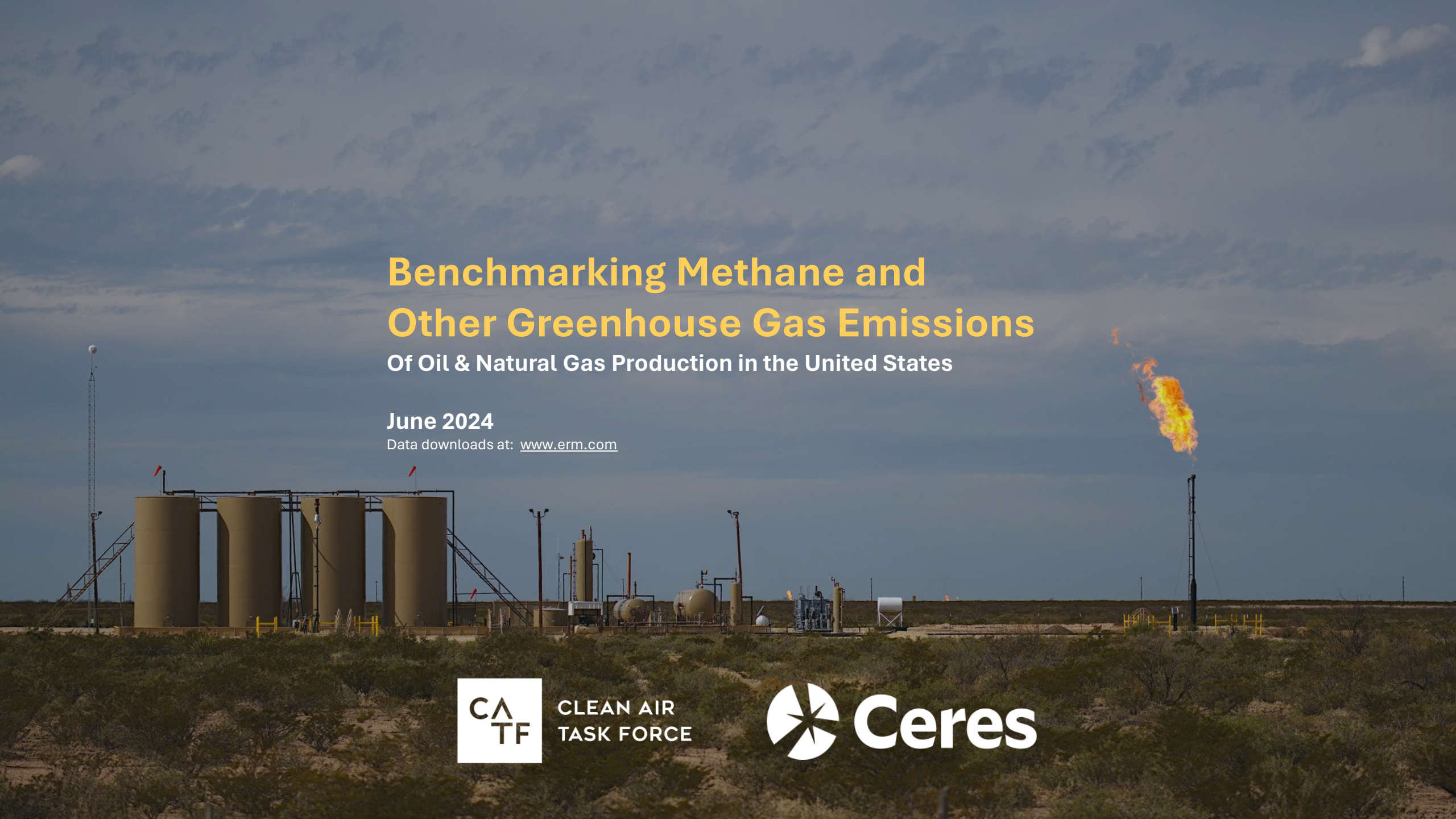

Benchmarking Methane and Other Greenhouse Gas Emissions

Of Oil & Natural Gas Production in the United States

June 2024

Data downloads at: www.erm.com

CLEAN AIR TASK FORCE

Ceres

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

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Key Findings

- Of 298 oil and natural gas producers with reported data, the top 100 oil and gas producers (by total energy production) were responsible for around 91% of energy production and approximately 74% and 76%, respectively, of total reported methane and GHG emissions in 2022. 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 over 32 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 67% of total reported methane emissions.
- Fuel combustion equipment, such as engines and heaters, was the largest source of total reported production-segment CO_2 emissions, responsible for 61% 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 50% of total reported GHG emissions. In gas-heavy basins, associated gas is limited or non-existent; for example, there was effectively no reported associated gas venting and flaring in the Appalachian basin. Across all basins, associated gas venting and flaring was responsible for 10% of total reported onshore production-segment GHG emissions.
- Methane and GHG intensity declined 31% and 17%, respectively, between 2020 and 2022 due to a reduction in methane and total GHG emissions reported to EPA and an increase in natural gas and total hydrocarbon production. However, these trends are not consistent across basins or individual companies and can fluctuate year to year (e.g., increase 2020-2021 and decrease 2021-2022).
- Total reported methane emissions have declined since 2019, largely driven by the reduction of reported emissions from pneumatic controllers and equipment leaks. Total CO_2 emissions have plateaued since 2020 as flaring emissions fall but emissions from combustion equipment increase.

Benchmarking Methane and Other GHG Emissions

Of Oil & Natural Gas Production in the United States

Download detailed data from the 2024 Benchmarking GHG Emissions report at: www.sustainability.com

Oil and 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 2022, companies reported to the U.S. Environmental Protection Agency (EPA) information on nearly 520 thousand onshore wells which together produced over 36 trillion cubic feet of natural gas and over 3.2 billion barrels of oil. Onshore oil and gas production reported under EPA's Greenhouse Gas Reporting Program increased 7.9% and 4.6%, respectively, from 2021 to 2022.

Background

Concern over climate change has brought increased focus on methane and greenhouse gas (GHG) emissions associated with oil and gas production. These emissions, especially methane, diminish the GHG 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 better positioned for a low-carbon future.

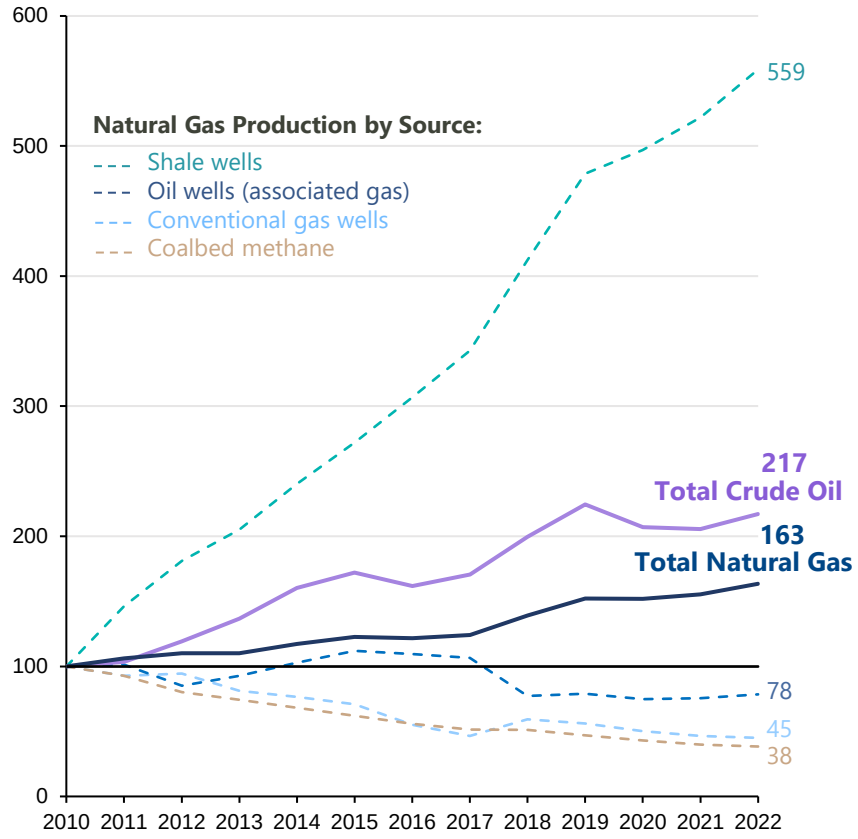
Stakeholder engagement with the industry—and the industry's ability to benchmark its own performance—has been stymied by a lack of clear and consistently calculated metrics, forcing stakeholders and companies to rely on voluntary metrics reported by companies that are often incomplete or non-comparable. The 2024 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 2022 production and emissions data, and includes production and emissions trends for 2015 to 2022.

Data Year and Company Operations

GHGRP data for the previous calendar year are reported to EPA by March 31 and published by EPA in October. This report focuses on 2022 data, the most recent year for which data are currently publicly 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.

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

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



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.

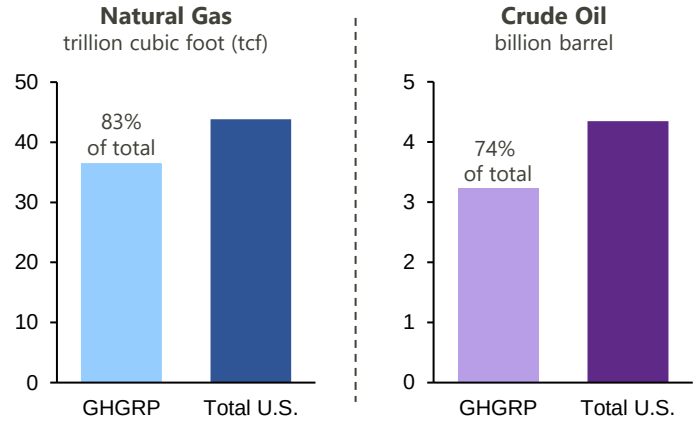
The Oil & Gas Benchmarking Report facilitates the comparison of emissions performance by using reported production and emissions data to calculate methane and GHG emissions intensities and presenting this information and source data in a graphical format that aids in understanding and evaluating the 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 emissions factors that do not properly account for emissions from infrequent, high-emitting occurrences and therefore underestimates emissions from sites 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 emissions 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 100-year GWPs from the Sixth Assessment Report of the Intergovernmental Panel on Climate Change (AR6; see page 81). 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.

