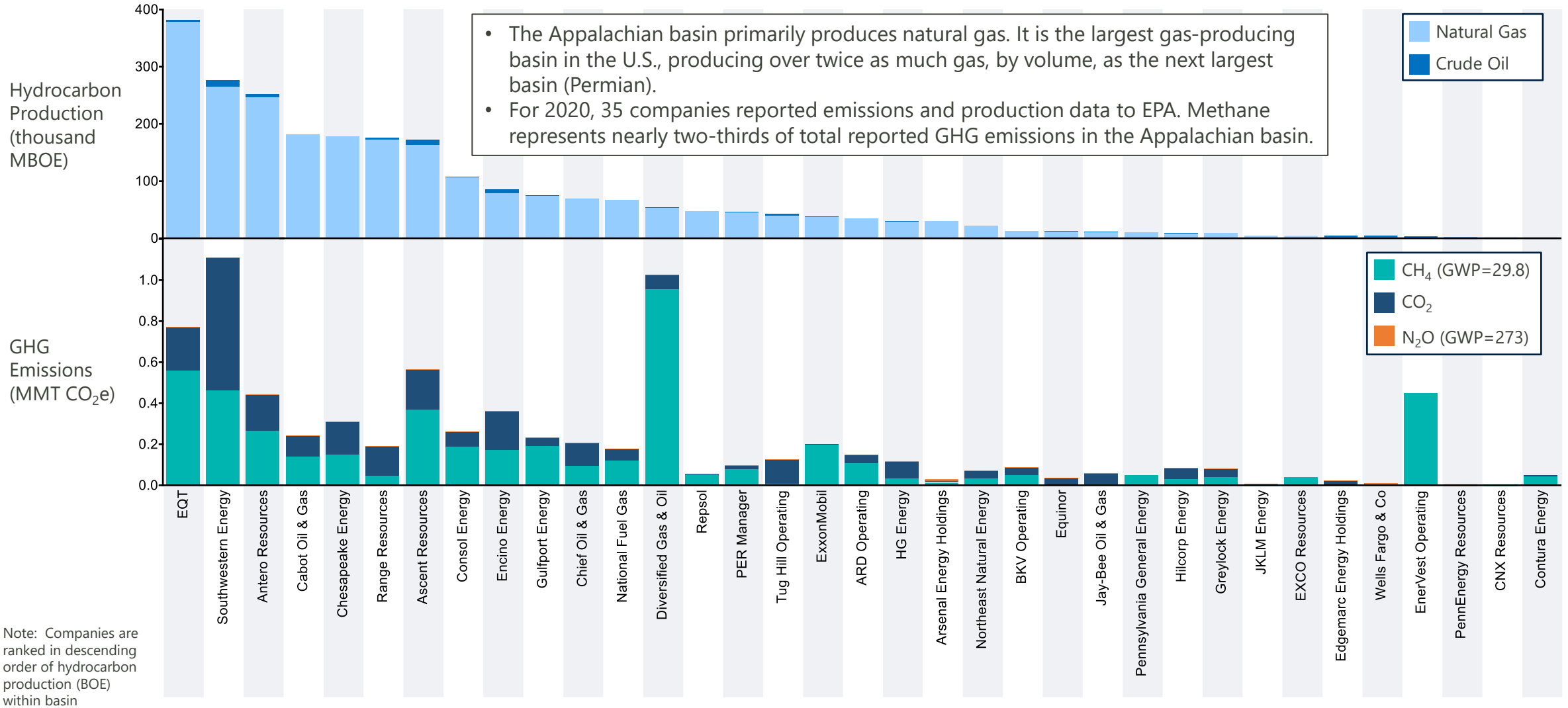
2018-2020 Trends Analysis: Change in GHG Intensity, by Top 100 Producer



*Note that some producers in 2020 were not in the EPA database for all three years and may not have data for 2018 and/or 2019.

Note: Reflects unpublished data submitted by ExxonMobil, Occidental, and Apache that are currently under EPA review

Hydrocarbon Production & Emissions (100-year GWP)



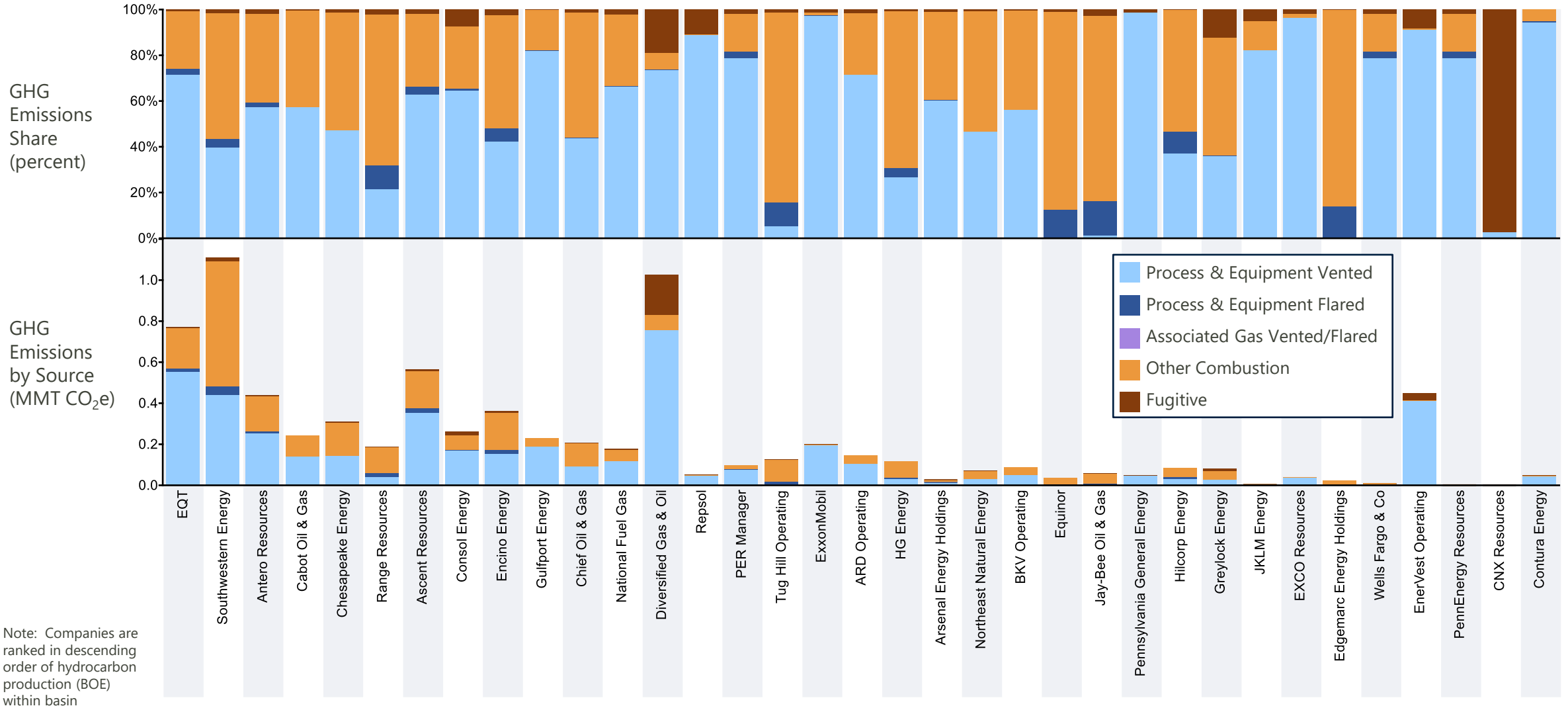
- The Appalachian basin primarily produces natural gas. It is the largest gas-producing basin in the U.S., producing over twice as much gas, by volume, as the next largest basin (Permian).
- For 2020, 35 companies reported emissions and production data to EPA. Methane represents nearly two-thirds of total reported GHG emissions in the Appalachian basin.

Note: Companies are ranked in descending order of hydrocarbon production (BOE) within basin

Note: Reflects unpublished data submitted by ExxonMobil that are currently under EPA review

Appalachian Basin Producers

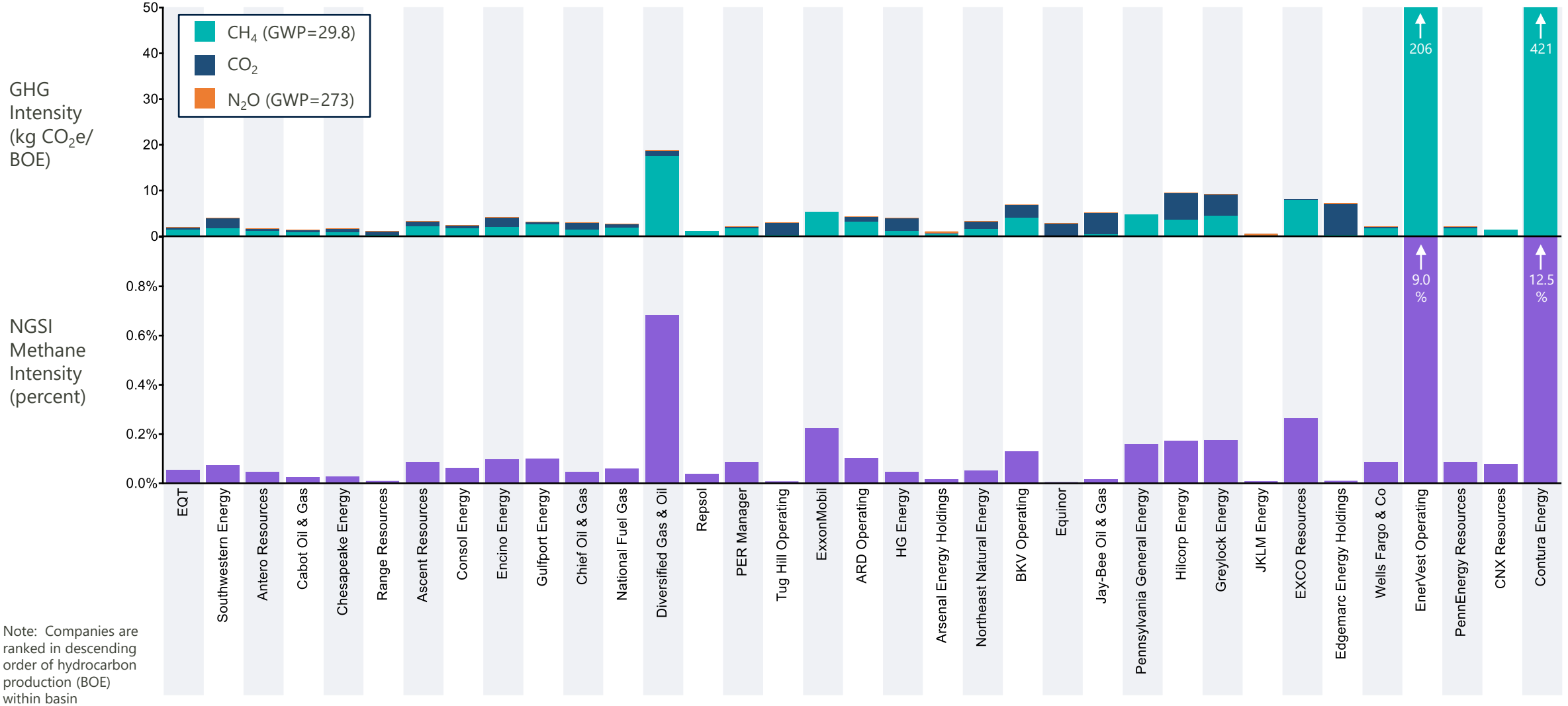
GHG Emissions by Source (100-year GWP)



Note: Companies are ranked in descending order of hydrocarbon production (BOE) within basin

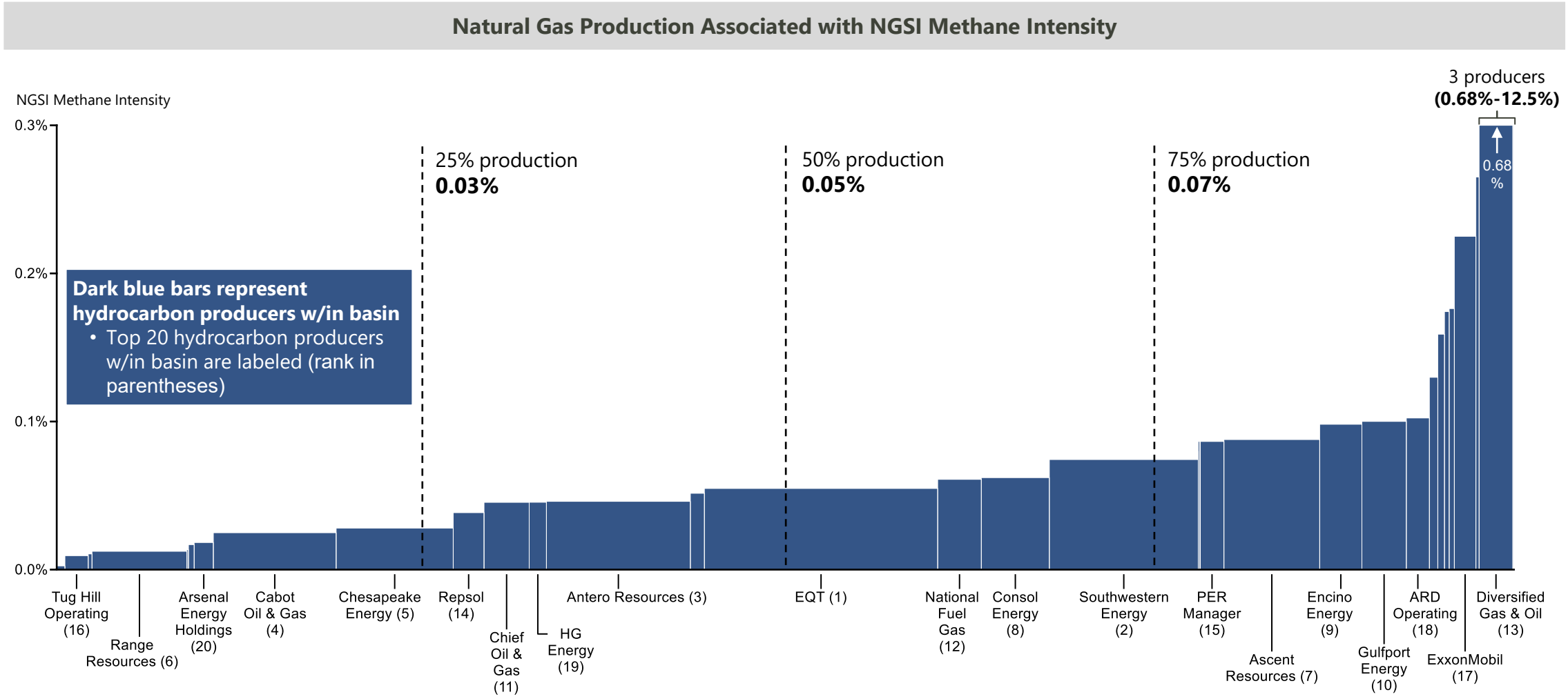
Appalachian Basin Producers

Methane & GHG Intensity (100-year GWP)



Note: Companies are ranked in descending order of hydrocarbon production (BOE) within basin

Total GHGRP Natural Gas Production, by Methane Intensity

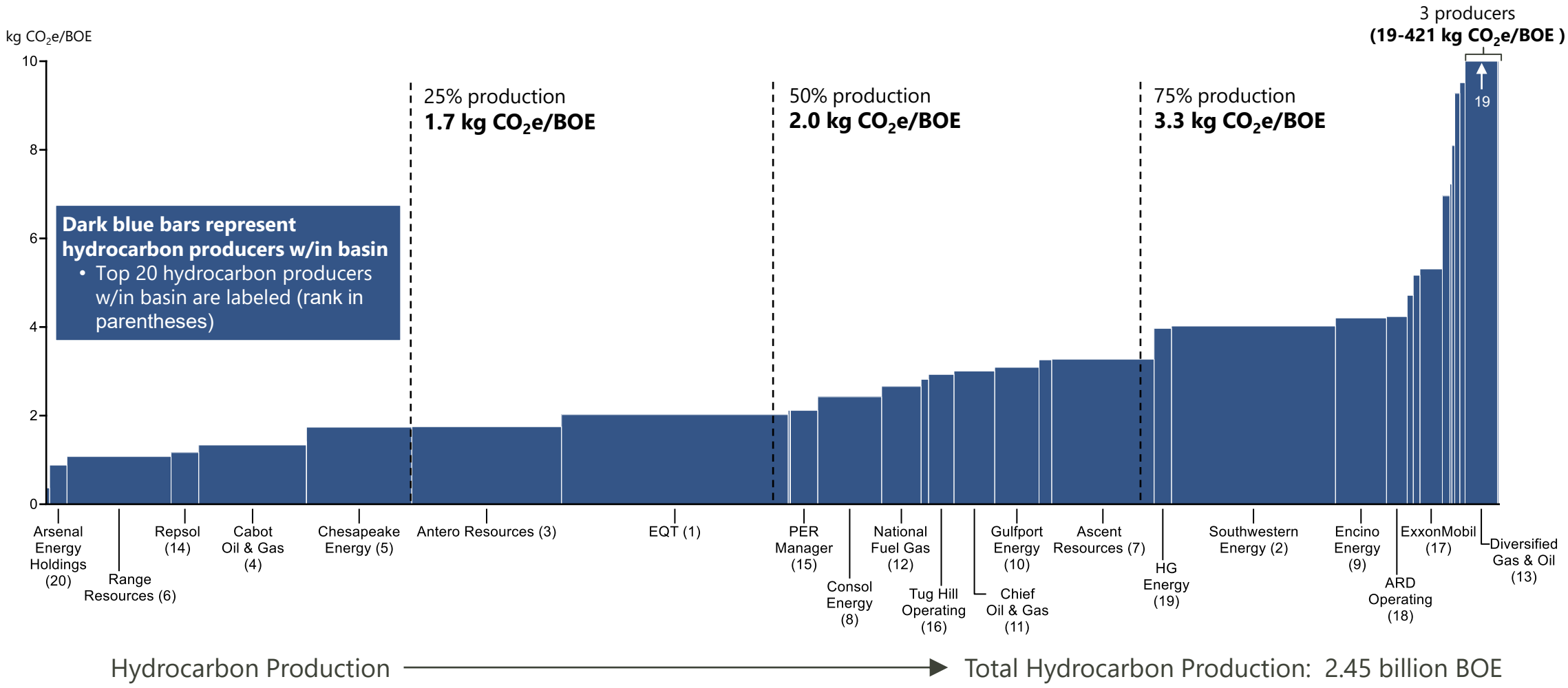


Note: Reflects unpublished data submitted by ExxonMobil that are currently under EPA review