2022 Hydrocarbon Production
GHGRP vs. Total U.S.*



*Source: U.S. EIA

Relative Scope of Data Analyzed (2022)

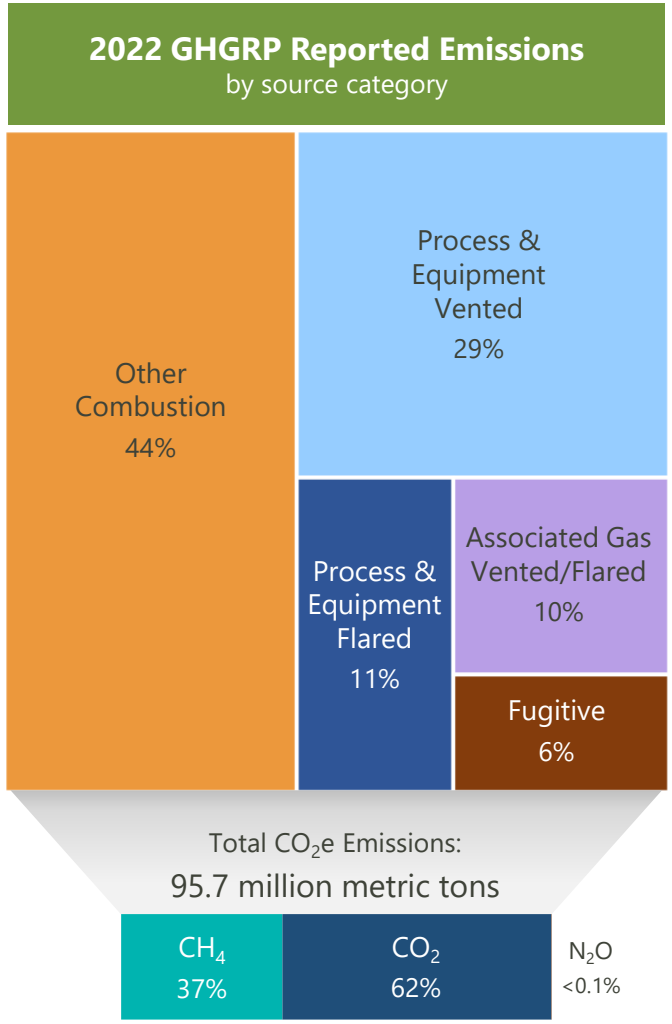
- Onshore oil and gas production reported to the GHGRP represents 74% of total U.S. annual oil production, and 83% of total U.S. annual gas production
- Reported onshore production segment methane represents 46% of total methane reported under Subpart W
- Reported onshore production segment CO_2e represents 42% 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 slightly increased from 2021-2022

Types of Emissions Associated with Oil & Gas Production

The GHGRP includes reporting on emissions from 17 emissions sources (see page 78). 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 79). 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, emissions sources are grouped into five categories:

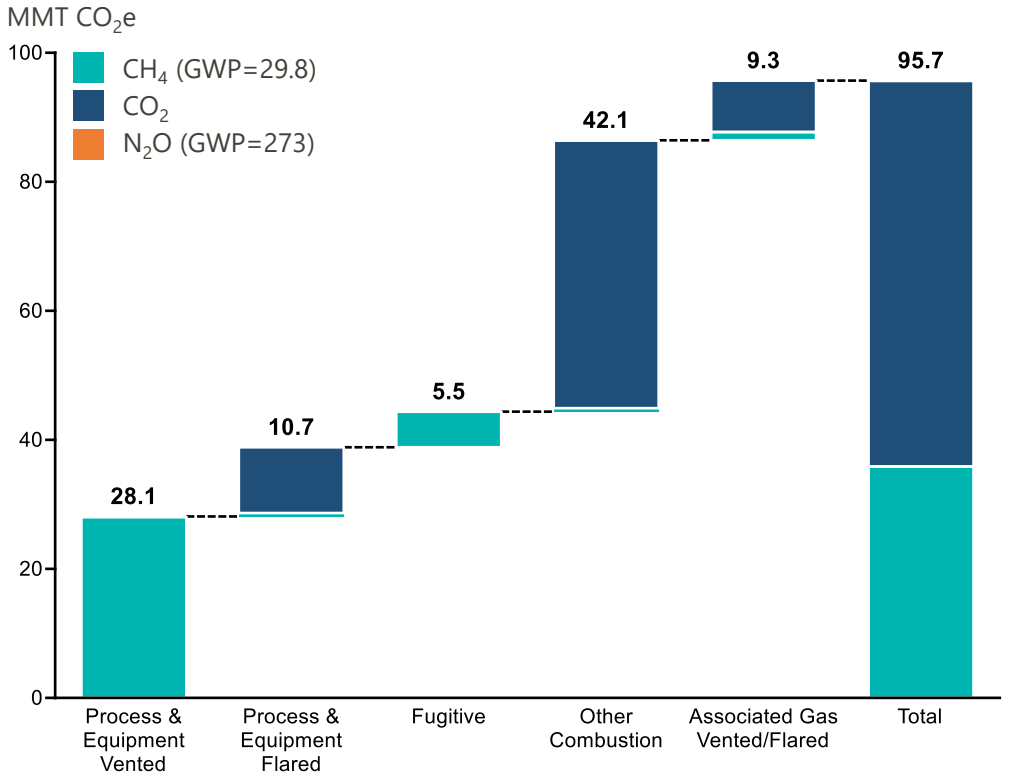
- **Process & Equipment Vented** Vented emissions are intentional releases of natural gas from equipment and processes. Common sources of vented emissions include gas-driven pneumatic devices, compressor seals, tanks, and liquids unloading.
- **Process & Equipment Flared** Flared emissions consist primarily 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.



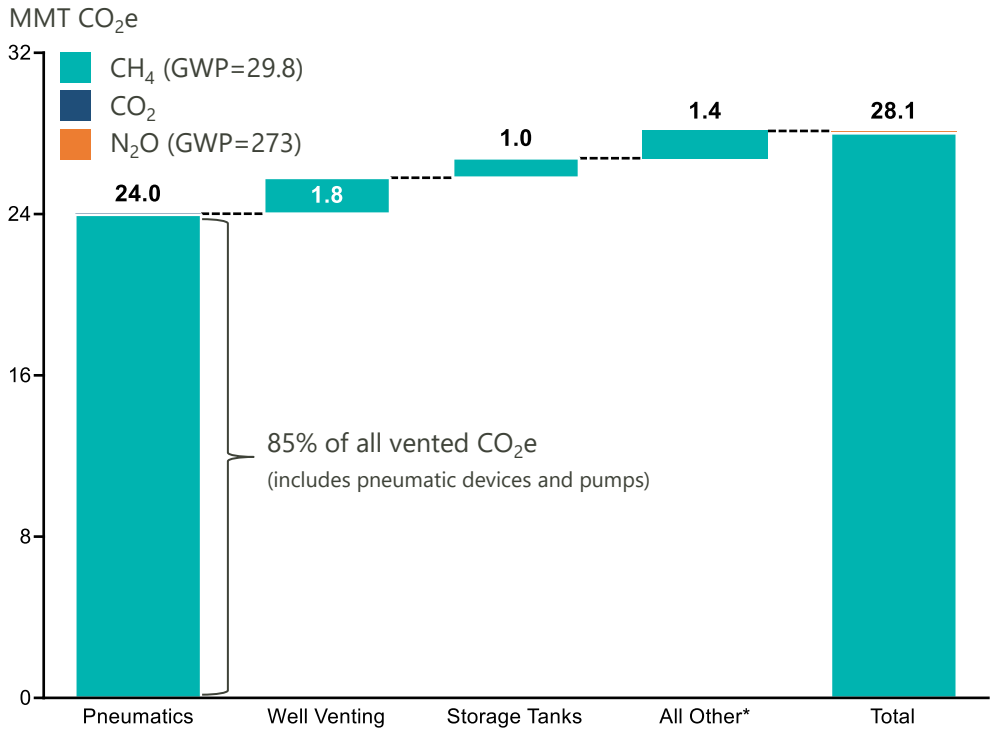
Sources of Methane Emissions

Process and equipment vented, and fugitive methane emissions make up approximately 93% and 35% 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.

2022 Reported Production Emissions, by Source Category
million metric ton CO_2e (MMT CO_2e)



2022 Reported 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 and identify historical trends. As noted earlier, the emissions in this report also include sources that are not included in the GHGRP but that can be estimated using emissions factors from the GHG Inventory. However, there are important limitations users should keep in mind when reviewing the data:

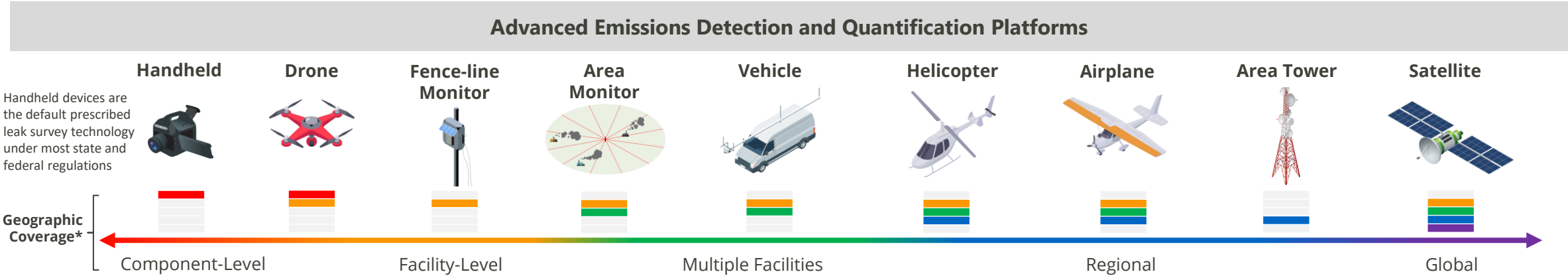
- **GHGRP emissions factors do not represent actual emissions**. The use of emissions factors to estimate total emissions relies on the emissions factor being representative of average emissions for a given activity. This approach can be effective where there is robust data on emissions per unit of activity. For example, automobile emissions are routinely and reliably estimated using emissions factors despite the fact that emissions from a single vehicle may be different than predicted by an emissions factor. With a diversity of emissions sources and the presence of low-frequency, high-emissions events, the use of emissions 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 not included.** 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.
- **Emissions source definitions from production and gathering & boosting activities inconsistently applied**. GHGRP requires companies to report emissions from production sources separately from gathering & 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 certain 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 emissions factors to GHGRP reported activity data, as described in the Appendix (see page 79).
- **Some emissions 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 (e.g., the replacement of pneumatic devices) 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 not considered.** 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.

Using Direct Measurement to Improve Estimates of Methane Emissions

Research over the last decade using technologies that directly measure methane emissions from oil and gas infrastructure has consistently shown that existing emissions inventories, including those calculated using EPA's methodologies, underestimate total industry emissions. Studies have repeatedly found that a major driver of this mismatch is a relatively small number of sources with high-emitting, abnormal process conditions. These anomalous emissions events often have random spatial and temporal distributions and have proven to be difficult to account for using equipment-level emissions factors.

Emissions inventories based on real-world measurements are critical because they better quantify the amount of methane emitted to the atmosphere, providing an improved understanding of the industry's climate impact. Fortunately, a growing number of advanced technologies that directly quantify methane emissions are being deployed by operators and industry stakeholders. At the same time, academic research and initiatives, such as the Oil and Gas Methane Partnership 2.0 and GTI Veritas, are working to establish processes and frameworks to demonstrate the effectiveness of technologies, and reconcile differences between emissions inventories and measured emissions to subsequently improve the quantification of emissions and determine the impact of emissions reduction strategies.

The analysis and benchmarking in this report primarily 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. As more data based on direct measurement become publicly available, benchmarking efforts such as this will be able to integrate these new data. For example, in response to a Congressional mandate in the Inflation Reduction Act to update Subpart W of the GHGRP to ensure that company reporting is based on "empirical data," EPA significantly updated GHGRP with rules finalized in May 2024. These updates increase the amount of measurement required of operators and require reporting of any known large emissions event.