Appalachian Basin Producers

Total GHGRP Hydrocarbon Production, by GHG Intensity

Hydrocarbon Production Associated with GHG Intensity

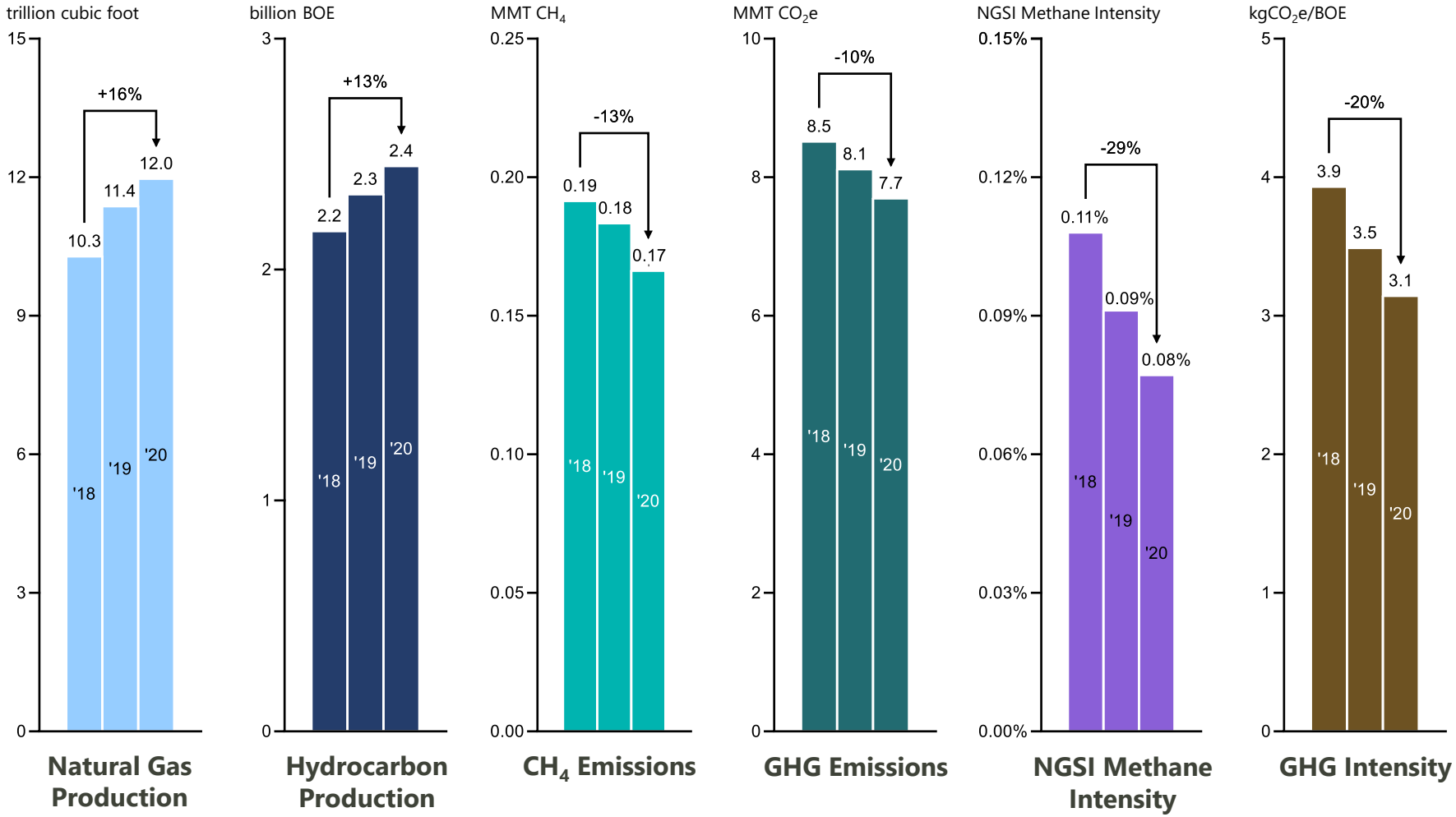


Appalachian Basin Producers

2018-2020 Trends Analysis: Production & Emission Metrics

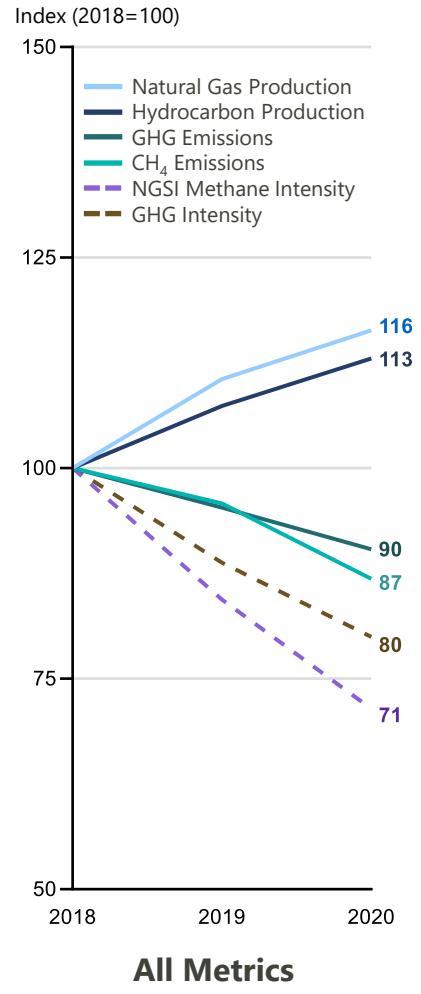
GHGRP Data Trends, 2018-2020

Appalachian Basin



Combined Data Metrics

Indexed; 2018 = 100



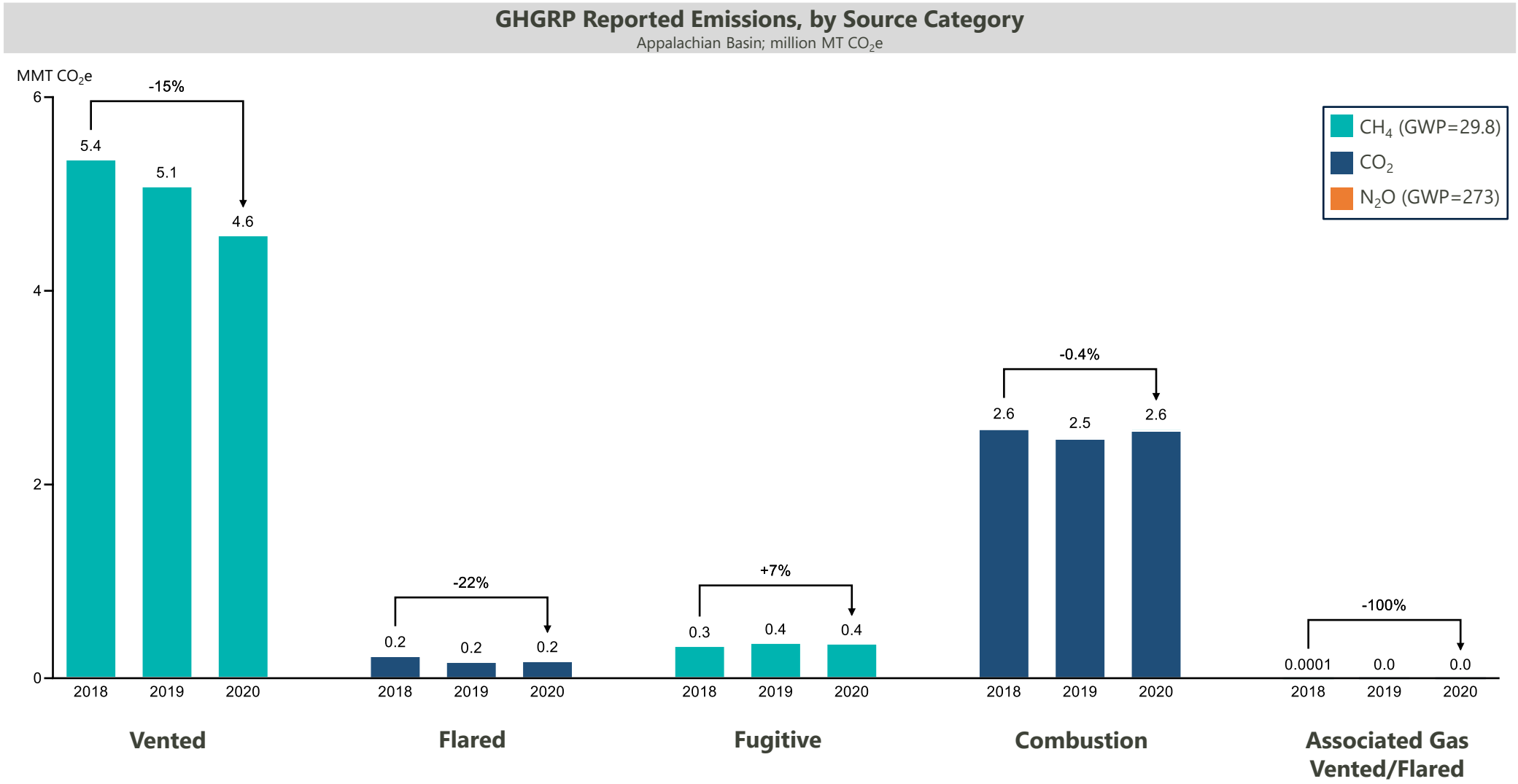
Benchmarking Methane and Other GHG Emissions of Oil & Natural Gas Production in the United States / July 2022
Data tables and maps at: www.sustainability.com

Note: Reflects unpublished data submitted by ExxonMobil that are currently under EPA review

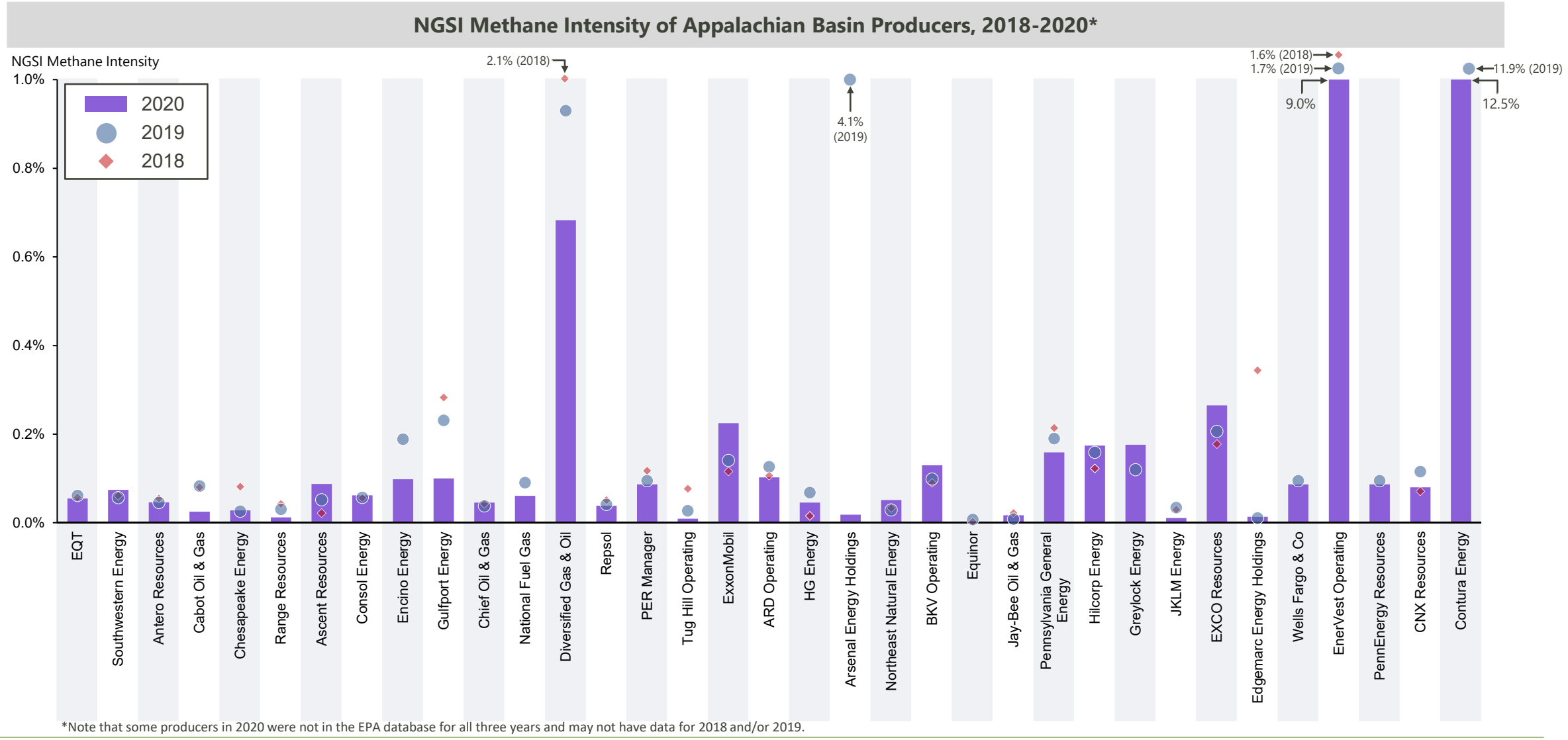
Appalachian Basin Producers

2018-2020 Trends Analysis: Emission Sources

GHG Emissions (MMT CO_2e)



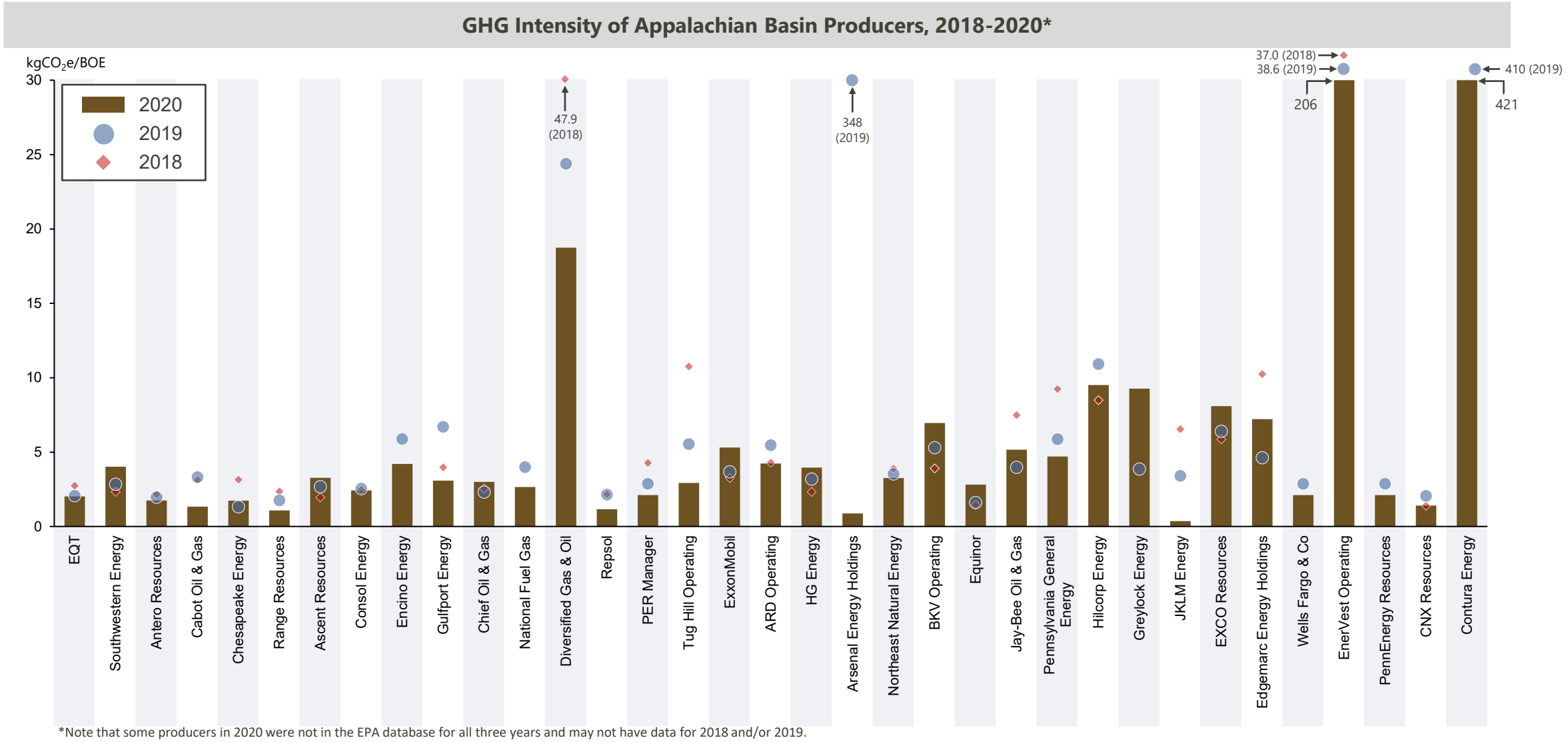
2018-2020 Trends Analysis: Change in Methane Intensity, by Top 100 Producer



*Note that some producers in 2020 were not in the EPA database for all three years and may not have data for 2018 and/or 2019.

Note: Reflects unpublished data submitted by ExxonMobil that are currently under EPA review

2018-2020 Trends Analysis: Change in GHG Intensity, by Top 100 Producer

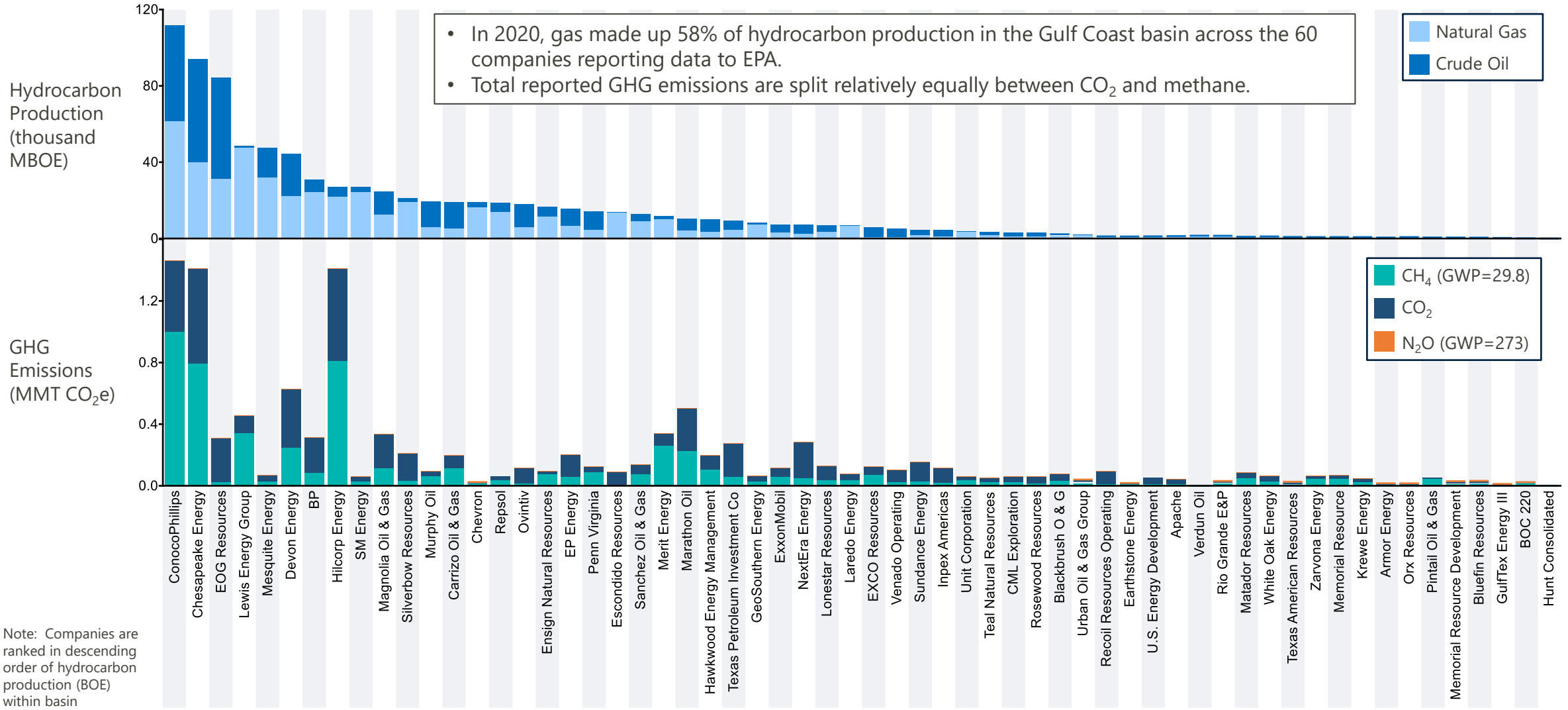


*Note that some producers in 2020 were not in the EPA database for all three years and may not have data for 2018 and/or 2019.

Note: Reflects unpublished data submitted by ExxonMobil that are currently under EPA review

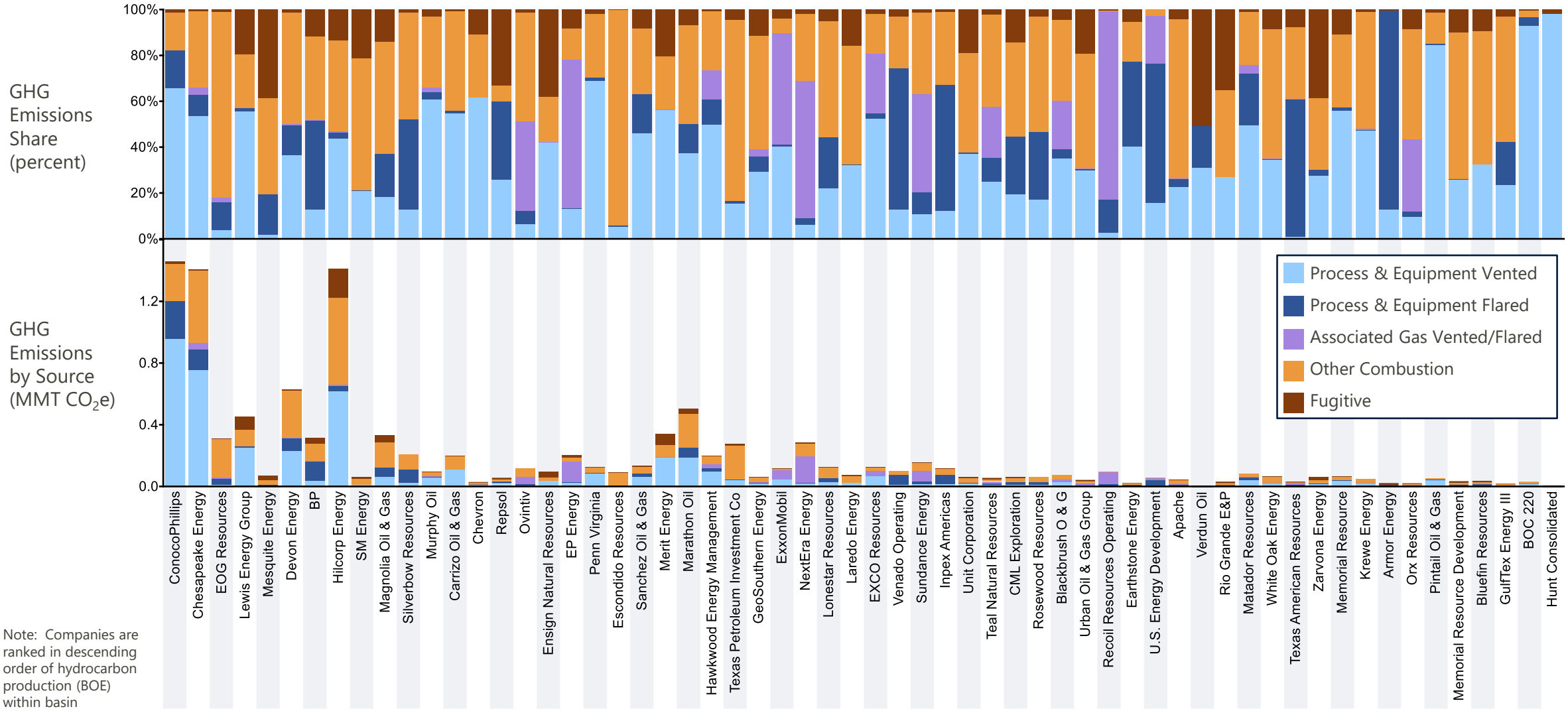
Gulf Coast Basin Producers

Hydrocarbon Production & Emissions (100-year GWP)



Note: Companies are ranked in descending order of hydrocarbon production (BOE) within basin

GHG Emissions by Source (100-year GWP)

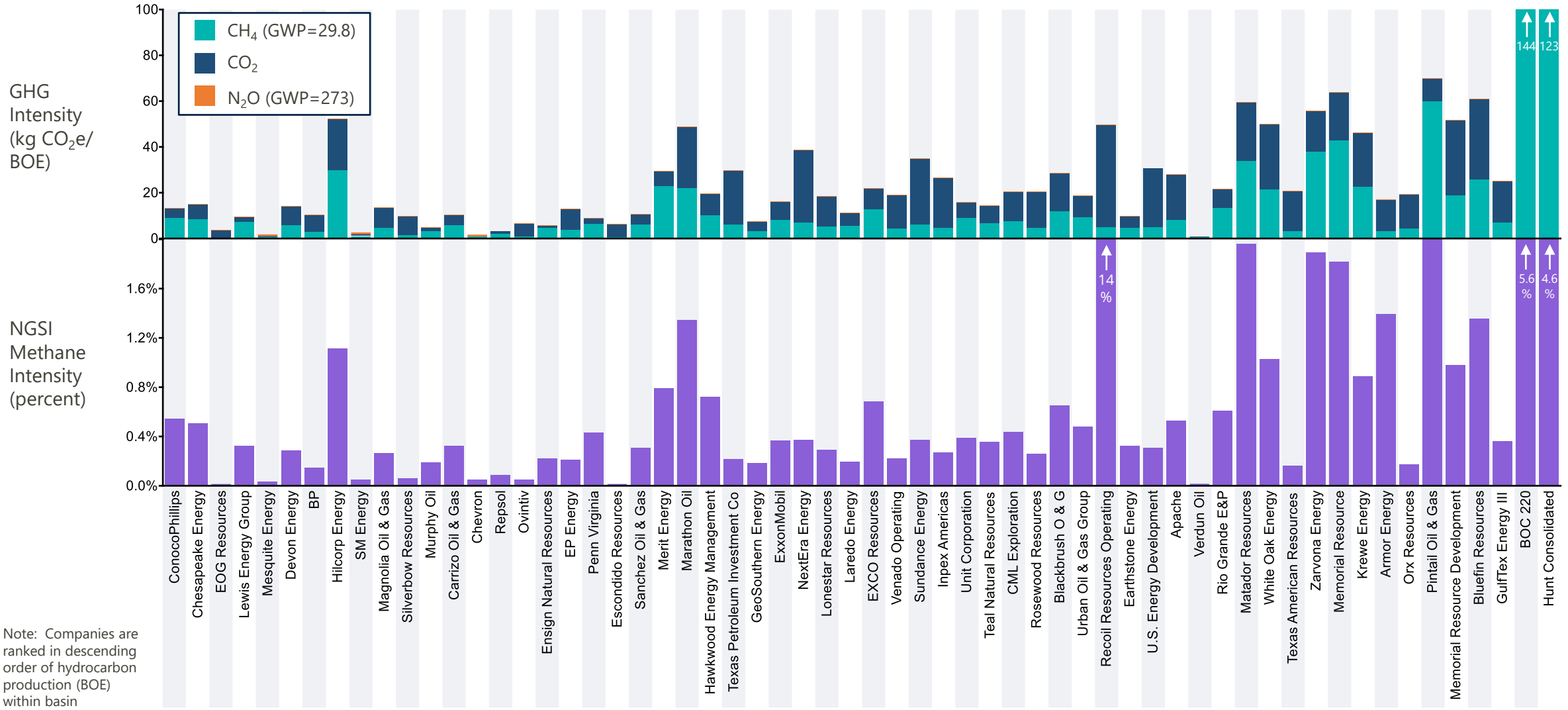


Note: Companies are ranked in descending order of hydrocarbon production (BOE) within basin

Note: Reflects unpublished data submitted by ExxonMobil and Apache that are currently under EPA review

Gulf Coast Basin Producers

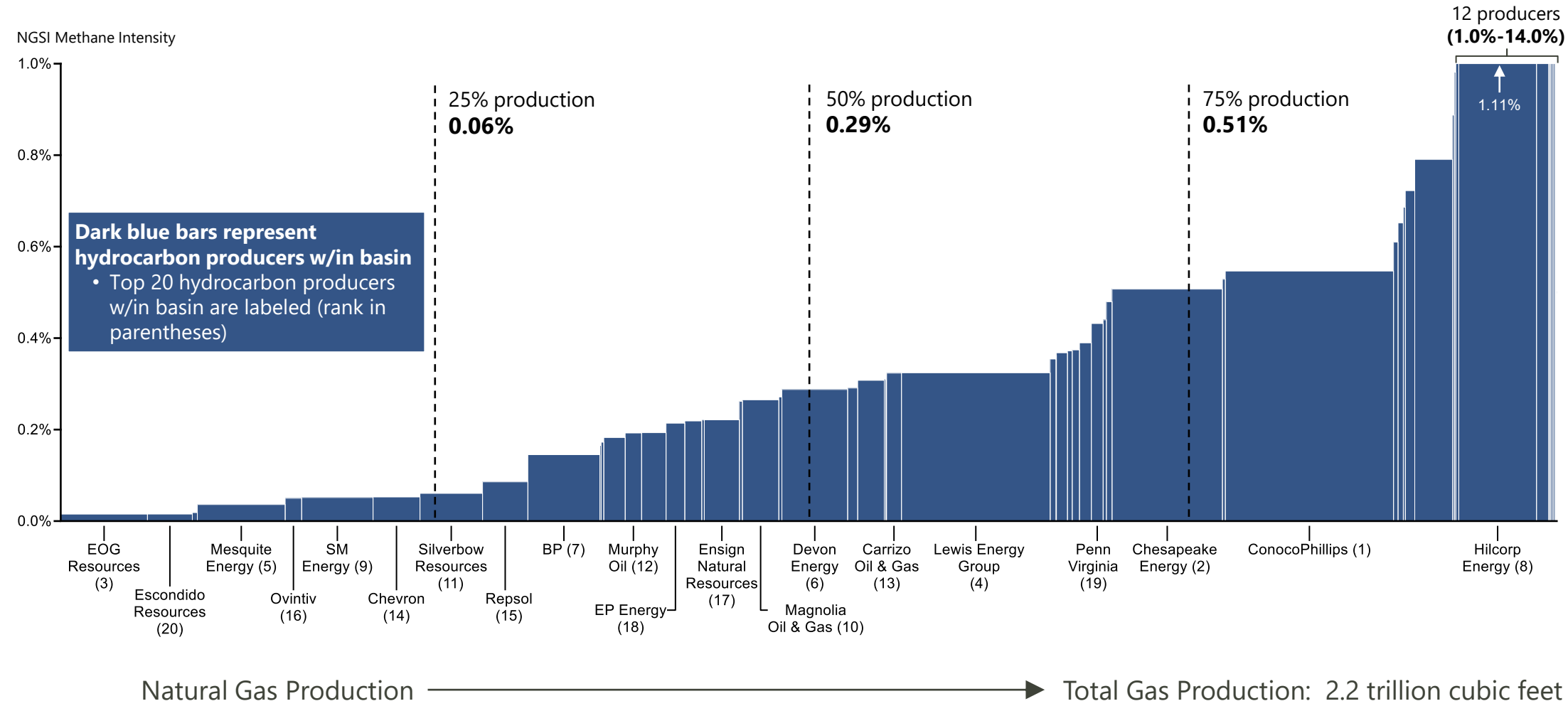
Methane & GHG Intensity (100-year GWP)



Note: Companies are ranked in descending order of hydrocarbon production (BOE) within basin

Gulf Coast Basin Producers

Total GHGRP Natural Gas Production, by Methane Intensity

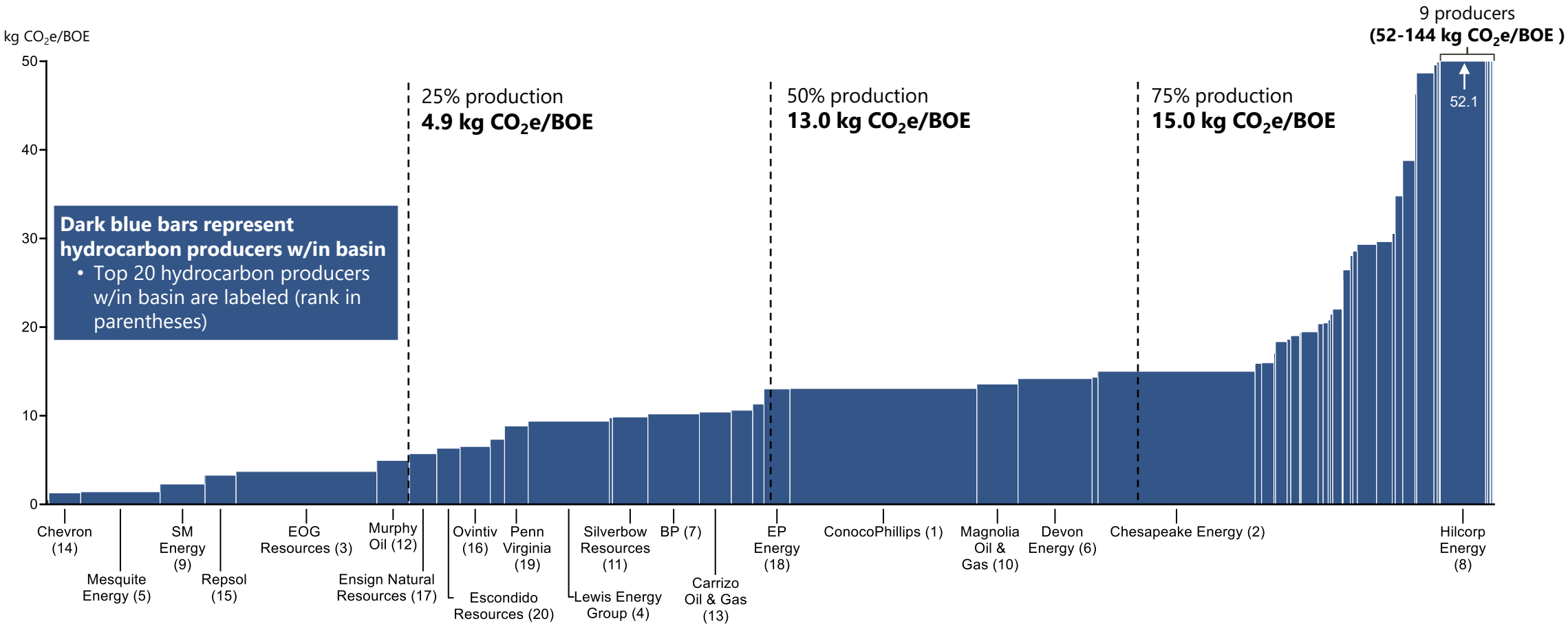


Note: Reflects unpublished data submitted by ExxonMobil and Apache that are currently under EPA review