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

Top-Down and Bottom-Up Emissions Studies

Many studies have evaluated and attempted to reconcile the emissions gap between top-down and bottom-up emissions inventories. Most studies have focused on specific regions or basins (such as the Permian), but a recent analysis (Shen *et al.*) summarizes satellite methane observations in basins across the United States. The table below shows estimated methane leakage rates as a percent of total natural gas production from recent top-down studies. **For comparison, 2018-2022 GHGRP data imply that oil and gas methane emissions range between 0.36%-0.63% of methane produced nationally and 0.37%-0.86% of methane produced in the Permian.***

Note that the leak rates in the following table 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 (i.e., gas ratio not applied);
2. They capture methane emissions from production, gathering & boosting, processing, and transmission compression.

Study**	Region	Leak Rate	Measurement Year(s)
Sherwin et al.	Permian	2.1% - 9.63%	2018-2021
Shen et al.	U.S.	2.0%	2018-2020
Chen et al.	Permian	9.4%	2018-2020
Lyon et al.	Permian	1.9% - 3.3%	2020
Schneising et al.	Permian	3.7%	2018-2019
Zhang et al.	Permian	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, as well as Subpart C methane emissions for processing, transmission compression, and underground storage facilities. Applies average calculated GHGRP-reported produced gas methane contents of 82.0%-83.3% (national) and 67.5%-70.1% (Permian).

**See page 84 for complete study citations.

The comparison of GHGRP and top-down study data shows that estimated methane leak rates in top-down studies can be multiple times higher than leak rates derived from emissions and production data reported under GHGRP. The primary drivers of the observed gap are GHGRP emissions 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 top-down measurements provide a snapshot of emissions performance for an area or region. However, these estimates do not isolate company performance; some companies within the region will have leak rates below the composite regional performance, while others will have leak rates above the regional performance. Although a growing number of technology providers offer companies proprietary estimates of company-level leak rates and the Environmental Defense Fund has launched regional monitoring initiatives, 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. For 2021 data year, the GHG Inventory's implied national methane leak rate of 0.83% is almost double that of the GHGRP's 0.42% for the same industry boundaries (onshore production through transmission compression). There are a variety of potential reasons for this disparity, including (but not limited to): different quantification methods for the same sources; GHG Inventory's inclusion of more sources; and GHGRP's exclusion of facilities that emit less than 25,000 metric tons of CO_2e.

Top-Down Uncertainty

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

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 reported 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.

*Note that the NGSI intensity is not a methane leak rate (total methane emissions divided by total produced methane) because of its allocation of emissions based on the gas ratio (energy content of produced gas vs. total hydrocarbons). The methane intensity metric proposed by EPA is different from the NGSI intensity used in this report (see page 14 for more details on the IRA).

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.

Potential Impacts of Rulemaking Across the U.S.

The reported emissions levels and calculated emissions intensities must be viewed in the context of the broader regulatory landscape in the U.S., both at the state and federal levels. Compliance with these regulations has led to emissions reductions. For example:

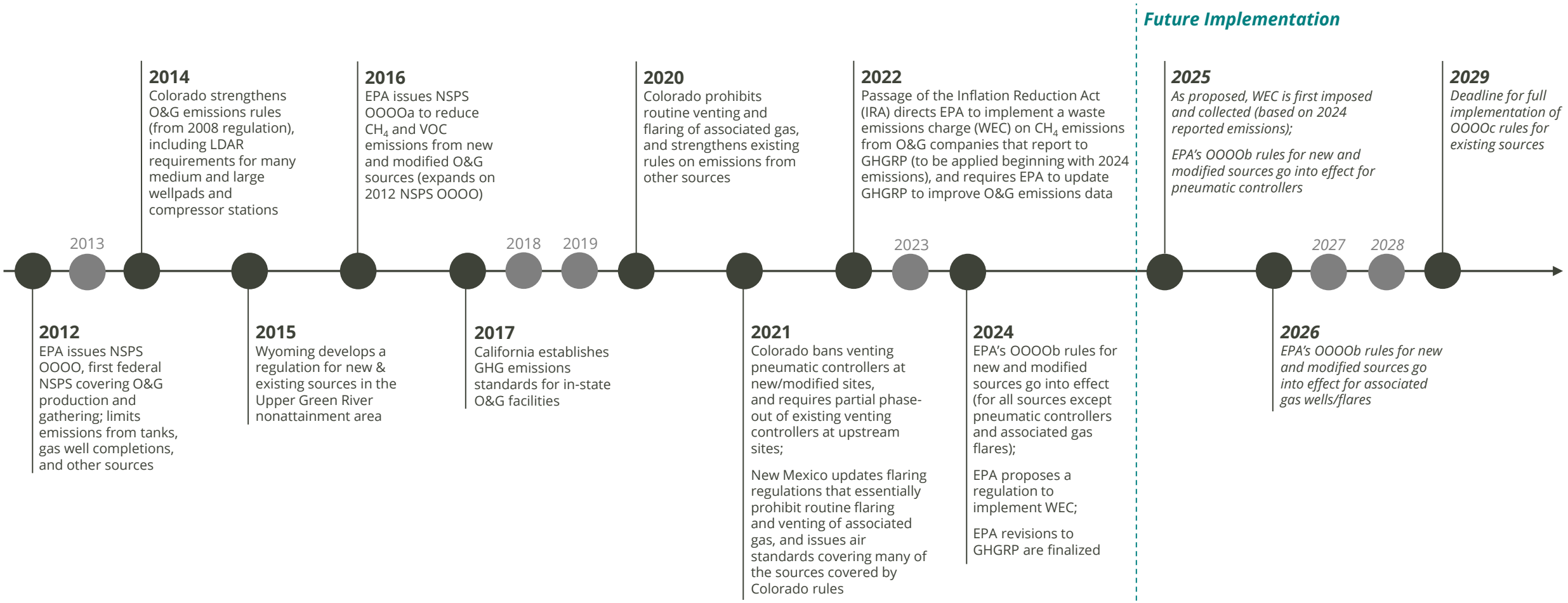
- Each year, as old wells are retired and new wells are drilled and reworked, a larger portion of the nation's reported oil and gas production and associated equipment become subject to the 2016 OOOOa New/Modified Source rules;
- Requirements for reduced emissions completions at oil and gas wells have driven down emissions from well completions and workovers;
- Requirements to replace or prohibit new high-bleed pneumatic and/or venting controllers/devices are lowering pneumatic controller emissions;
- Leak detection and repair (LDAR) requirements are improving the identification of leaks and leading to fewer fugitive emissions detections;
- Regulations that put limits on flaring volumes or prohibit routine venting and flaring of associated gas have likely lowered CO_2 and CH_4 emissions from associated gas venting and flaring in some basins.

However, it is difficult to separate the impact of regulatory compliance from other factors:

- GHGRP reporting basins often do not fall within one state, making it complex to isolate the impact of state-level regulatory actions;
- As of 2024, EPA regulations only apply to new or modified facilities, and it is not feasible to separate the affected facilities in the reported GHGRP data (although state rules covering existing sources will be required under EPA's recently finalized rules, these rules are not required until March 2026 and operators will subsequently have up to 3 years for before full implementation);
- If a company sells assets in a basin to small firms that are not required to report to GHGRP, reported emissions will fall despite actual emissions not changing;
- Companies may choose to invest in lower emissions equipment (such as zero-emitting pneumatic controllers) prior to full implementation of the recently finalized 2024 OOOOb New/Modified Source requirements, the OOOOc Existing Source Guidelines, or the Waste Emissions Charge (see page 14);
- GHGRP reported data does not accurately capture LDAR emissions because of high-emitting, abnormal process conditions (see page 9);
- An increase in new (and highly productive) wells tends to reduce overall emissions intensity, regardless of voluntary or regulatory compliance actions;
- Voluntary company actions may play a role but are difficult to document and quantify.

Timeline of Major Oil & Gas Emissions Regulations

Selected State & Federal Emissions Regulations



New Rulemaking Across the U.S. – Methane Emissions Reduction Program

A number of new regulations will soon be finalized and implemented across the U.S., which will have a significant impact on both reported methane emissions and actual methane emissions in the coming years.

In 2022, **Congress passed the Inflation Reduction Act (IRA), which included the Methane Emissions Reduction Program (MERP)**. Through MERP, Congress established an additional methane reduction framework that complements EPA's standards and guidelines for new and existing sources. In addition to providing $1.55 billion for EPA to distribute for programs to reduce methane emissions from the oil and gas industry, MERP requires EPA to impose and collect an annual methane waste emissions charge (WEC) on methane emissions from owners or operators of oil and gas facilities that report to the GHGRP and exceed statutorily-established and segment-specific emissions intensity thresholds. The WEC will first be imposed in 2025 and calculated using 2024 reporting year emissions data.

As part of the MERP program, Congress also instructed EPA to update the GHGRP to include "empirical" emissions estimates to ensure the total reported emissions are accurately reflected. EPA has finalized an update to GHGRP Subpart W that will significantly change the methodology companies use to estimate emissions. Along with the inclusion of additional emissions sources (such as large release events), these changes will likely have an impact on total reported emissions.

EPA's proposed WEC regulation applies a methane intensity threshold to each GHGRP facility, across all industry segments (excluding distribution). As articulated in the proposal, this intensity is calculated annually at the facility-level by dividing methane emissions by the product of gas quantity sent to sale (relevant throughput metric specific to segment) and methane density. In cases where companies operate in multiple industry segments, it is proposed to allow companies to "net" emissions of facilities under common ownership through the summation of emissions above and below the waste emissions thresholds from all applicable facilities.*

*Note that the proposed WEC regulation utilizes a methane intensity calculation methodology that differs from that of the NGSI intensity used in this report (see page 11). The NGSI methane intensity should not be used to project or estimate potential WEC obligations under the IRA's MERP. Future versions of this report may adopt the WEC intensity metric once it has been finalized by EPA. Furthermore, this report only considers onshore oil and gas production facilities that report to the GHGRP and therefore may not include all facilities necessary to calculate company-level methane emissions subject to WEC.

New Rulemaking Across the U.S. – Section 111 Rules

In March 2024, **EPA finalized its New/Modified Source Standards (OOOOb) and Existing Source Guidelines (OOOOc)**, also known as Section 111 rules (section of Clean Air Act from which EPA derives its authority to regulate). These requirements build from the initial 2021 proposal, the 2022 supplemental proposal, and the 2012 and 2016 New/Modified Source rules (OOOO and OOOOa, respectively). Pursuant to Clean Air Act and final rule requirements for existing sources, states now have until March 2026 to develop their own regulations that are at least as stringent as those defined in OOOOc. In these plans, states must ensure that their plans are fully implemented by March 2029. If a state chooses not to submit a plan, or submits an inadequate plan, the existing sources will be addressed under a Federal Implementation Plan promulgated by EPA. The standards include:

- Expanded LDAR based on risk of super-emitters; all facilities are inspected regularly, and most facilities perform quarterly instrument-based inspections;
- Super Emitter Program, which allows third parties to notify EPA of large emissions events (i.e., leaks that exceed 100 kilograms CH_4 per hour); operators are required to repair confirmed leaks;
- Requirements of zero-emitting pneumatic equipment at most sites;
- No routine flaring of associated gas at new sources; associated gas at existing sites must route to sales lines unless unavailable and other use is technically infeasible;
- Expansion of storage vessel provisions, including applicability triggers now based on methane and/or VOC emissions, as well as clarifications regarding consideration of legally and practicably enforceable emission limits
- Updated requirements for all compressors.