Gulf Coast Basin Producers

Total GHGRP Hydrocarbon Production, by GHG Intensity

Hydrocarbon Production Associated with GHG Intensity



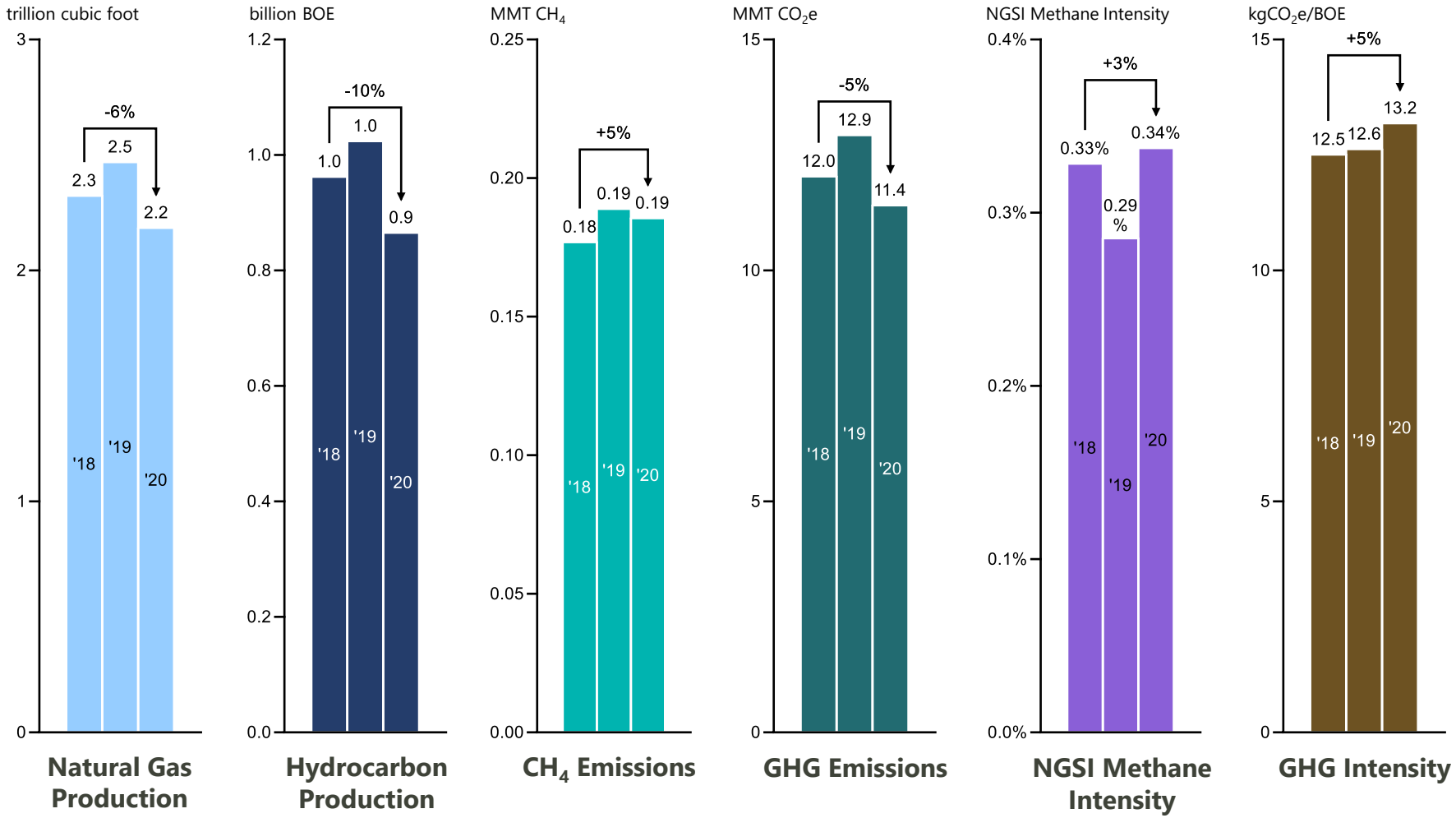
Hydrocarbon Production → Total Hydrocarbon Production: 0.87 billion BOE

Note: Reflects unpublished data submitted by ExxonMobil and Apache that are currently under EPA review

2018-2020 Trends Analysis: Production & Emission Metrics

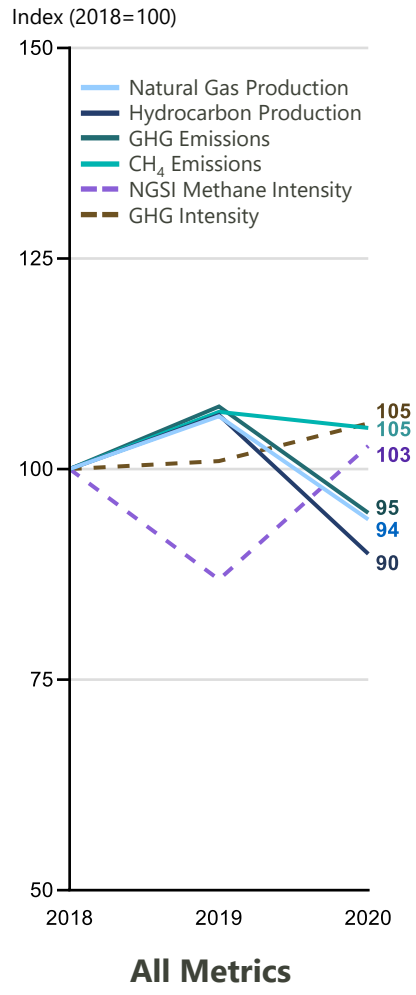
GHGRP Data Trends, 2018-2020

Gulf Coast Basin



Combined Data Metrics

Indexed; 2018 = 100

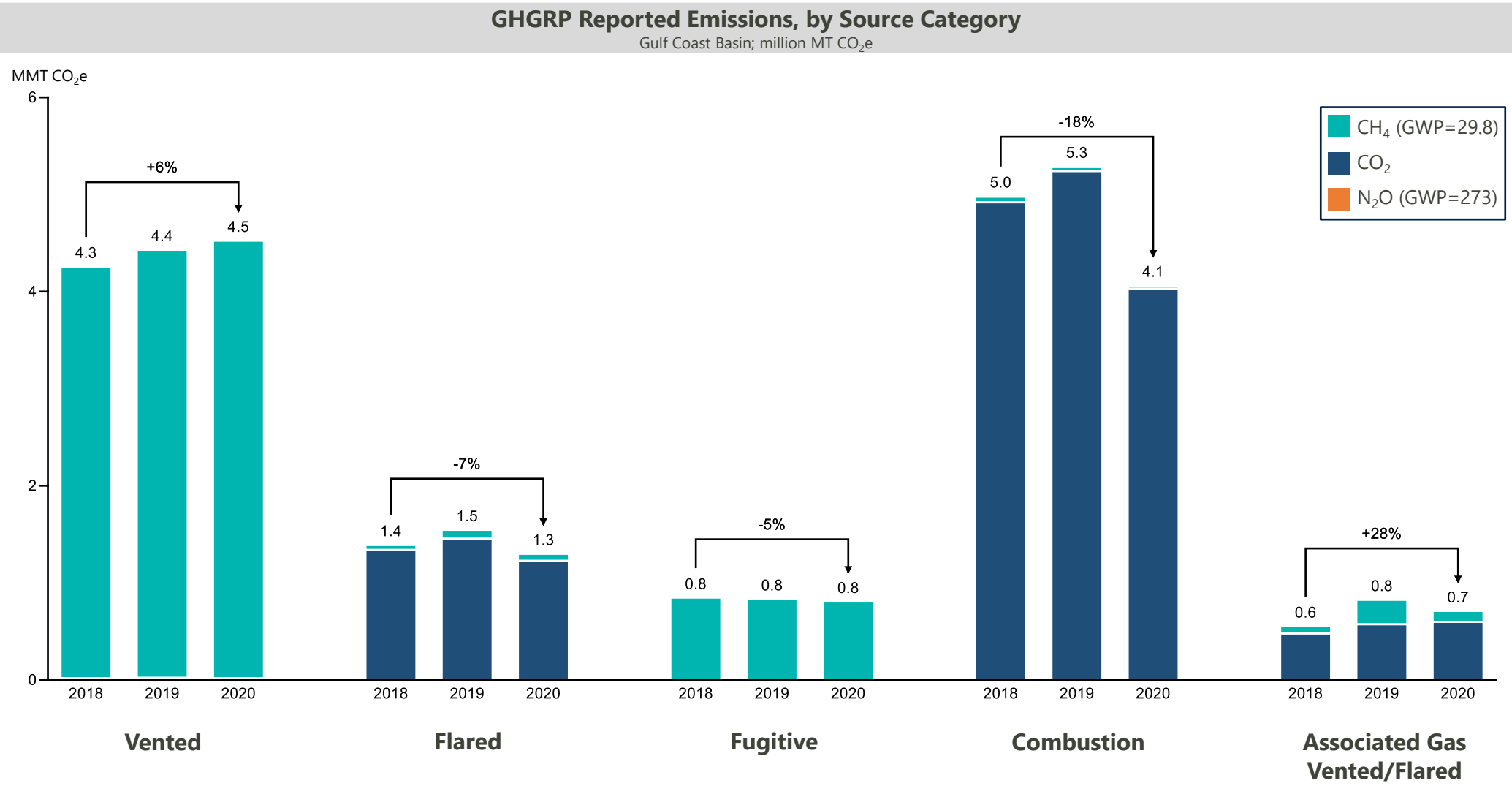


Note: Reflects unpublished data submitted by ExxonMobil and Apache that are currently under EPA review

Gulf Coast Basin Producers

2018-2020 Trends Analysis: Emission Sources

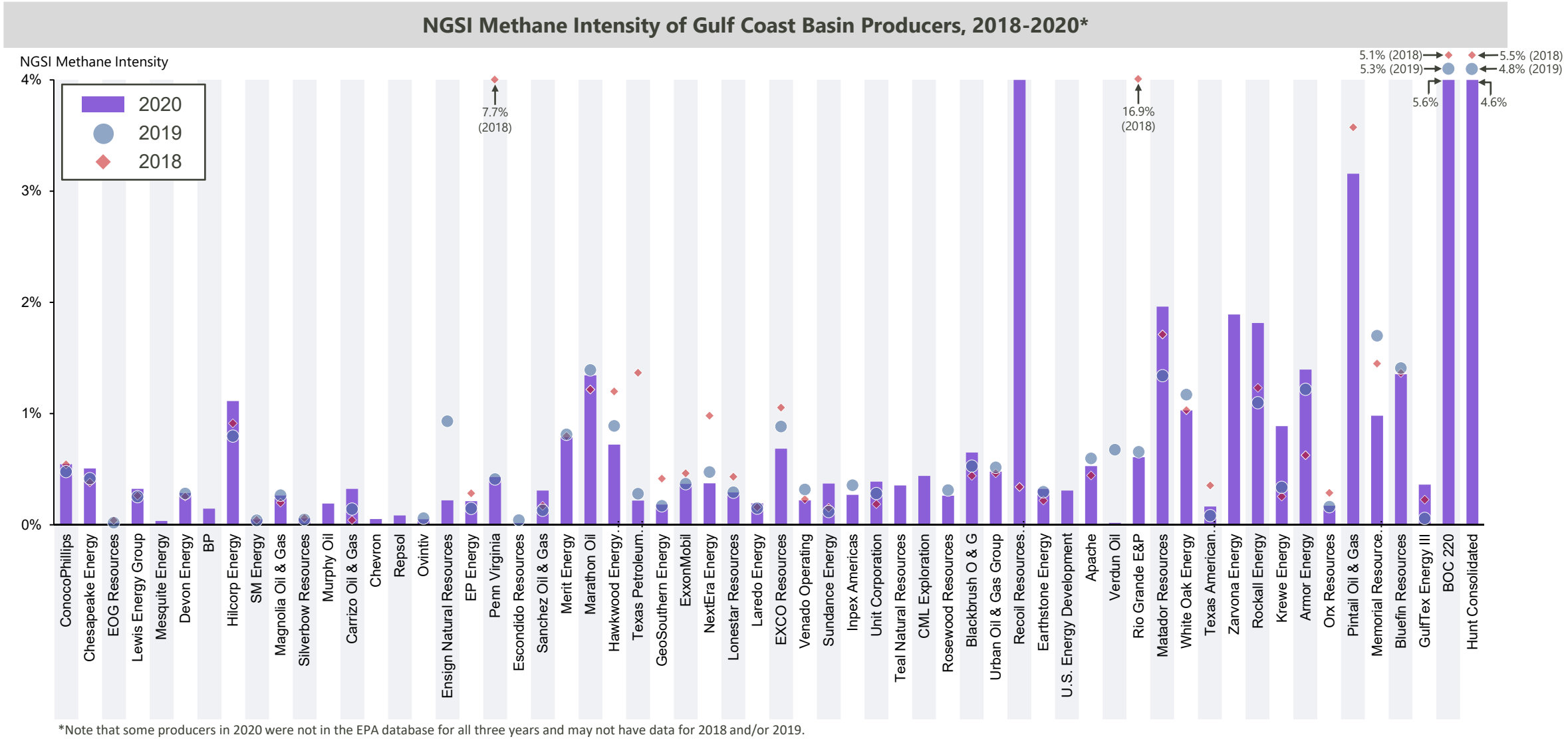
GHG Emissions (MMT CO_2e)



Benchmarking Methane and Other GHG Emissions of Oil & Natural Gas Production in the United States / July 2022
Data tables and maps at: www.sustainability.com

Note: Reflects unpublished data submitted by ExxonMobil and Apache that are currently under EPA review

2018-2020 Trends Analysis: Change in Methane Intensity, by Top 100 Producer



*Note that some producers in 2020 were not in the EPA database for all three years and may not have data for 2018 and/or 2019.

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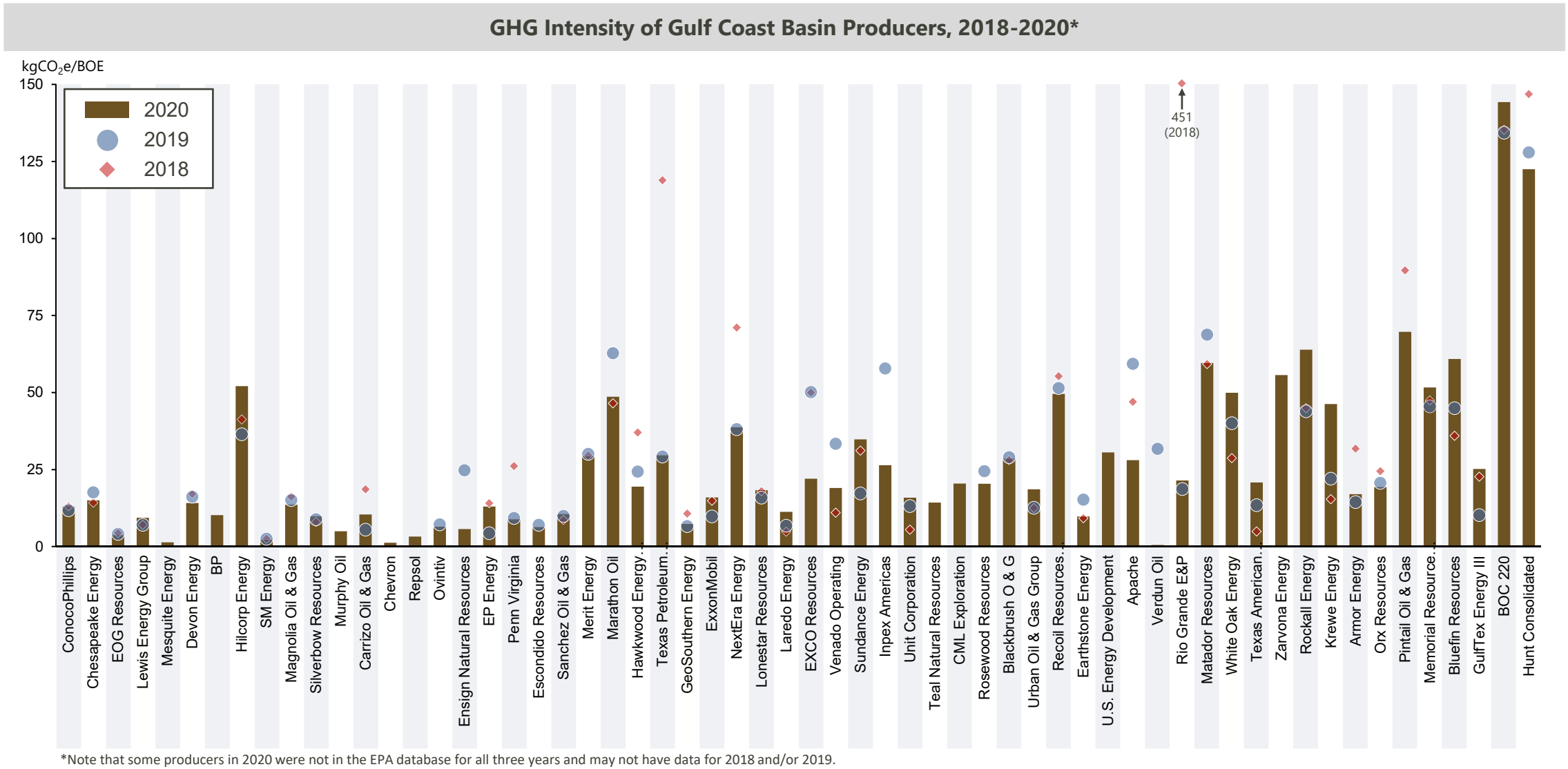
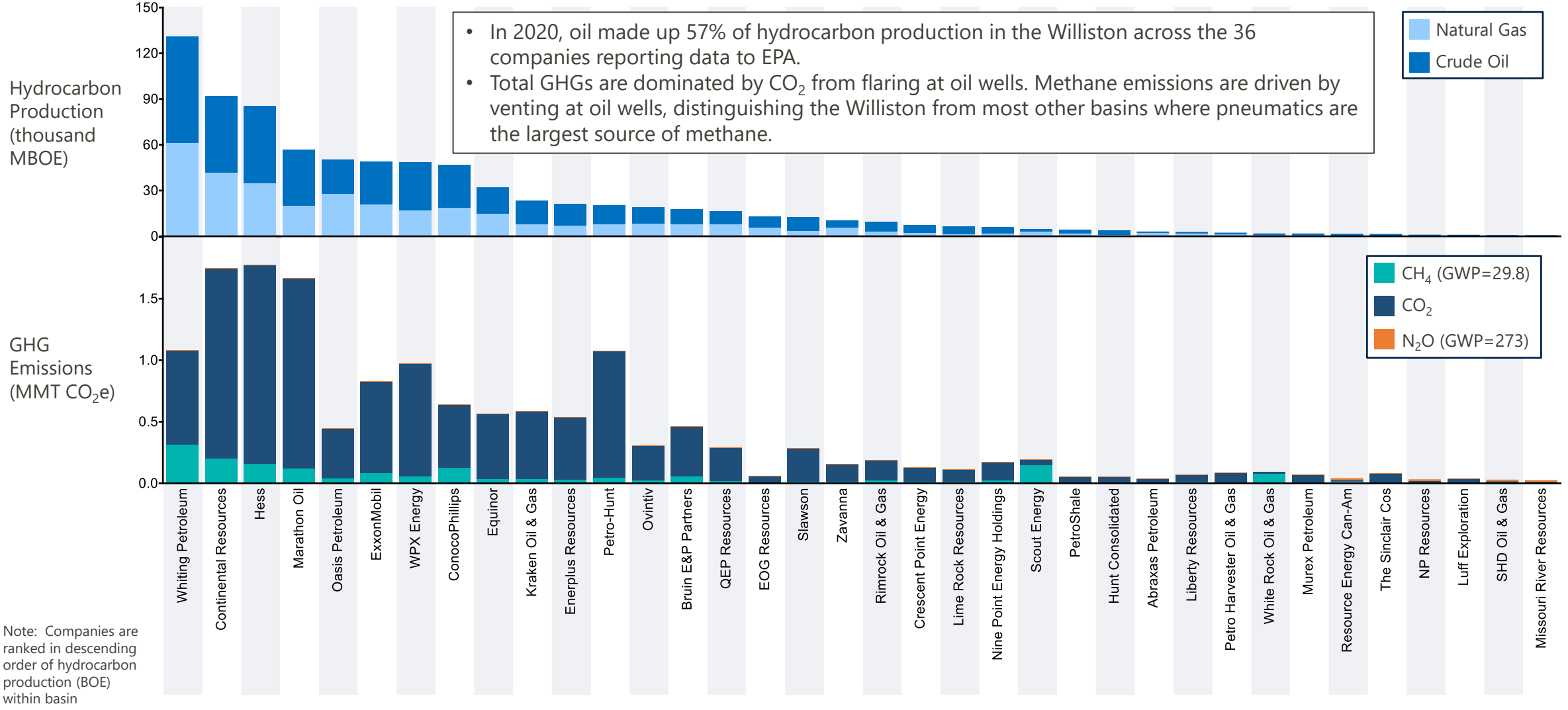
2018-2020 Trends Analysis: Change in GHG Intensity, by Top 100 Producer



*Note that some producers in 2020 were not in the EPA database for all three years and may not have data for 2018 and/or 2019.

Note: Reflects unpublished data submitted by ExxonMobil and Apache that are currently under EPA review

Hydrocarbon Production & Emissions (100-year GWP)



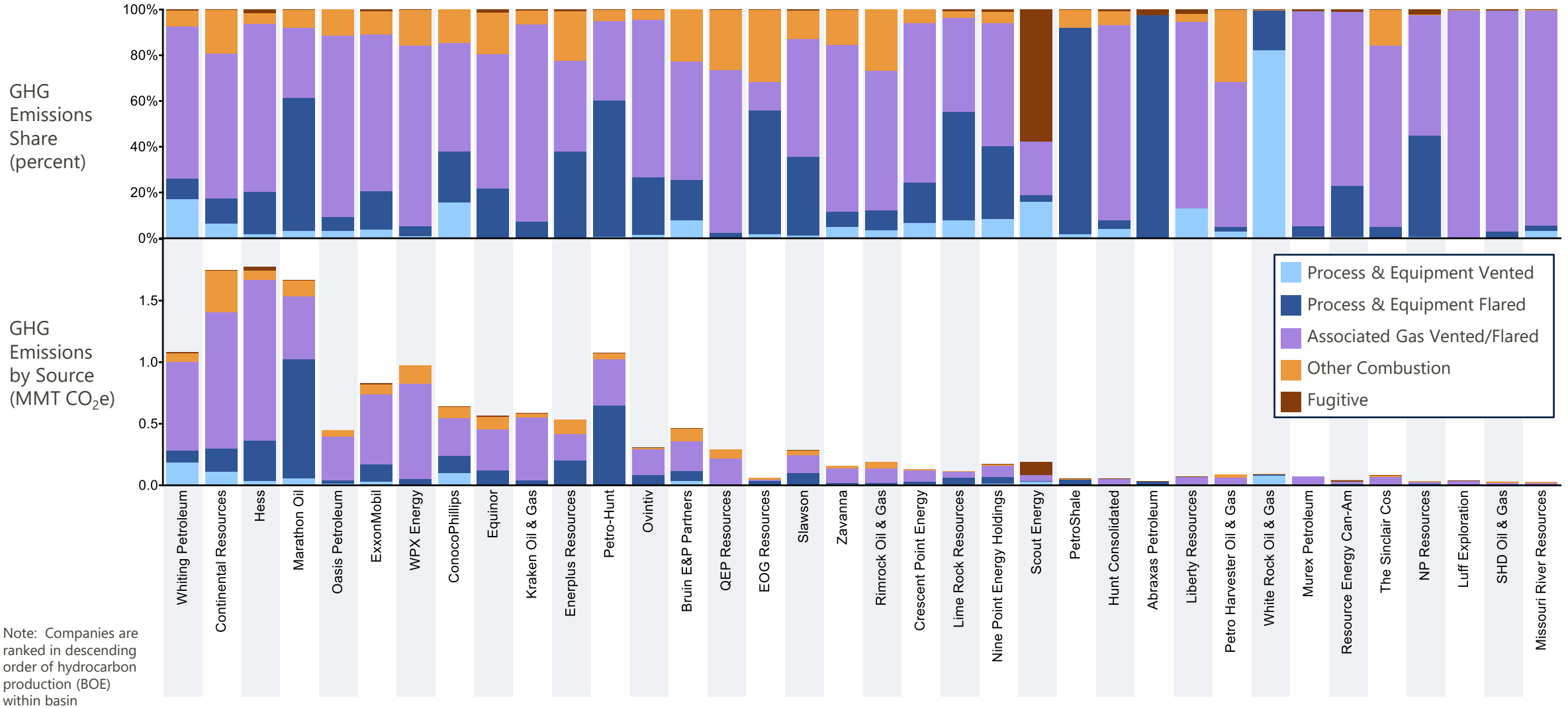
- In 2020, oil made up 57% of hydrocarbon production in the Williston across the 36 companies reporting data to EPA.
- Total GHGs are dominated by CO_2 from flaring at oil wells. Methane emissions are driven by venting at oil wells, distinguishing the Williston from most other basins where pneumatics are the largest source of methane.

Note: Companies are ranked in descending order of hydrocarbon production (BOE) within basin

Note: Reflects unpublished data submitted by ExxonMobil that are currently under EPA review

Williston Basin Producers

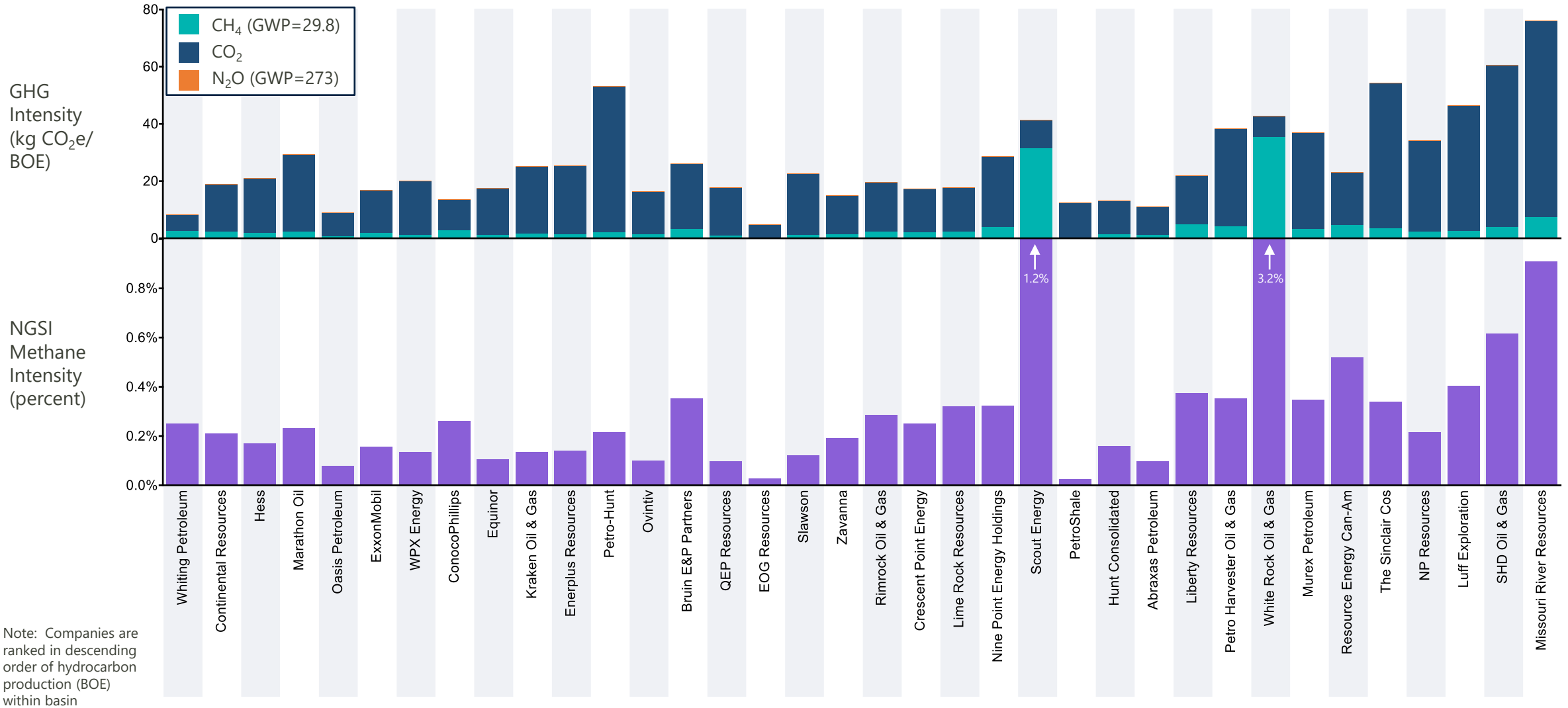
GHG Emissions by Source (100-year GWP)



Note: Companies are ranked in descending order of hydrocarbon production (BOE) within basin

Williston Basin Producers

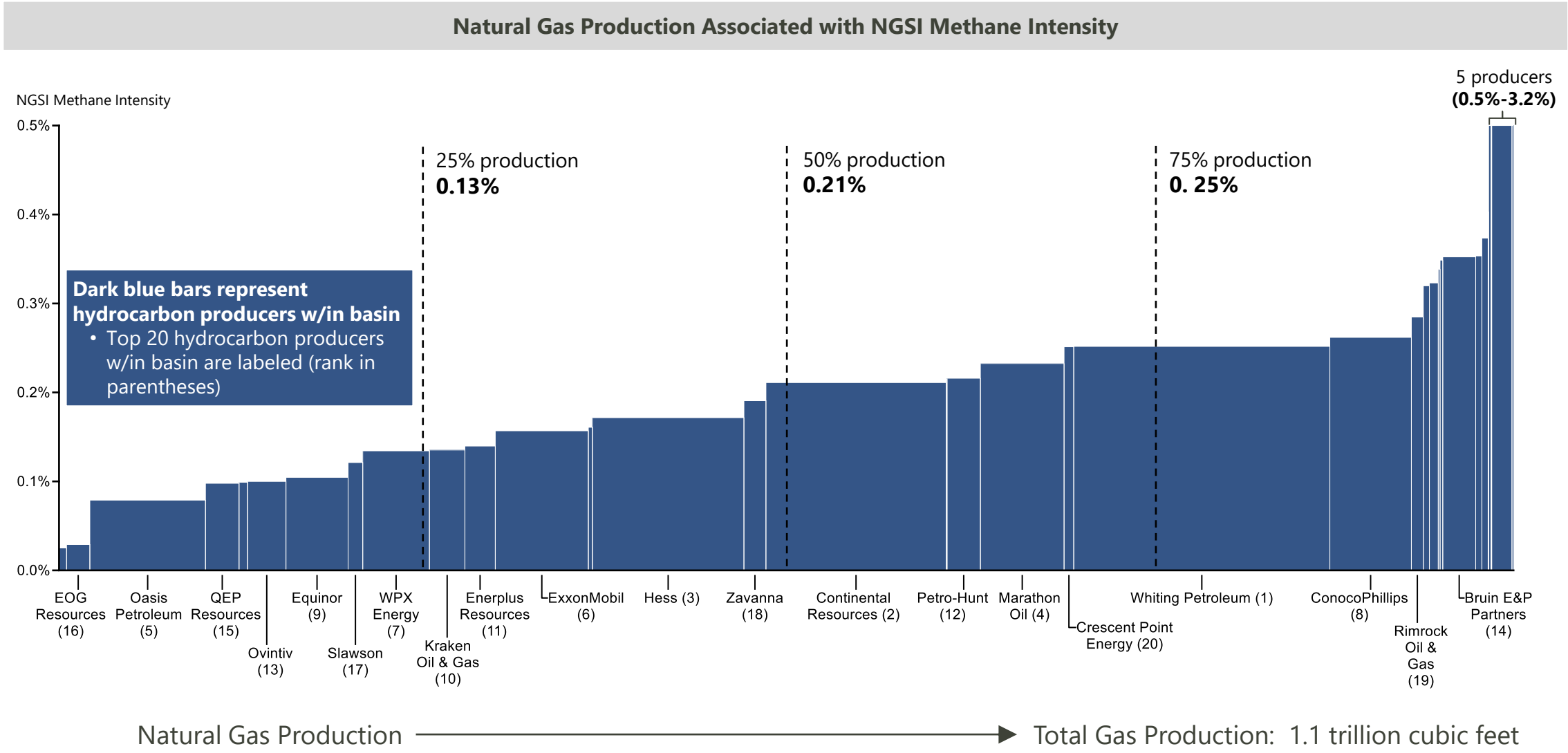
Methane & GHG Intensity (100-year GWP)



Note: Companies are ranked in descending order of hydrocarbon production (BOE) within basin

Williston Basin Producers

Total GHGRP Natural Gas Production, by Methane Intensity

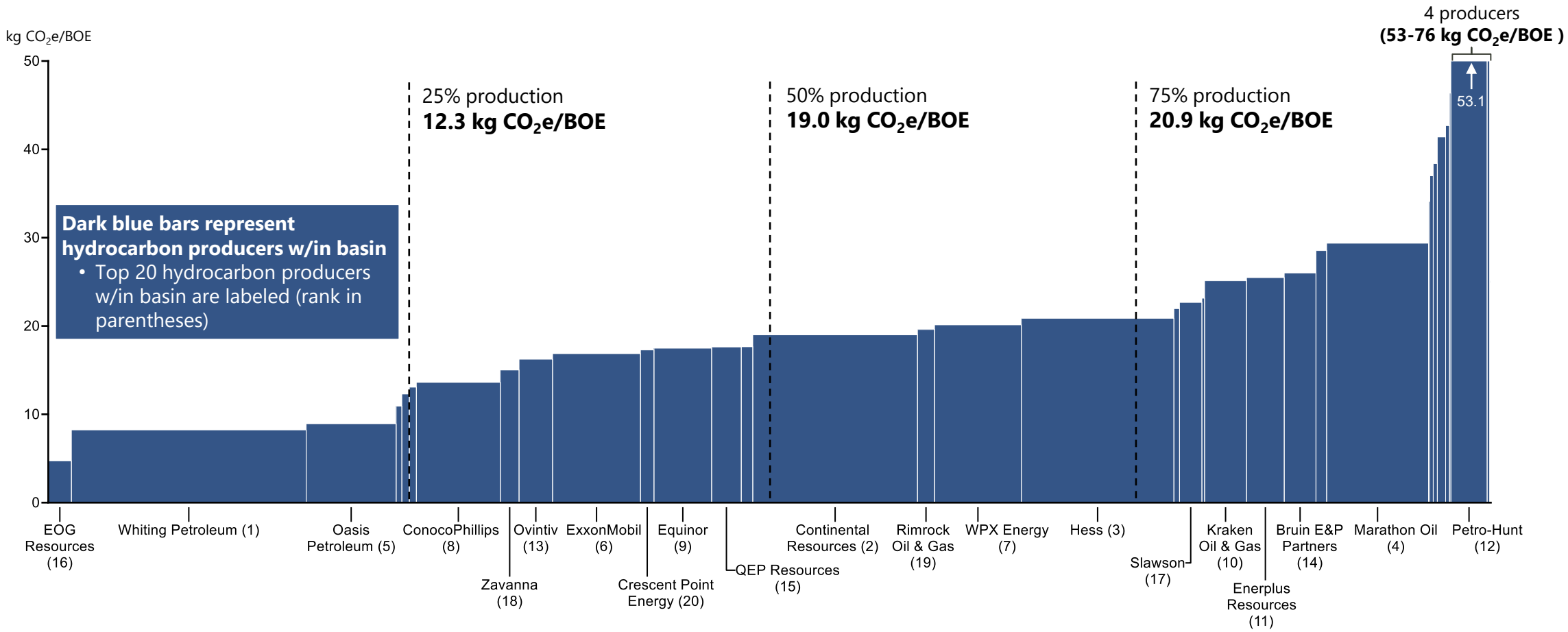


Note: Reflects unpublished data submitted by ExxonMobil that are currently under EPA review