As designed, the Waste Emissions Charge (WEC) and Section 111 rules are complementary. Applicable facilities will be subject to WEC beginning in reporting year 2024, but they can be partially or fully exempt from WEC if they are subject to and in full compliance with Section 111 regulations, once EPA determines that state plans have been approved and are in effect in all states, and compliance with such standards will achieve equivalent or greater reductions than would be achieved under the 2021 proposal. State standards for existing oil and gas infrastructure will likely not be in effect, and thus the exemption not available, until at least 2027. Thus, WEC can achieve methane emissions reductions prior to full implementation of Section 111 rules.

As companies progress with compliance of OOOOb and planning for OOOOc, the pending WEC provisions and expanded scope of Subpart W of the GHGRP offer new incentives for many operators to accelerate actions that reduce methane emissions, especially. These efforts could take the form of activities to lower or avoid the WEC, or the establishment/revision of company goals and voluntary actions that support reduced overall GHG emissions and/or emissions intensities.

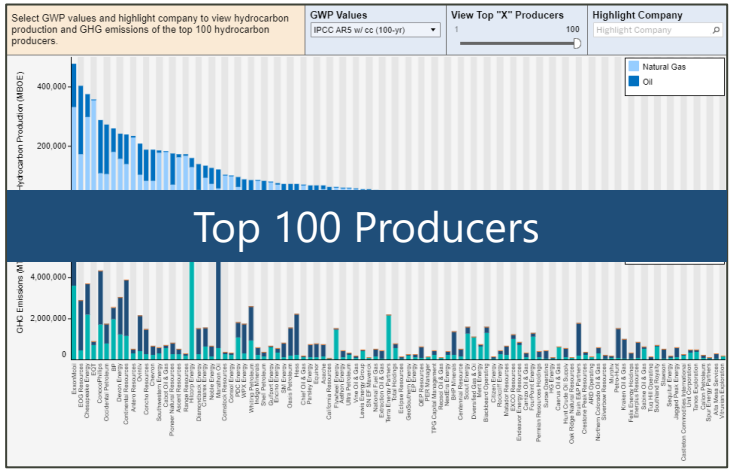
Benchmarking Analytical Resources

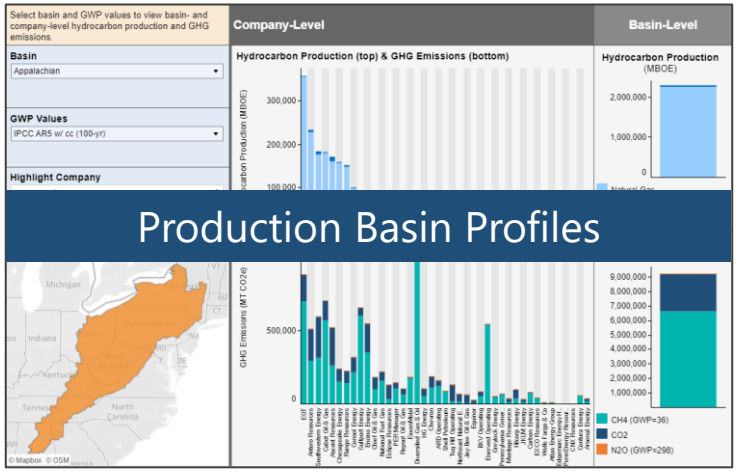
The Oil & Gas Benchmarking Report includes a series of interactive, web-based dashboards to further visualize GHG emissions from oil and gas producers and production basins in the United States. These tools provide insight into how company- and basin-level emissions and emissions intensity vary as well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

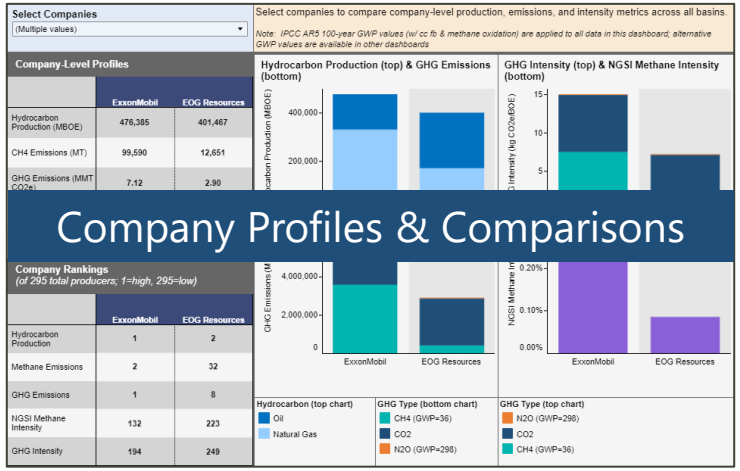
The online resources include data for all companies and basins in the GHGRP database, including those not highlighted in this report. Data dashboards include:

- **Top 100 Producers:** Oil and 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 https://www.erm.com/insights



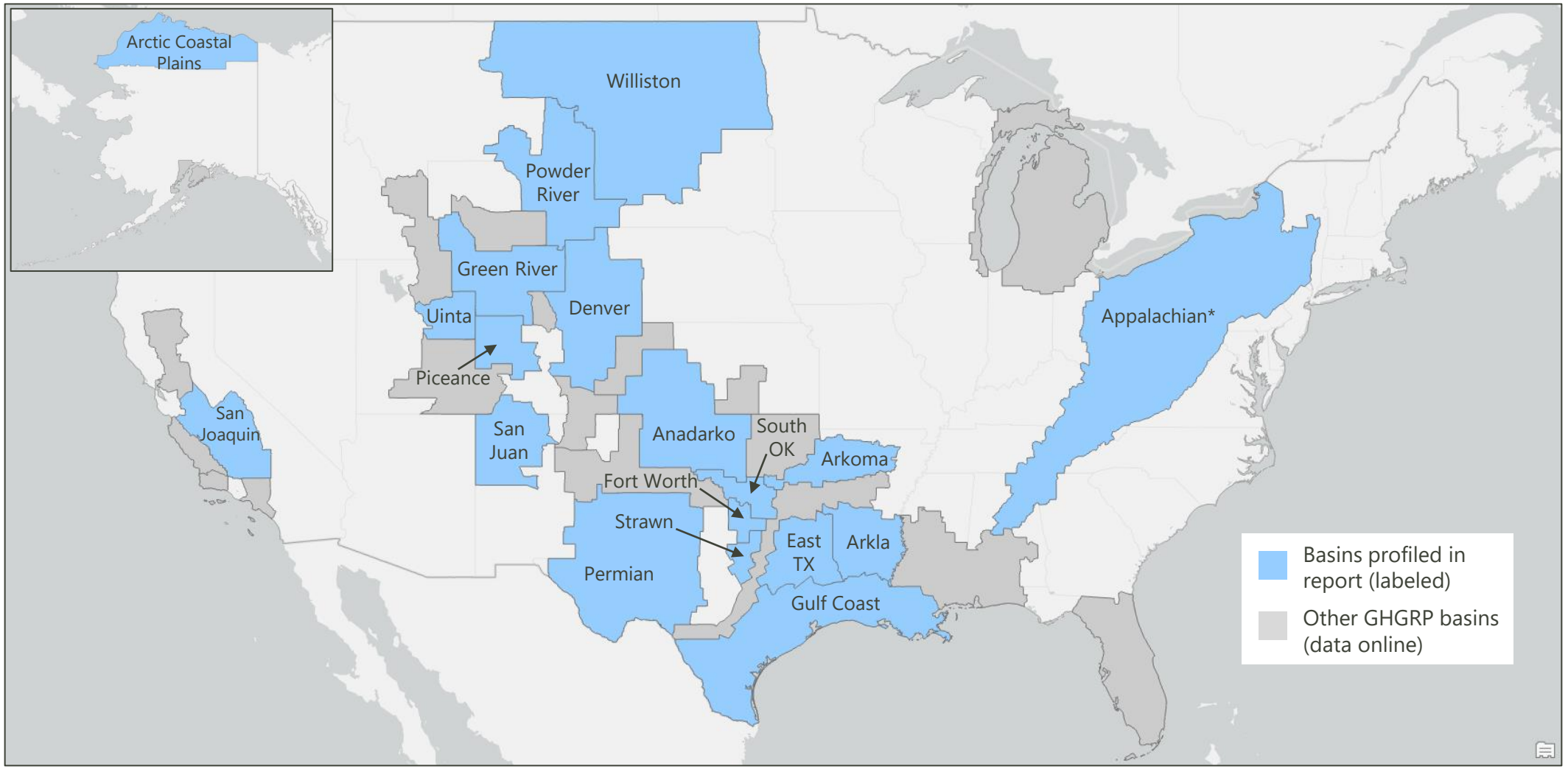




Basin-Level Summary Data

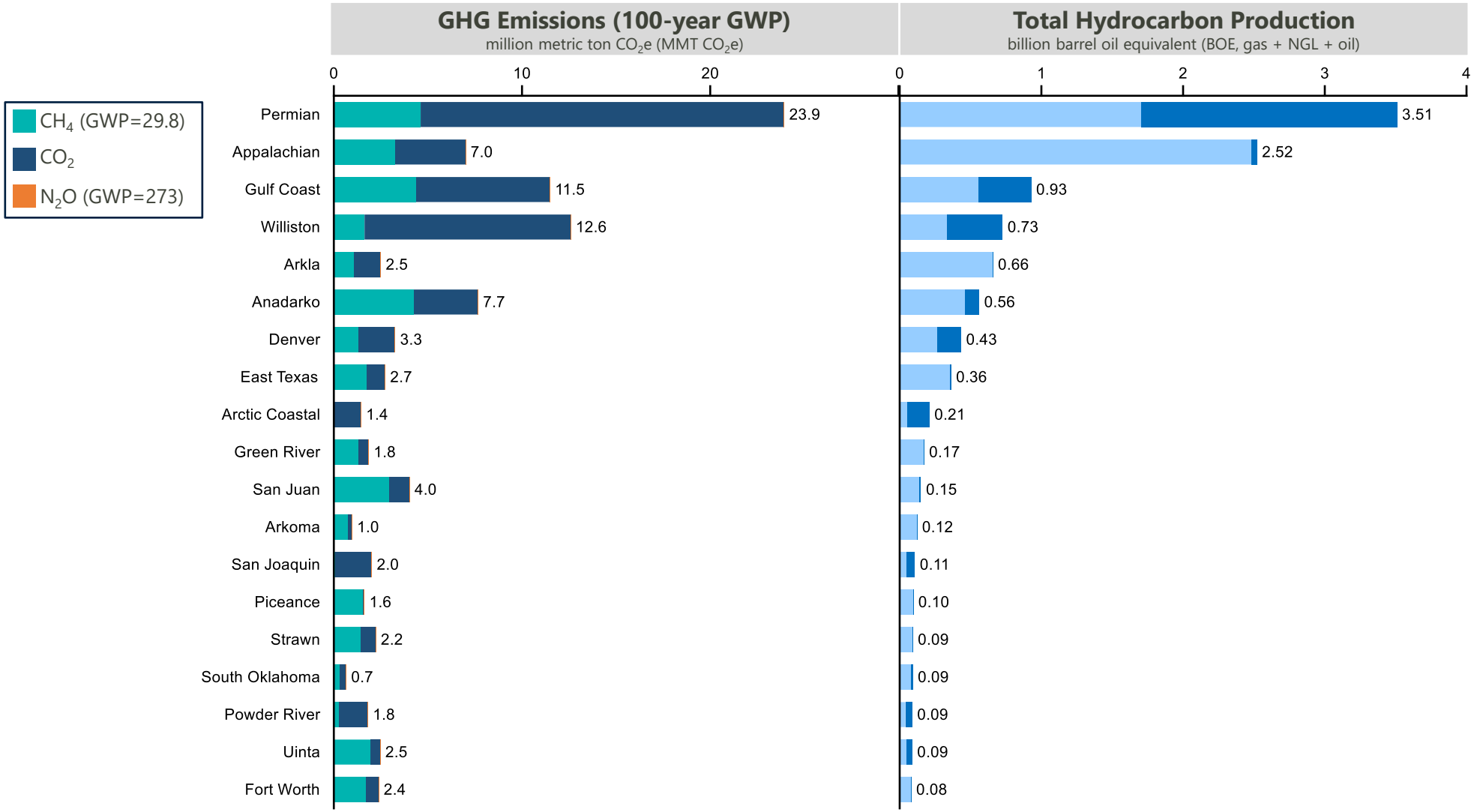
This section provides data on hydrocarbon production, GHG emissions, emissions intensity, and sources of emissions for the 19 largest hydrocarbon production basins in the U.S. by 2022 production volume. Together these basins represent 98.3% and 99.3% of total 2022 natural gas and oil production, respectively, 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.