Williston Basin Producers

Total GHGRP Hydrocarbon Production, by GHG Intensity

Hydrocarbon Production Associated with GHG Intensity

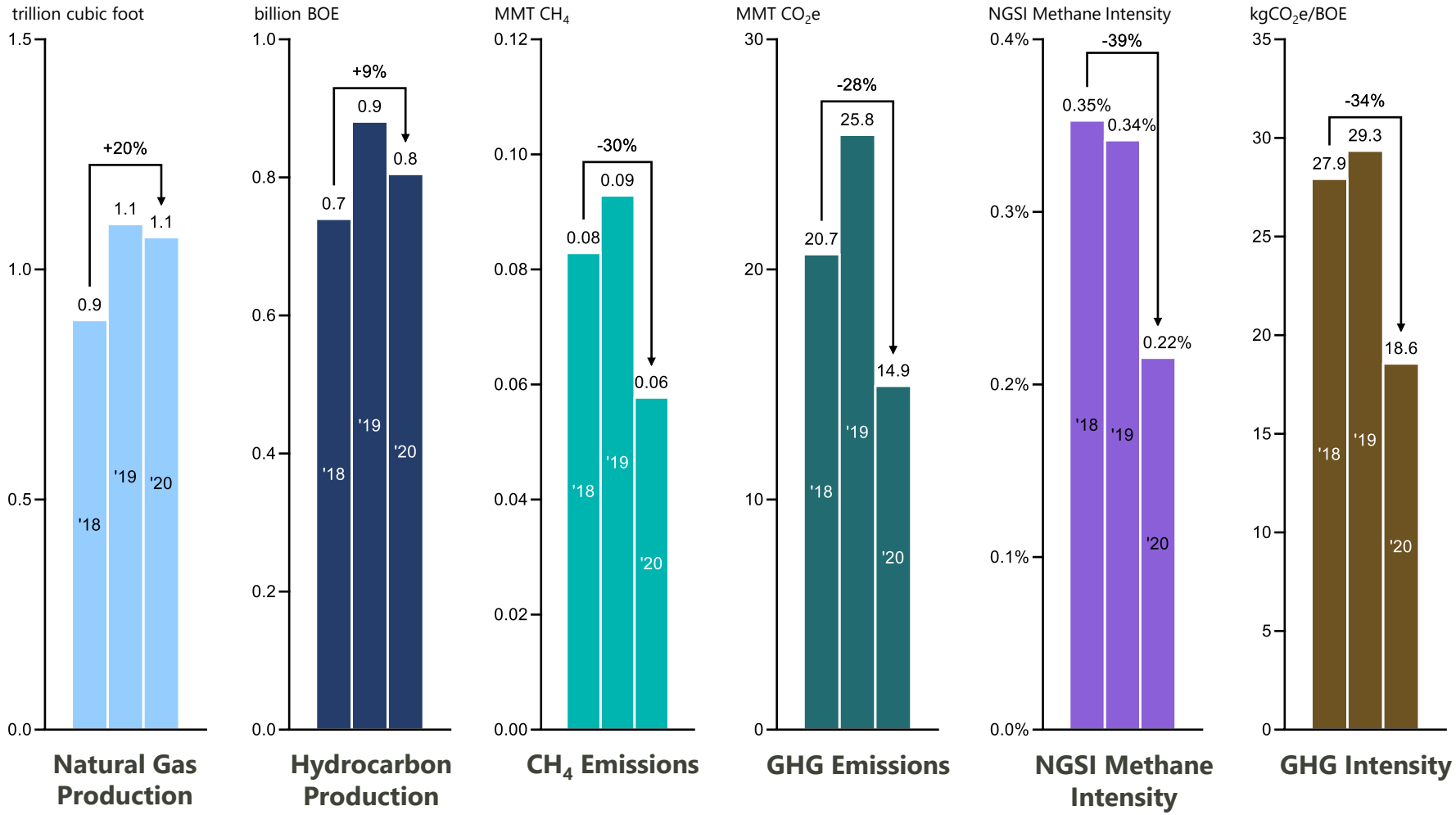


Williston Basin Producers

2018-2020 Trends Analysis: Production & Emission Metrics

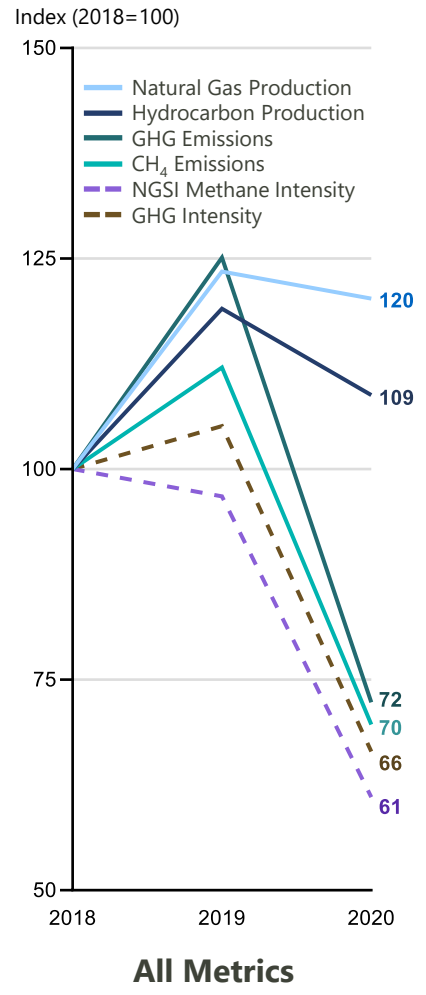
GHGRP Data Trends, 2018-2020

Williston Basin



Combined Data Metrics

Indexed; 2018 = 100



Benchmarking Methane and Other GHG Emissions of Oil & Natural Gas Production in the United States / July 2022
Data tables and maps at: www.sustainability.com

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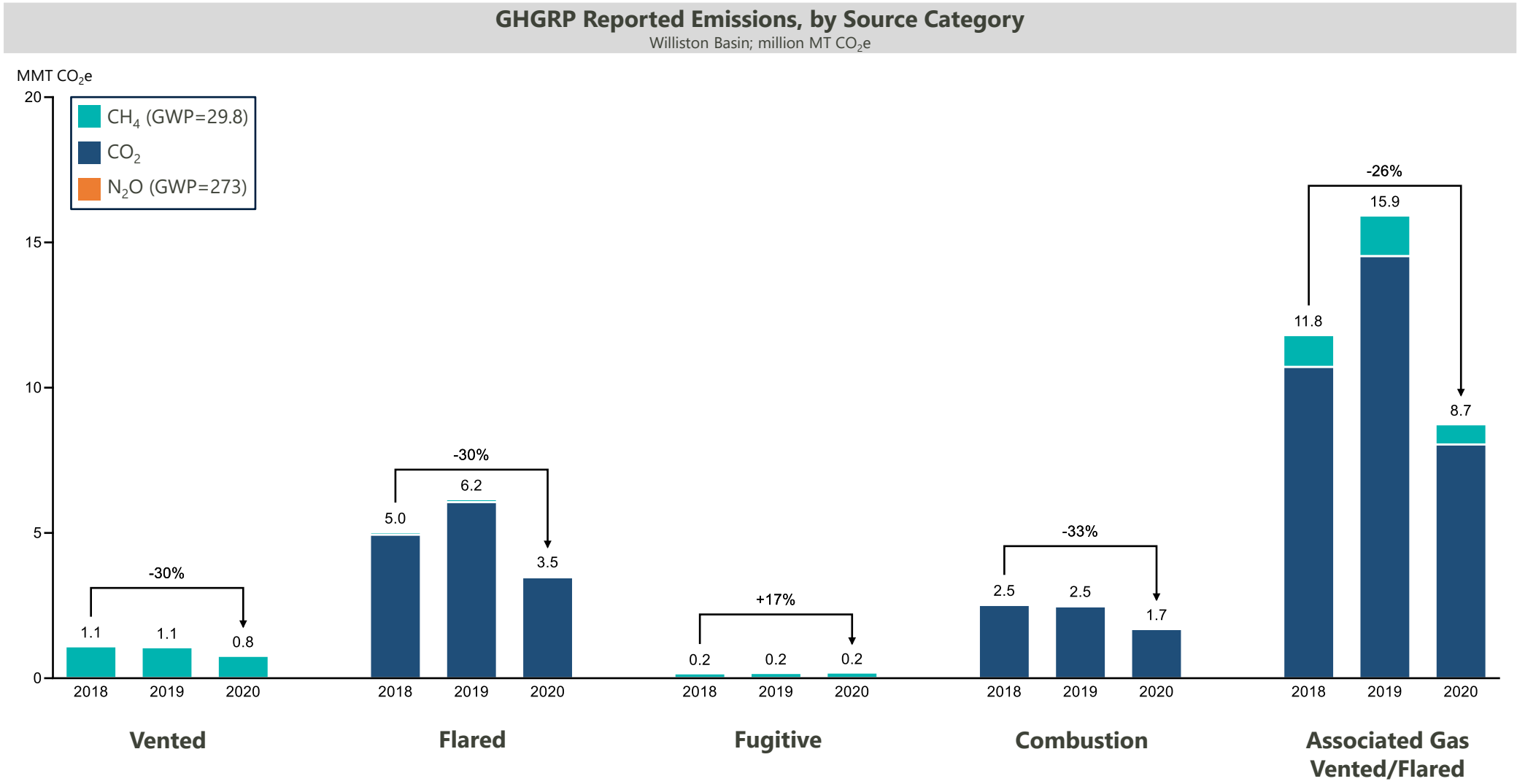
Williston Basin Producers

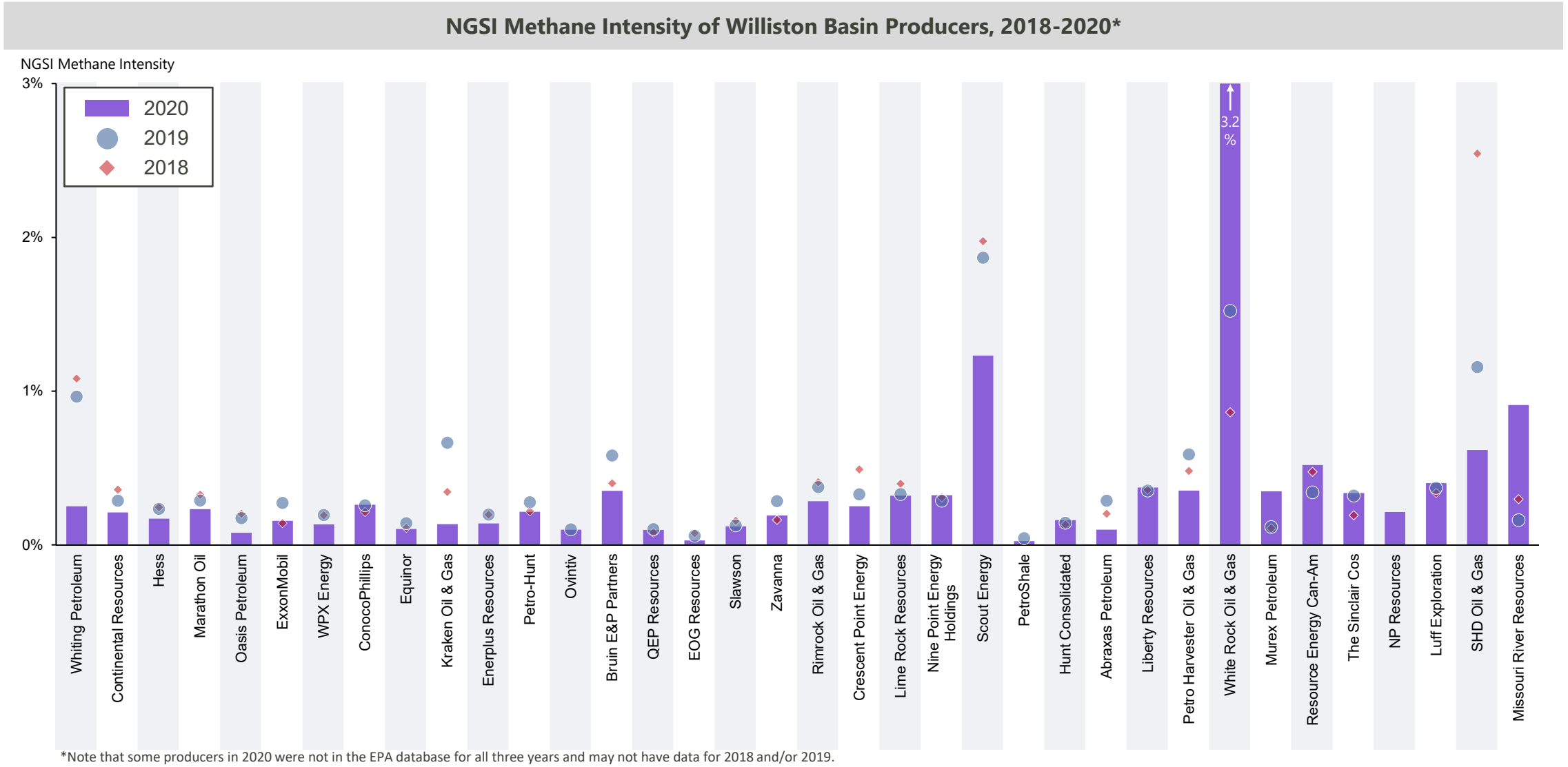
2018-2020 Trends Analysis: Emission Sources

GHG Emissions (MMT CO_2e)



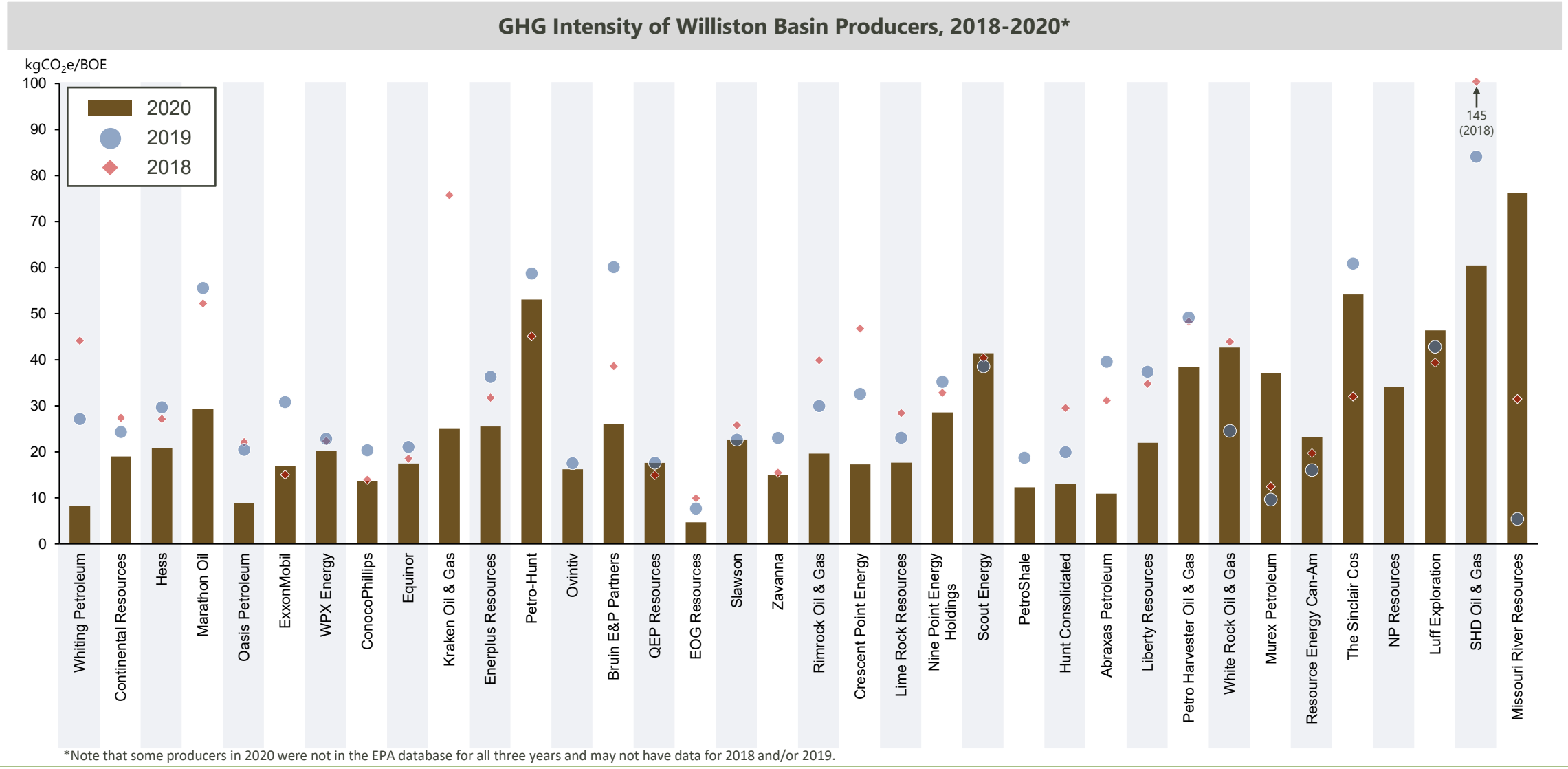
Williston Basin Producers

2018-2020 Trends Analysis: Change in Methane Intensity, by Top 100 Producer



*Note that some producers in 2020 were not in the EPA database for all three years and may not have data for 2018 and/or 2019.

2018-2020 Trends Analysis: Change in GHG Intensity, by Top 100 Producer



*Note that some producers in 2020 were not in the EPA database for all three years and may not have data for 2018 and/or 2019.

Note: Reflects unpublished data submitted by ExxonMobil that are currently under EPA review

Data Sources & Methodology

This section describes the data sources and methodology used in this study. The methodology was developed by ERM with support from Ceres and CATF as part of a scoping study funded by the Bank of America Foundation in 2019. The scoping study included the development of a framework and methodology for using publicly available data, including GHG emissions data reported to and published by the U.S. EPA, to benchmark the production-segment methane and GHG emissions intensity of U.S. oil and natural gas producers. This 2022 report uses the same methodology as the 2021 report with the exception of updated global warming potentials.

As part of the scoping study, ERM engaged with and sought feedback from a Producer Review Panel composed of leading oil and gas companies with operations in the U.S. In addition to verifying the approaches and metrics used in the analysis, the Producer Review Panel provided valuable context on the data reported to EPA and recommendations on approaches for presenting the data in clear and meaningful ways. Final decisions on the methodology and the presentation of data were made by ERM.

Data Sources Used in this Analysis

U.S. EPA Greenhouse Gas Reporting Program (GHGRP)

EPA's GHGRP is the primary data source for this analysis. The GHGRP requires facilities with GHG emissions greater than 25,000 metric tons CO_2e per year to report these emissions and other data to EPA annually (note that EPA uses a GWP of 25 for methane in its threshold calculation). Subpart W of the GHGRP covers most segments of the oil and natural gas supply chains and requires reporting of methane, carbon dioxide, and nitrous oxide. Most emissions are calculated under Subpart W by multiplying company activity data by default emission factors that are applied to all companies; some emissions are based on direct measurements or company-specific emission factors derived from direct measurements.

This report includes emissions reported to EPA under Subpart W from facilities in the oil and gas production segment. Oil and gas production facilities are defined by EPA at the basin level for the purposes of GHGRP. All equipment on or associated with well pads within a production basin that are under common control by a company are considered a single facility. Under this framework, a given company has one production facility per basin, even if it operates hundreds of wells within that basin.

This report does not include emissions from sources in the gathering & boosting segment. Production and gathering & boosting infrastructure may be collocated, and different companies may classify equipment differently in their Subpart W reporting; equipment that one company reports in the production segment another company may report in the gathering & boosting segment.

Subpart W data reported by EPA's Envirofacts database accounts for all of the production data analyzed in this report, 99.5 percent of the methane data, more than 99.998 percent of the CO_2 data, and all of the N_2O data. The remainder is based on sources not included in the GHGRP but estimated based on the GHG Inventory, as described on page 75. This report uses the following 2020 Subpart W Envirofacts files:

- "EF_W_EMISSIONS_SOURCE_GHG"
- "EF_W_FACILITY_OVERVIEW"
- "EF_W_EQUIP_LEAKS_ONSHORE"
- "EF_W_ACIDGASREMOVAL_UNITS"
- "EF_W_CENTRIF_COMP_ONSHORE"
- "EF_W_RECIP_COMP_ONSHORE"

Data Sources Used in this Analysis (continued)

U.S. EPA Greenhouse Gas Inventory

EPA's GHG Inventory is an annual report that estimates total GHG emissions from the U.S. economy. The GHG Inventory is not a reporting program and does not estimate emissions from individual companies. Instead, it estimates emissions from major industries, including the oil and natural gas sectors. EPA calculates GHG Inventory estimates using national activity data and default emission factors.

The GHG Inventory estimates emissions from a number of sources that are not included in Subpart W reporting. This analysis calculates company emissions from these sources and adds them to emissions reported under Subpart W using activity data from Subpart W and emission factors from the GHG Inventory. Not all of the GHG Inventory emissions sources that are additional to Subpart W can be included due to lack of corresponding activity data in Subpart W (e.g., the GHG Inventory has a produced water emission factor, but Subpart W does not require reporting of the applicable activity factor).

For some of these sources, the GHG Inventory lists different emission factors for natural gas and oil wells. Subpart W does not distinguish between natural gas and oil wells. This report uses the natural gas emission factor for these sources. The GHG Inventory emission factors are used in conjunction with activity data reported under Subpart W to calculate approximately 0.5 percent of the methane emissions and 0.002 percent of the CO_2 emissions analyzed in this report. The GHG Inventory data used in this report are available in the natural gas and petroleum systems methodology annex files:

https://www.epa.gov/system/files/documents/2022-02/2022_ghgi_petroleum_systems_annex35_tables.xlsx
https://www.epa.gov/system/files/documents/2022-02/2022_ghgi_natural_gas_systems_annex36_tables.xlsx

EIA Data

As described in the Methodology section below, EIA data on regional natural gas liquid (NGL) production is used to estimate the non-methane and non-CO_2 composition of reported natural gas production. The ratio of NGL production for each region reported to EIA is applied to the unknown component of gas composition for gas produced in corresponding regions. EIA Natural Gas Plant Field Production file is the source of these data:

https://www.eia.gov/dnav/pet/pet_pnp_gp_dc_r10_mbbl_m.htm

Where available or provided, company-specific data were used to estimate the non-methane and non-CO_2 composition of reported natural gas production.

EIA natural gas and oil production data are used in this report to compare hydrocarbon production reported under Subpart W to total U.S. production:

https://www.eia.gov/dnav/ng/ng_prod_sum_a_EPG0_FGW_mmcf_m.htm
https://www.eia.gov/dnav/pet/pet_crd_crpdn_adc_mbbl_a.htm

Methodology

Greenhouse Gas Reporting Program Data

This report assigns production and emissions data to individual companies based on the facility owner/operator listed in the GHGRP's "Reported Parent Companies" database. These data are reported at the basin level; the national level data in this report are calculated by summing basin level data across basins using parent companies listed in the GHGRP. For production facilities with multiple owners/operators, production and emissions are allocated based on each company's percent ownership of the facility.

GHGRP data are based on facility ownership or operating control, not ownership of hydrocarbons. A company's equity share of emissions and hydrocarbons may therefore be higher or lower than reported to EPA and calculated in this analysis. Although most companies report equity production and a growing number report equity GHG emissions, publicly available data do not allow for the application of a uniform equity-based methodology to all of the producers in the GHGRP data set.

Production Segment Sources and GHGs Covered by Subpart W

Source	CH_4	CO_2	N_2O
Acid Gas Removal Units		✓	
Associated Gas Venting/Flaring	✓	✓	✓
Atmospheric Storage Tanks	✓	✓	✓
Centrifugal Compressors	✓	✓	
Combustion Equipment	✓	✓	✓
Completions/Workovers w/ Hydraulic Fracturing	✓	✓	✓
Completions/Workovers w/o Hydraulic Fracturing	✓	✓	✓
Dehydrators	✓	✓	✓
EOR Hydrocarbon Liquids		✓	
EOR Injection Pumps		✓	
Equipment Leak Surveys/Population Counts	✓	✓	
Flare Stacks	✓	✓	✓
NG Pneumatic Devices	✓	✓	
NG-Driven Pneumatic Pumps	✓	✓	
Reciprocating Compressors	✓	✓	
Well Testing	✓	✓	✓
Well Venting (Liquids Unloading)	✓	✓	

Methodology (continued)

GHG Inventory Data

The table at right provides details on the assumptions for calculating emissions from sources using GHG Inventory emission factors, which were used for sources not reported to GHGRP. For compressor blowdowns, compressor starts, pressure release valve upsets, well drilling, and acid gas removal units, emissions are calculated by multiplying the GHG Inventory emission factor by the activity count reported under Subpart W. Only methane emissions are calculated for acid gas removal units as CO_2 emissions are captured in Subpart W.

The number of vessels is not reported under Subpart W. To calculate emissions from vessel blowdowns, the GHG Inventory assumption on the number of vessels located at each well is first applied. This number is multiplied by the reported well count to estimate the number of vessels and this product is then multiplied by the GHG Inventory emission factor to estimate emissions. Emissions from sources calculated using GHG Inventory emission factors are small and generally account for a small percentage of total emissions from a company or basin.

Emission factors for historic years may be updated in each annual GHG Inventory. This report uses the emission factors published in the 2022 GHG Inventory for each respective year.

Emissions Source	GHG Inventory CH_4 Emission Factor			GHG Inventory CO_2 Emission Factor			Activity Factor (unit)
	2018	2019	2020	2018	2019	2020	
Vessel Blowdowns (applies to separators, heater-treaters, dehydrators, and in-line heaters)	1.6	1.6	1.6	0.2	0.2	0.2	Well count from GHGRP; 0.87 vessels/well as per GHG Inventory (kg/vessel)
Compressor Blowdowns	76.8	76.7	76.6	8.5	8.5	8.6	Compressor count from GHGRP (kg/compressor)
Compressor Starts	171.7	171.6	171.4	19.0	19.1	19.2	Compressor count from GHGRP (kg/compressor)
Pressure Relief Valve Upsets	0.7	0.7	0.7	0.1	0.1	0.1	Valve count from GHGRP (kg/valve)
Well Drilling	51.3	51.2	51.2	6.7	6.7	6.7	Gas wells completed from GHGRP (kg/well)
Acid Gas Removal Units	598.3	598.3	598.3	Captured in GHGRP			AGRU count from GHGRP (kg/AGRU)

Methodology (continued)

EIA Natural Gas Liquids Data

Companies in the oil and gas sector produce oil and natural gas as well as NGLs. NGLs include ethane, propane, butane, isobutane, and natural gasoline. These hydrocarbons are separated from oil and natural gas after production during processing and refining. In the production stage, NGLs are entrained with oil and natural gas and can impact the energy content of the produced hydrocarbons, as they have an energy content that is higher than natural gas but lower than oil.

For the purposes of the calculations in this report, the energy content of the reported natural gas production is adjusted to include the energy content of produced NGLs. The natural gas production data reported under Subpart W includes information on the methane and CO_2 molar content of produced gas but does not include information on other components of the gas. Because the percentage of methane and CO_2 does not add up to 100 percent, a portion of the gas content is unknown. NGLs are commonly coproduced with natural gas and oil and in most cases represent some of the unknown gas composition. This analysis assumes the unknown portion of gas composition is made up of NGLs and allocates it to five individual NGLs based on EIA regional NGL production data. Each NGL is allocated a share of the unknown percentage based on its regional production share. This approach recognizes the energy content of non-oil and non-methane hydrocarbons; because methane emissions are allocated to the natural gas value chain using an energy-weighted gas ratio, the allocation of NGLs affects company methane emissions and methane intensity. This impact is minor for most companies and only significantly impacts companies that report low methane and CO_2 molar fractions.

The regional NGL percentages applied to the unknown gas component are shown in the table to the right. Company-specific data were used where available or provided. It is important to note that nitrogen is also a common component of natural gas and represents a portion of the unknown gas component. However, little public data is available on the nitrogen molar fraction of natural gas produced across the U.S. This analysis assumes that produced gas contains no nitrogen and fills the missing gas component entirely with NGLs. This conservative approach slightly increases the amount methane emissions allocated to the natural gas value chain and methane intensity for most companies.

Region	Area	Ethane	Propane	Butane	Isobutane	Natural Gasoline (pentane plus)
PADD 1	East Coast	0%	36%	64%	0%	0%
	Appalachian	38%	36%	11%	5%	10%
PADD 2	IN, IL, & KY	35%	41%	9%	8%	7%
	MN, WI, ND, & SD	20%	41%	18%	6%	16%
	OK, KS, & MO	42%	31%	10%	6%	10%
PADD 3	LA (Gulf)	39%	34%	12%	7%	10%
	N. LA & AR	25%	27%	12%	10%	26%
	NM	42%	31%	10%	7%	11%
	TX (Inland)	44%	30%	10%	6%	10%
PADD 4 (Rocky Mountain)		28%	36%	14%	7%	15%
PADD 5 (West Coast)		0%	15%	22%	15%	48%

Methodology (continued)

Global Warming Potentials

Global warming potential (GWP) is used to quantify the climate impact of individual GHGs relative to CO_2 to allow for the comparison of different gases over different timescales. After conversion using GWPs, emissions are expressed using a standard metric, carbon dioxide equivalent (CO_2e).

This report uses the 100-year GWPs for methane and N_2O emissions from the Sixth Assessment Report of the Intergovernmental Panel on Climate Change (AR6), which reflect the most recent scientific understanding of the climate impacts of individual GHGs. Both 100-year GWPs include the impact of climate-carbon feedbacks, and the methane GWP includes the impact of CO_2 from methane oxidation.

This report's online database allows users to select IPCC AR6 20- and 100-year GWPs for GHG emission calculations.

Note that the updated IPCC GWPs in AR6 were released in August 2021. The 2021 version of this benchmarking report, published in June 2021, used GWPs from AR5. While all 2018-2020 data in this report and the accompanying online dashboard use the AR6 GWPs, the methane and CO_2e data in this written report cannot be directly compared to data in the 2021 written report.

GHG	Additional Mechanisms	20-year GWP	100-year GWP
Methane (CH_4)	**With climate-carbon feedbacks and methane oxidation**	**82.5**	**29.8**
Nitrous oxide (N_2O)	**With climate-carbon feedbacks**	**273**	**273**

Source: https://www.ipcc.ch/report/ar6/wg1/downloads/report/IPCC_AR6_WGI_Full_Report_smaller.pdf

Methodology (continued)

Emissions Source Categories

Emissions sources in this report are grouped into five categories: process and equipment vented ("vented"), process and equipment flared ("flared"), associated gas vented and flared, fugitive, and other combustion. The table to the right shows the assignment of individual emission sources to source categories.

Emissions data on individual sources and their relative contribution to total emissions, by both individual GHG and total CO_2e, are available at the national, basin, and company level on the Oil and Gas Benchmarking interactive data website.

Source	CH_4 & N_2O Emissions Category	CO_2 Emissions Category
Acid Gas Removal Units	Vented	Vented
Associated Gas Venting/Flaring	Associated Gas Vented/Flared	Associated Gas Vented/Flared
Atmospheric Storage Tanks	Vented	Flared
Centrifugal Compressors	Vented	Flared
Combustion Equipment	Combustion	Combustion
Completions/Workovers w/ Hydraulic Fracturing	Vented	Flared
Completions/Workovers w/o Hydraulic Fracturing	Vented	Flared
Dehydrators	Vented	Flared
EOR Hydrocarbon Liquids	NA	Vented
EOR Injection Pumps	NA	Vented
Equipment Leak Surveys/Population Counts	Fugitive	Fugitive
Flare Stacks	Flared	Flared
NG Pneumatic Devices	Vented	Vented
NG-Driven Pneumatic Pumps	Vented	Vented
Reciprocating Compressors	Vented	Flared
Well Testing	Vented	Flared
Well Venting (Liquids Unloading)	Vented	Vented
Vessel Blowdowns	Vented	Flared
Compressor Blowdowns	Vented	Vented
Compressor Starts	Vented	Vented
PRV Upsets	Vented	Vented
Well Drilling	Vented	Flared

Methodology (continued)

Company Data Revisions

During the development of this report, ERM contacted companies in the GHGRP data set and asked them to confirm their facility-specific data. ERM received responses from several companies stating that the publicly-available EPA database set does not currently reflect their 2020 data. There are two reasons for these discrepancies: 1) The company has resubmitted or plans to resubmit updated data to EPA, or 2) the listed facility parent company does not match actual 2020 facility ownership. Updated data provided to ERM by companies have been included in this report under the condition of company commitments to resubmit the revised data to EPA, if it has not already been resubmitted.

Companies that are known to have resubmitted data to EPA are flagged throughout this report. EPA accepts data resubmissions for historic years at any time, but these changes are not incorporated into the public database until the annual release of new data each October. The revised data included in this report should therefore align with the EPA database when 2021 reporting year data are released in October 2022. Note that EPA may reject or flag resubmitted data. If any of the resubmitted data used in this report is rejected by EPA, report data for those companies or facilities will remain unaligned with the EPA dataset after October 2022.

Changes to facility ownership were made after confirmation of asset transactions. All facility ownership changes were noted by companies whose divested assets were still allocated to them in the current EPA database. Reporting of ownership changes is the responsibility of the new asset owner and it is not clear if all new owners will resubmit data to reflect actual ownership. If they do not, the data in this report will continue to be different from the EPA data set for certain companies after October 2022.

Oil and gas producers that would like to review their company-specific data prior to the release of future versions of this report are asked to contact the report authors.

Permian Top-Down Studies

Yuanlei Chen et al. “Quantifying regional methane emissions in the New Mexico Permian basin with a comprehensive aerial survey.” *Environmental Science & Technology*, March 2022. https://doi.org/10.1021/acs.est.1c06458.

David Lyon et al. “Concurrent variation in oil and gas methane emissions and oil price during the COVID-19 pandemic.” *Atmospheric Chemistry and Physics*, May 2021. https://doi.org/10.5194/acp-21-6605-2021.

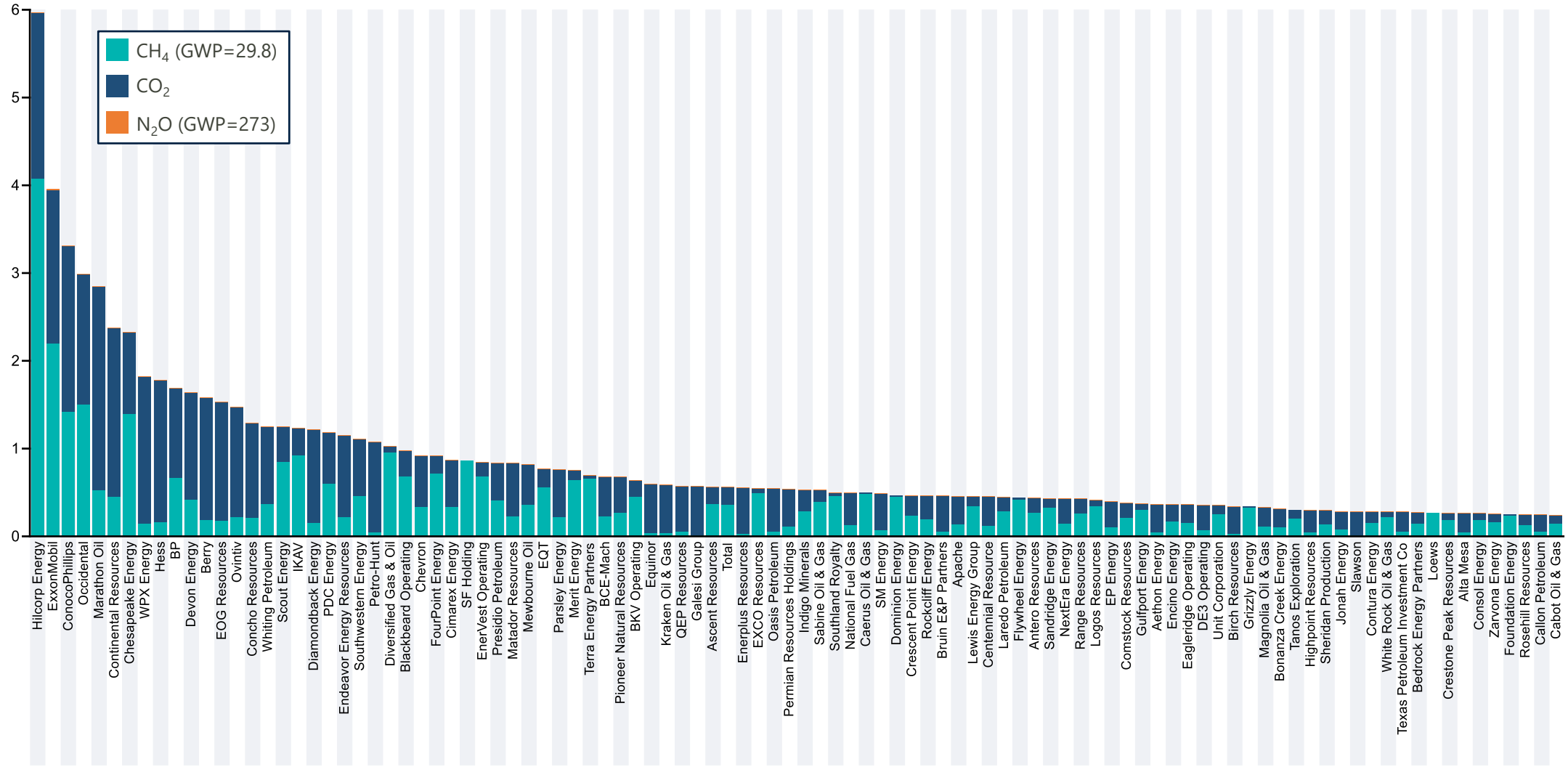
Oliver Schneising et al. “Remote sensing of methane leakage from natural gas and petroleum systems revisited.” *Atmospheric Chemistry and Physics*, August 2020. https://doi.org/10.5194/acp-20-9169-2020.