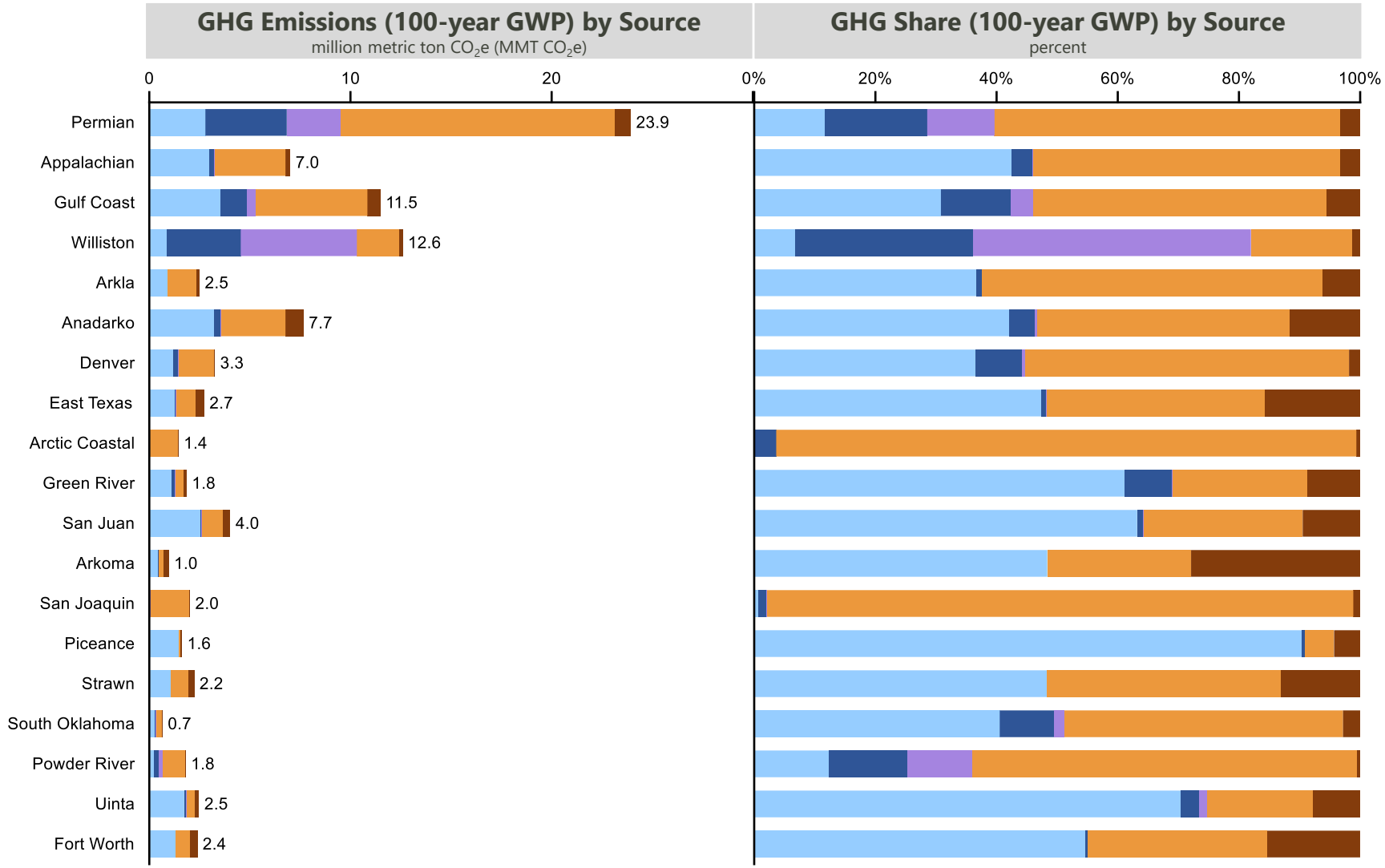
GHGRP Basin Production & Emissions



- 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 37% and 62% 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)

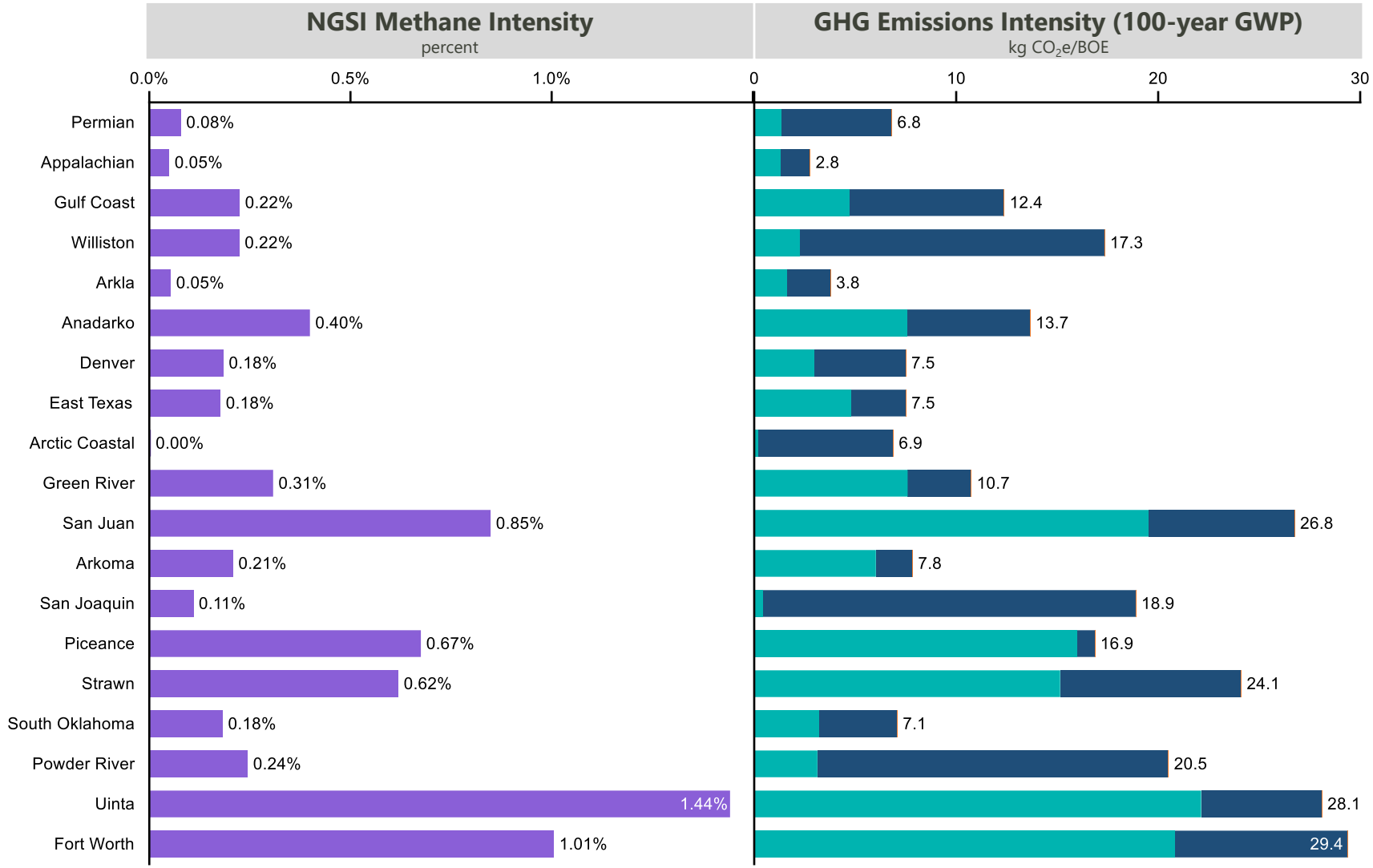
GHGRP Basin Emissions by Source



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)

2015-2022 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). New, high-producing wells can also drive down emissions intensities, as increased production initially outpaces resulting emissions. 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., 2022) may not reflect current asset ownership.