Yuzhong Zhang et al. “Quantifying methane emissions from the largest oil-producing basin in the United States from space.” *Science Advances*, April 2020. https://doi.org/10.1126/sciadv.aaz5120.

Appendix

Top 100 GHG Emitters

GHG Emissions (100-year GWP)

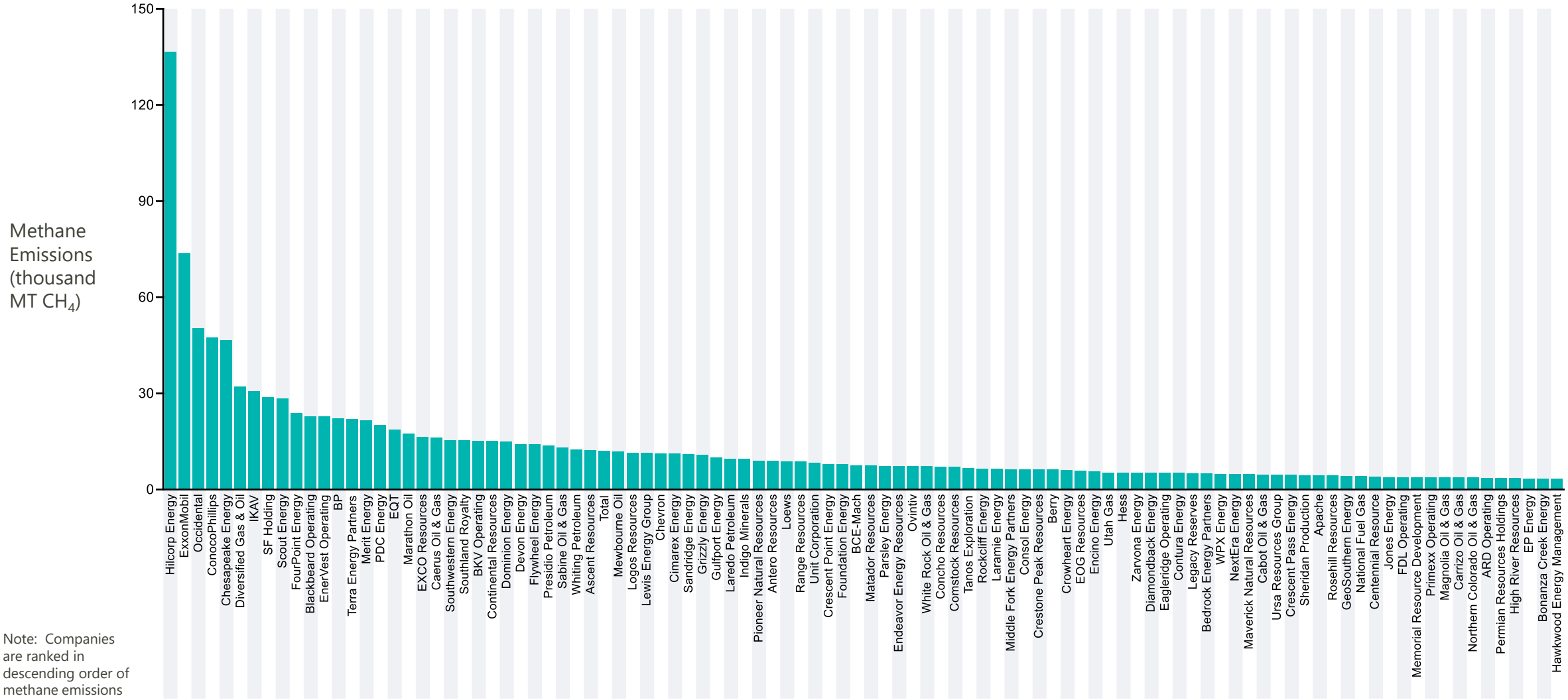


Note: Companies are ranked in descending order of GHG emissions (MMT CO_2e)

Note: Reflects unpublished data submitted by ExxonMobil, Occidental, Apache, and Tanos Exploration currently under EPA review. Presidio Petroleum reflects assets purchased in 2019 that were allocated to Apache in current EPA data; IKAV reflects assets purchased in 2020 that were allocated to BP in current EPA data

Top 100 Methane Emitters

Methane Emissions

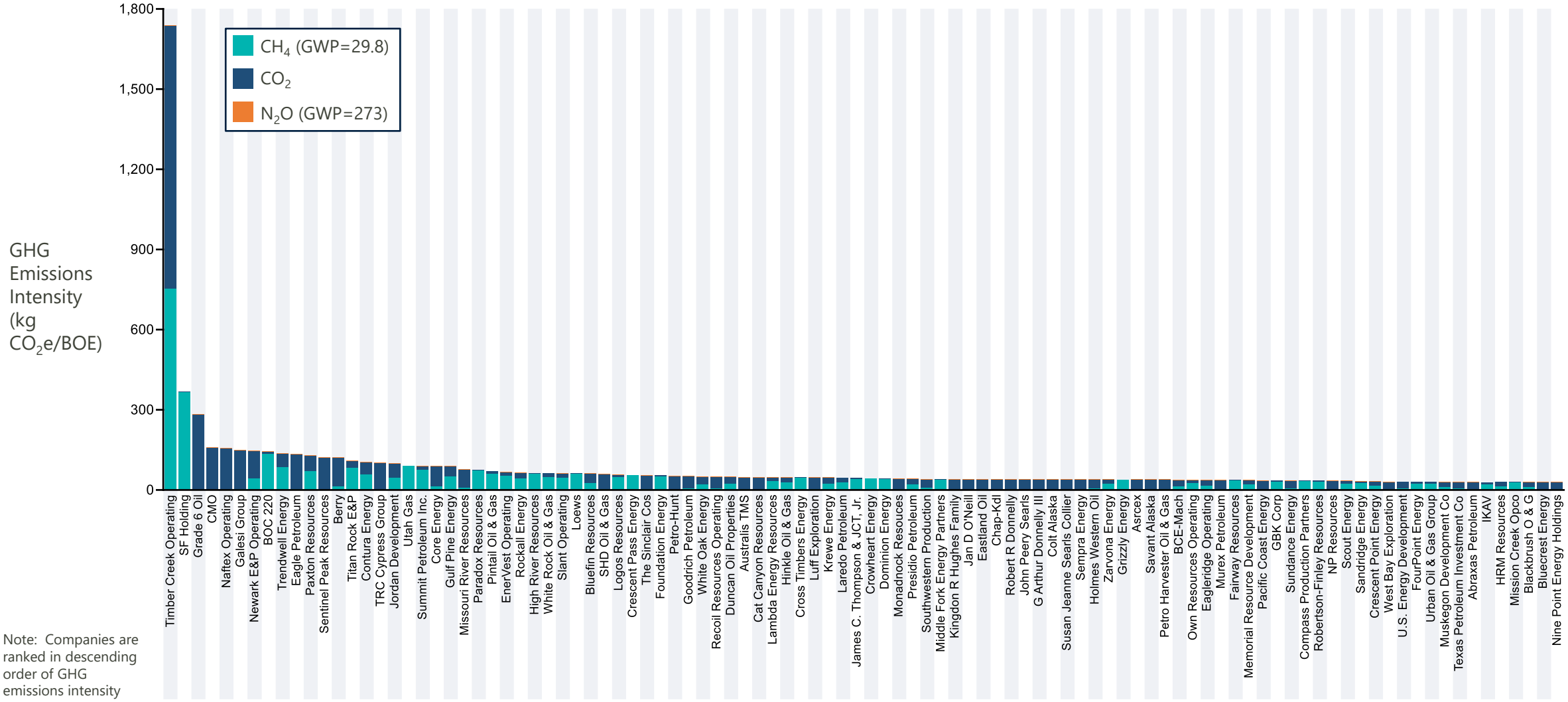


Note: Companies are ranked in descending order of methane emissions (thousand MT CH_4)

Note: Reflects unpublished data submitted by ExxonMobil, Occidental, Apache, and Tanos Exploration currently under EPA review. Presidio Petroleum reflects assets purchased in 2019 that were allocated to Apache in current EPA data; IKAV reflects assets purchased in 2020 that were allocated to BP in current EPA data

Top 100 Highest GHG Emissions Intensities

GHG Emissions Intensity

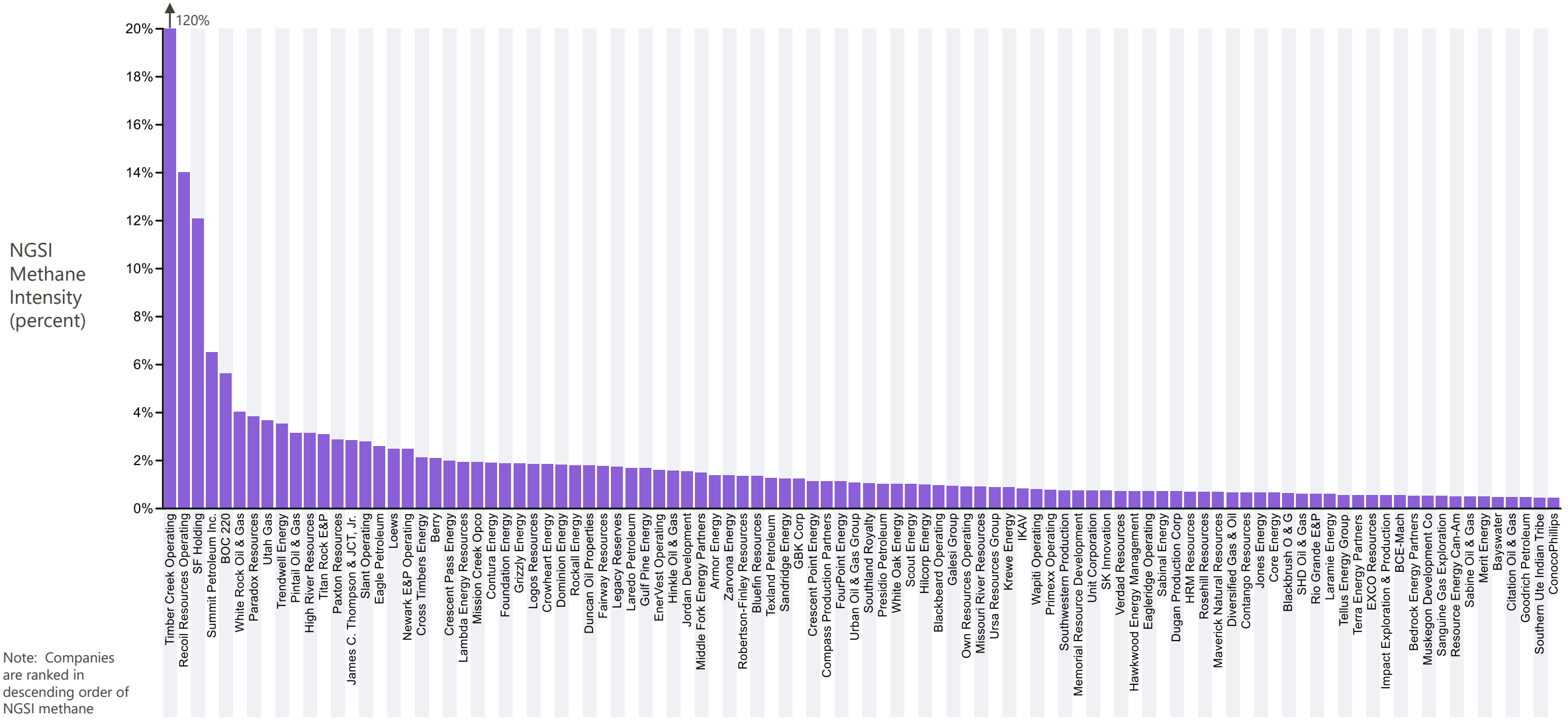


Note: Companies are ranked in descending order of GHG emissions intensity (kg CO_2e/BOE)

Note: Reflects unpublished data submitted by Dominion Energy currently under EPA review. Presidio Petroleum reflects assets purchased in 2019 that were allocated to Apache in current EPA data; IKAV reflects assets purchased in 2020 that were allocated to Apache in current EPA data

Top 100 Highest NGSI Methane Intensities

Methane Intensity

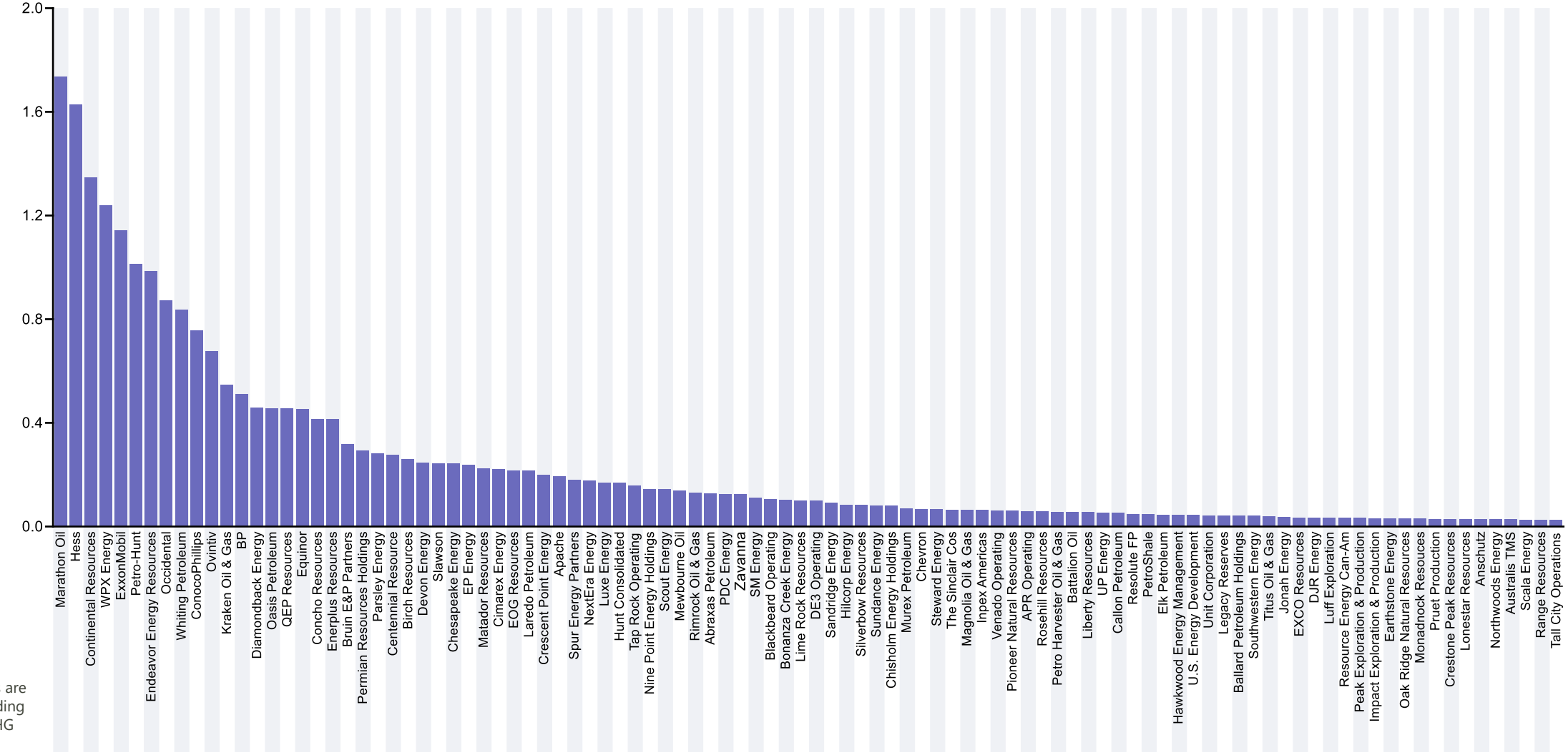


Note: Companies are ranked in descending order of NGSI methane intensity (percent)

Note: Reflects unpublished data submitted by Dominion Energy currently under EPA review. Presidio Petroleum reflects assets purchased in 2019 that were allocated to Apache in current EPA data; IKAV reflects assets purchased in 2020 that were allocated to Apache in current EPA data

Top 100 Flared GHG Emissions

Associated Gas Venting/Flaring and Other Flaring GHG Emissions (100-year GWP)



Includes associated gas vented/ flared and process & equipment flared GHG emissions

Note: Companies are ranked in descending order of flared GHG emissions (MMT CO_2e)

Note: Reflects unpublished data submitted by ExxonMobil, Occidental, and Apache that are currently under EPA review