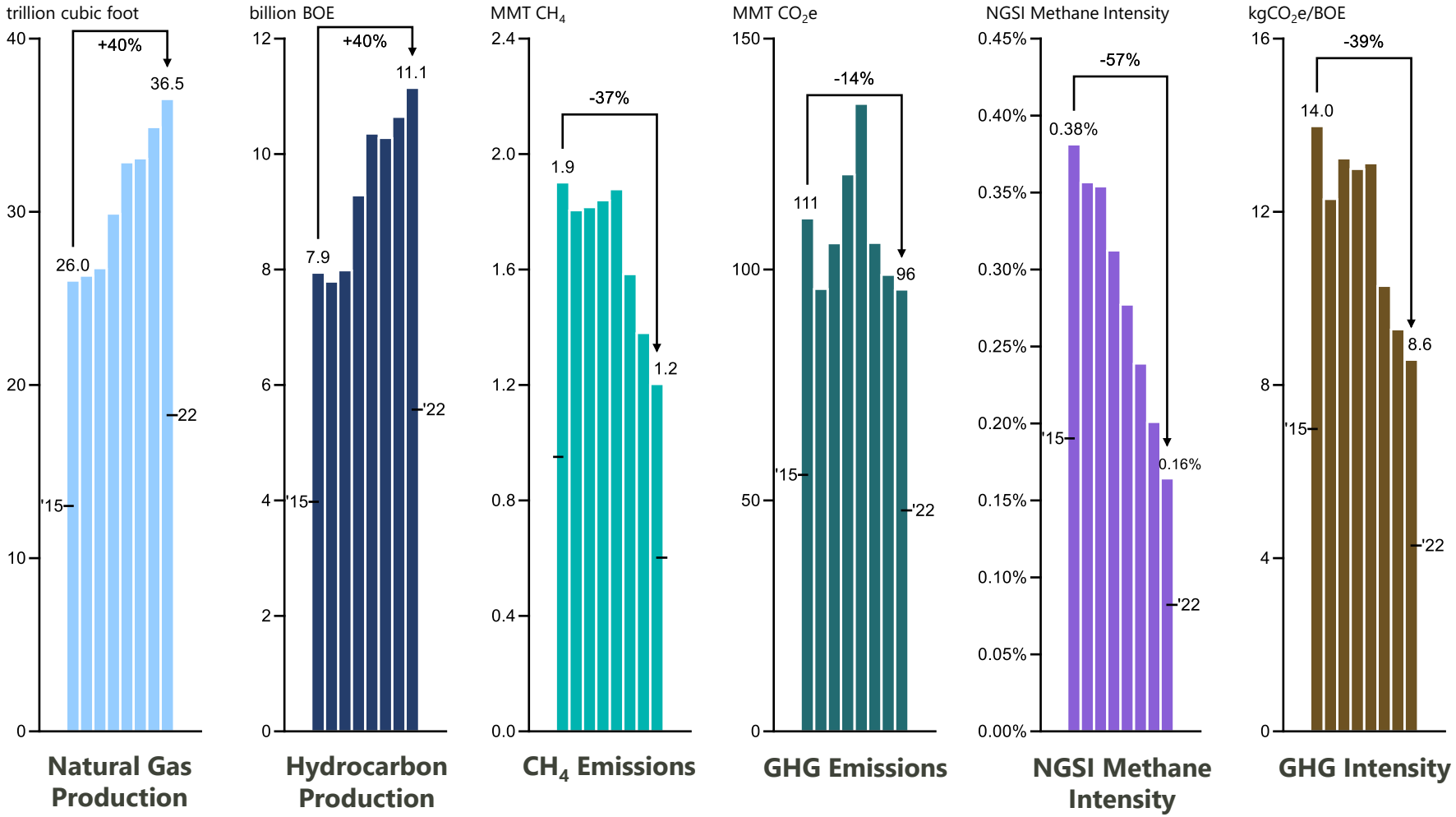
Methodological Changes. Methodological changes are changes to the way companies estimate emissions within the GHGRP's prescribed calculation methodologies. For example, several approaches use equipment operating hours as an input to the emissions calculation equation. Different interpretations of how 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 2021 and ramped up production in 2022 may be included in the 2022 data but not the 2021 data. Similarly, if assets are sold to smaller firms that do not meet the reporting threshold, emissions associated with those assets may no longer be reflected in the GHGRP.

*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.

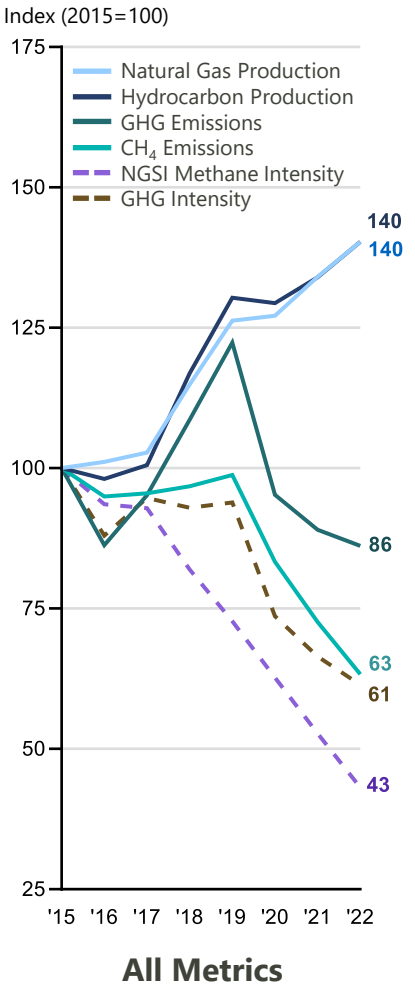
2015-2022 Trends Analysis: Production & Emissions Metrics

GHGRP Data Trends, 2015-2022



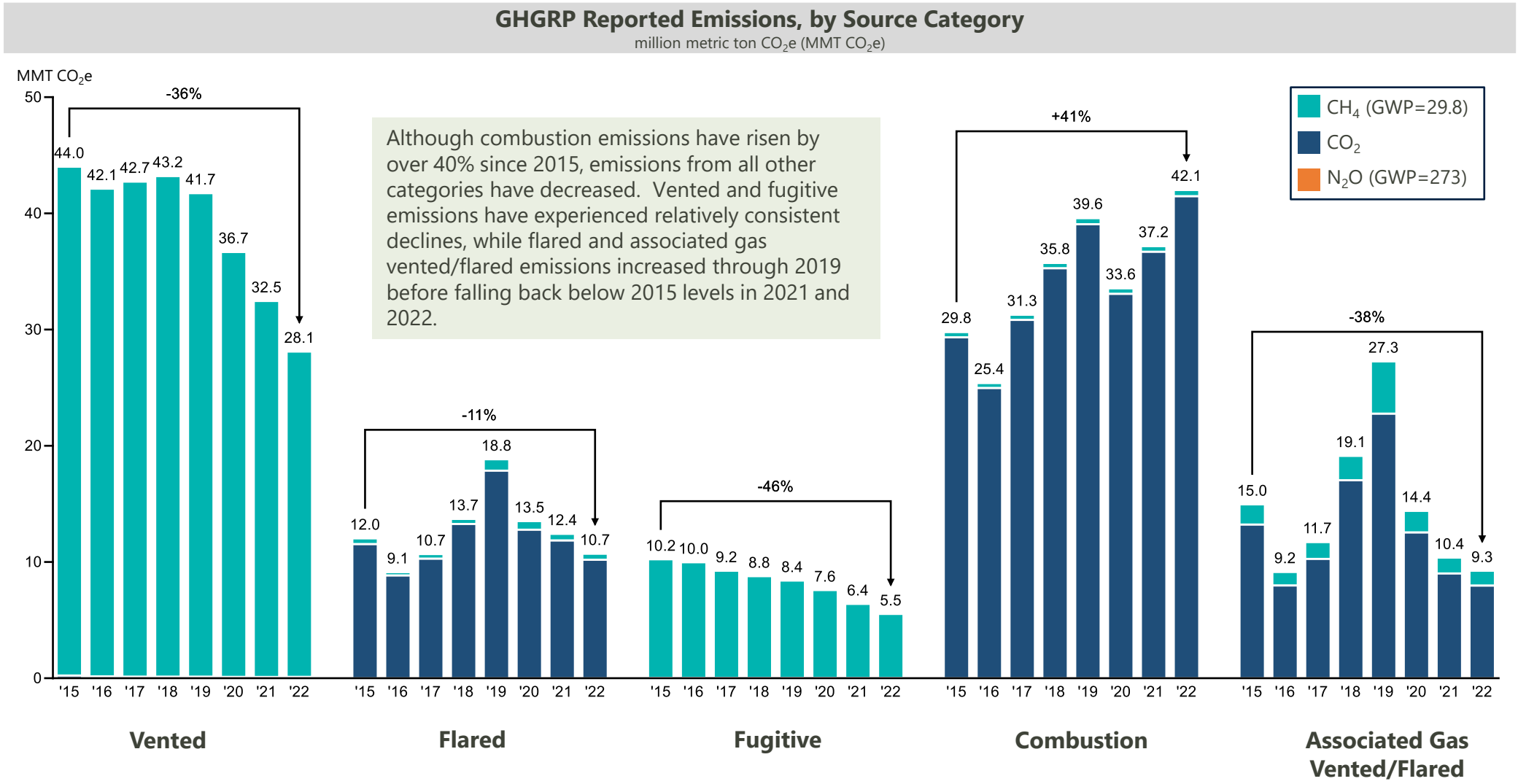
Combined Data Metrics

Indexed; 2015 = 100

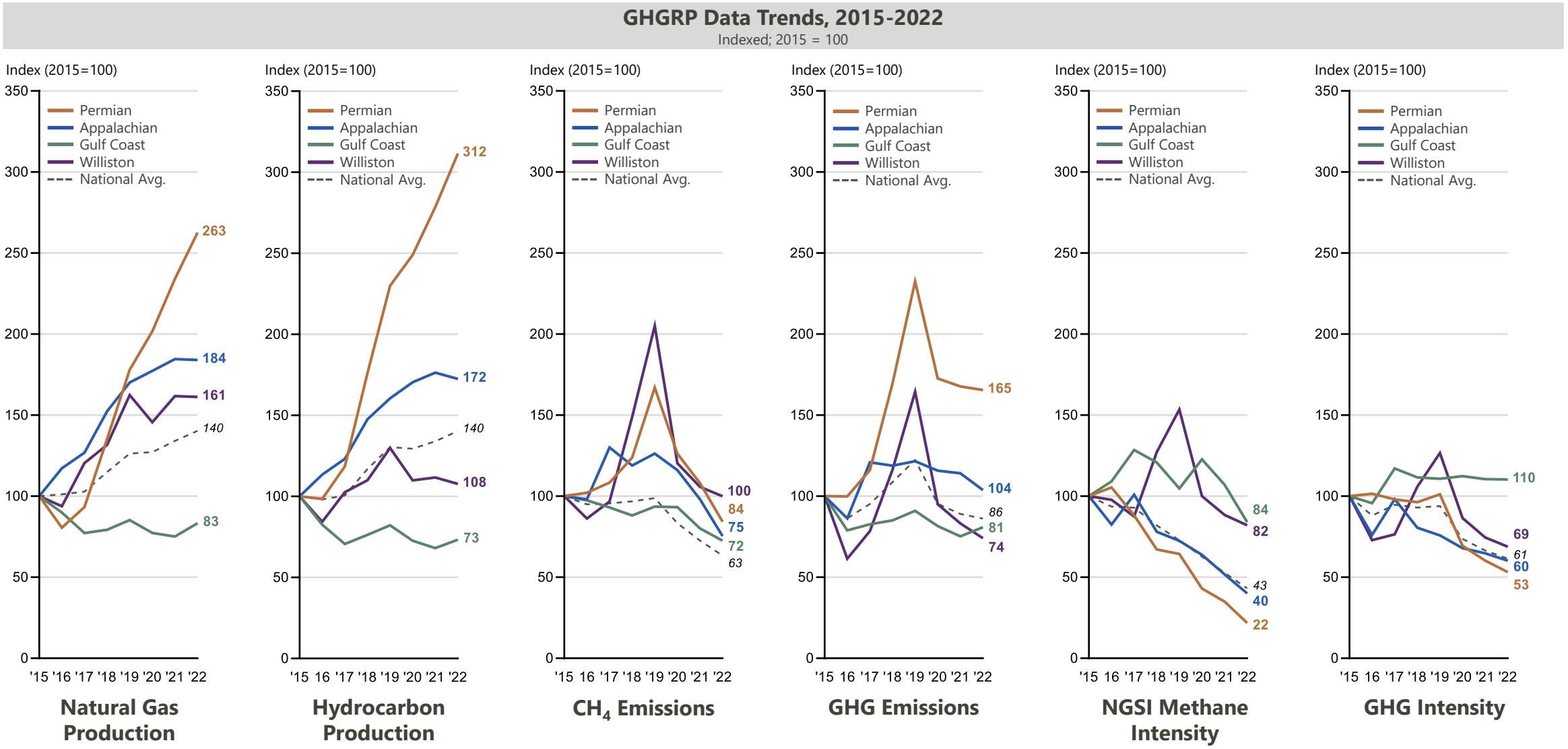


2015-2022 Trends Analysis: Emissions Sources

GHG Emissions (MMT CO_2e)



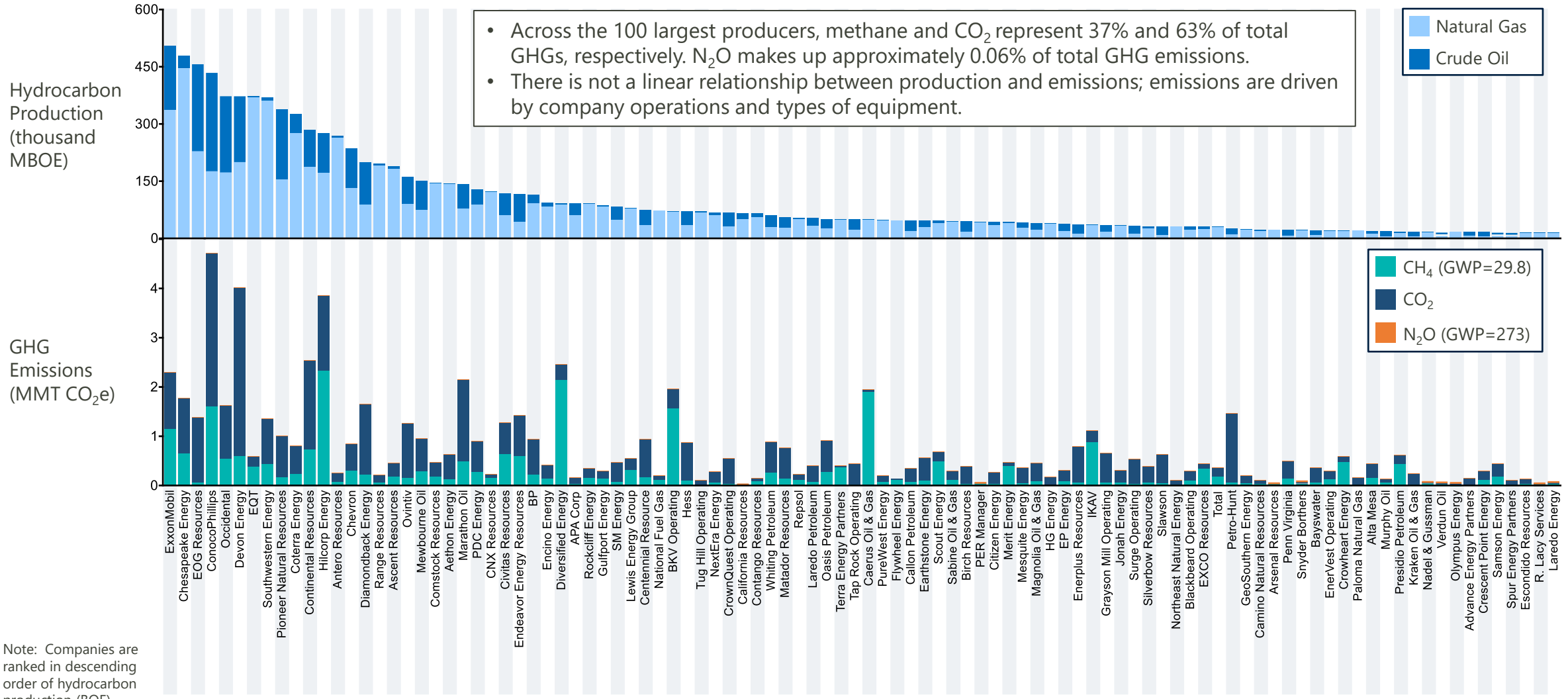
2015-2022 Trends Analysis: Production & Emissions Metrics of Top Production Basins



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.

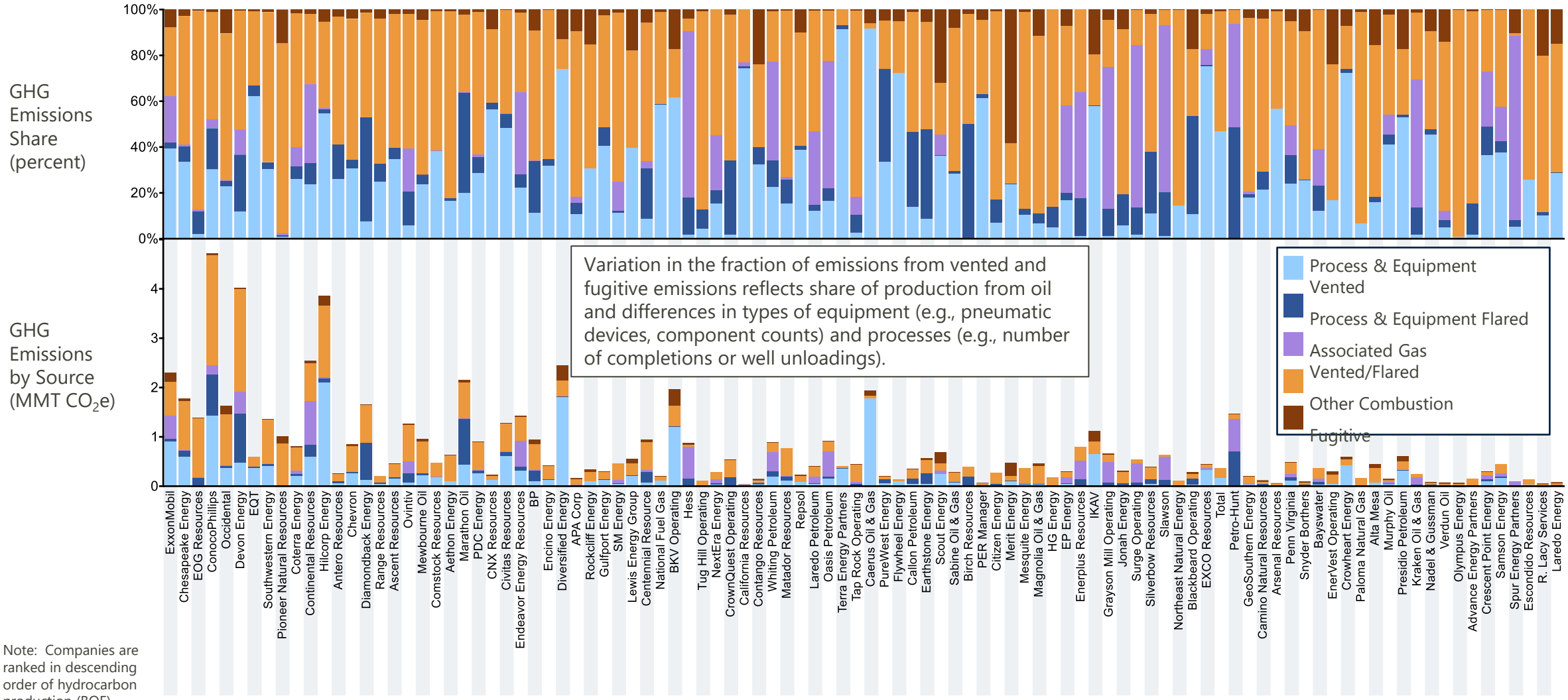
Hydrocarbon Production & Emissions (100-year GWP)



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

Note: Reflects unpublished data submitted by NextEra Energy currently under EPA review. Southwestern Energy reflects assets purchased in 2021 that were allocated to GeoSouthern in current EPA data; EQT reflects assets purchased in 2021 that were allocated to ARD Operating; IKAV reflects assets purchased in 2020 that were allocated to BP; Hilcorp reflects assets purchased in 2020 that were allocated to BP; Presidio Petroleum reflects assets purchased in 2019 that were allocated to Apache.

GHG Emissions by Source (100-year GWP)



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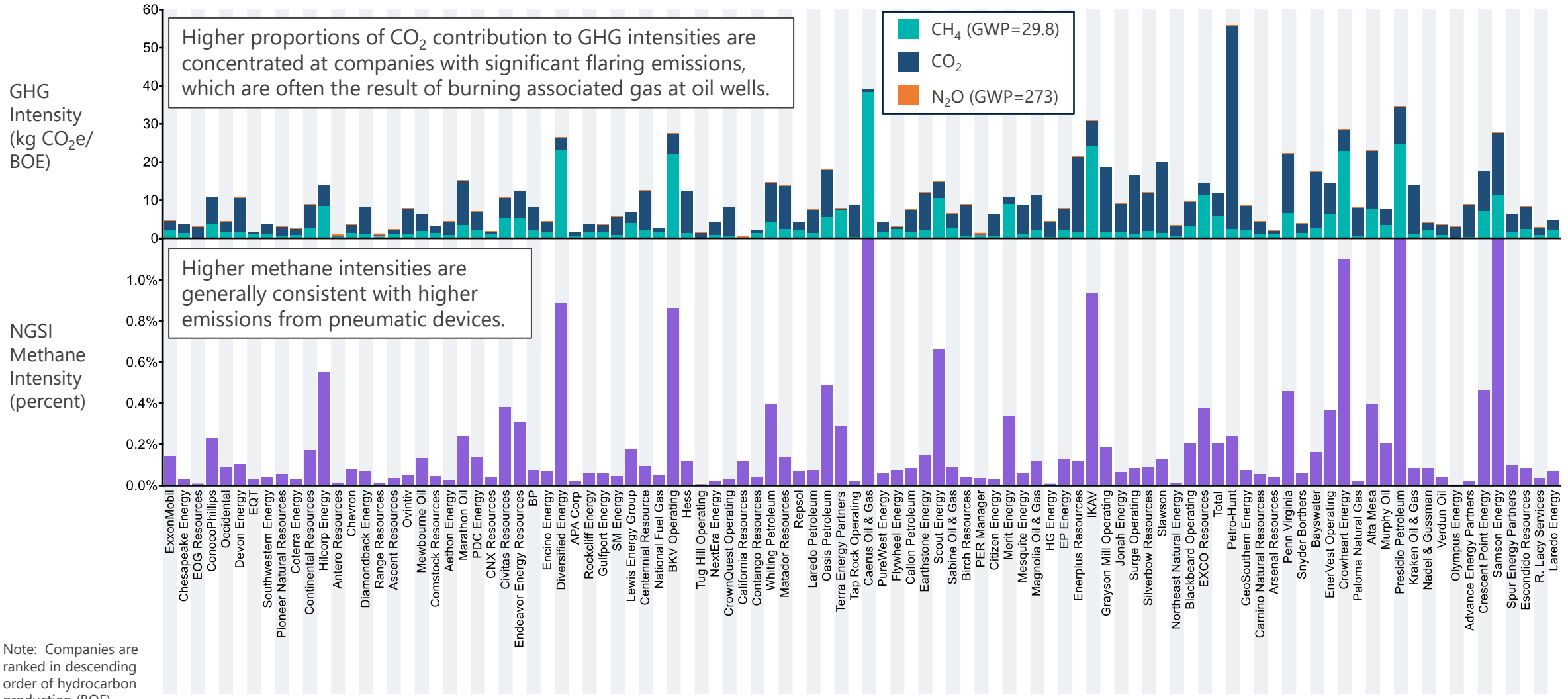
Methane & GHG Intensity (100-year GWP)



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

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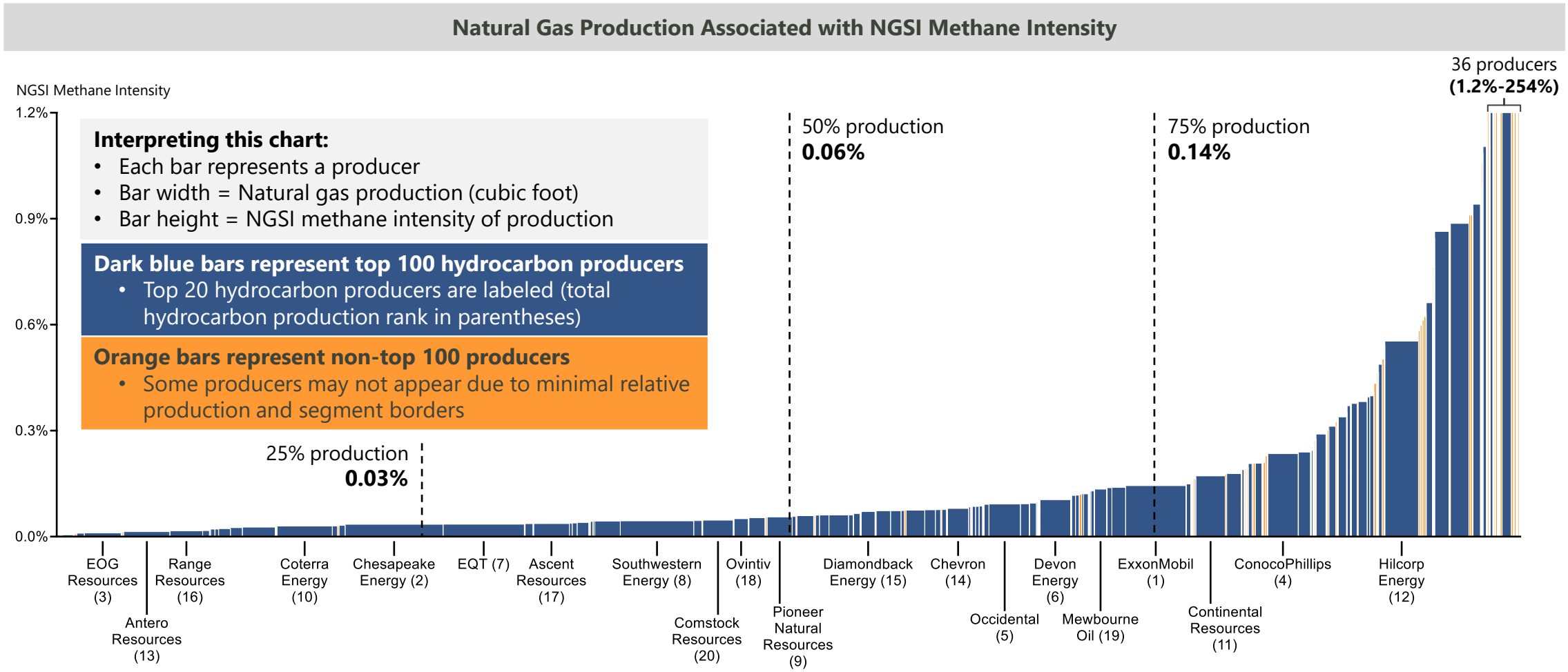
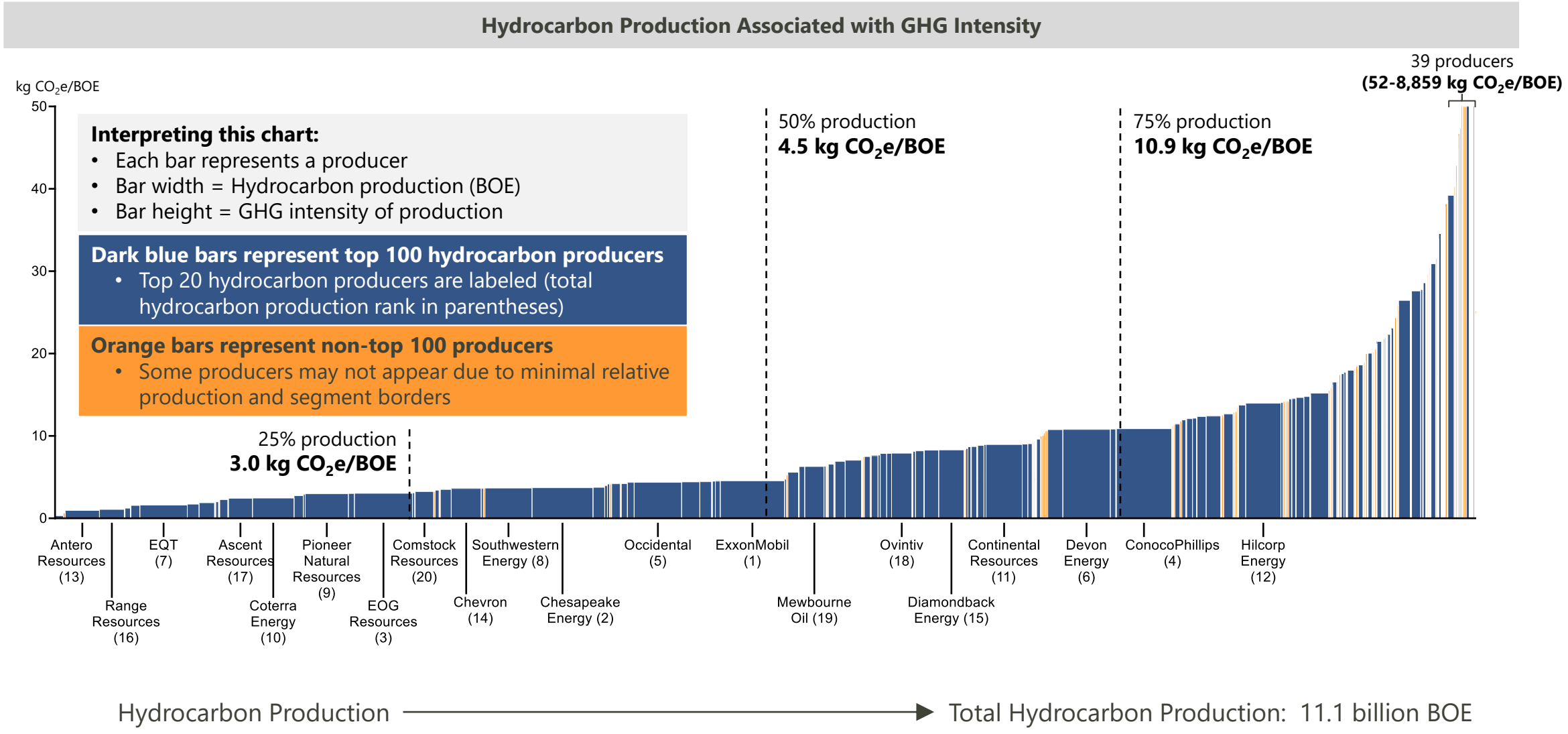
Total GHGRP Natural Gas Production, by Methane Intensity



Note: Reflects unpublished data submitted by NextEra Energy currently under EPA review. Southwestern Energy reflects assets purchased in 2021 that were allocated to GeoSouthern in current EPA data; EQT reflects assets purchased in 2021 that were allocated to ARD Operating; IKAV reflects assets purchased in 2020 that were allocated to BP; Hilcorp reflects assets purchased in 2020 that were allocated to BP; Presidio Petroleum reflects assets purchased in 2019 that were allocated to Apache.

Total GHGRP Hydrocarbon Production, by GHG Intensity



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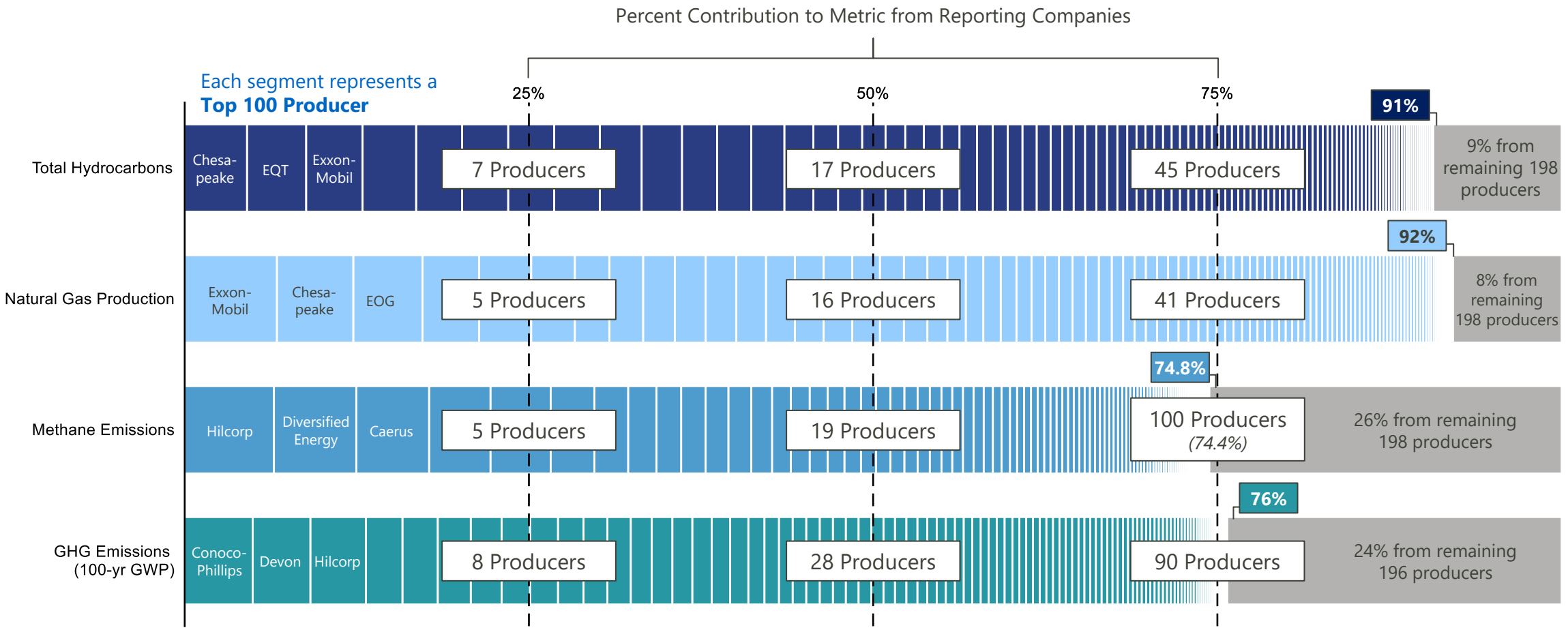
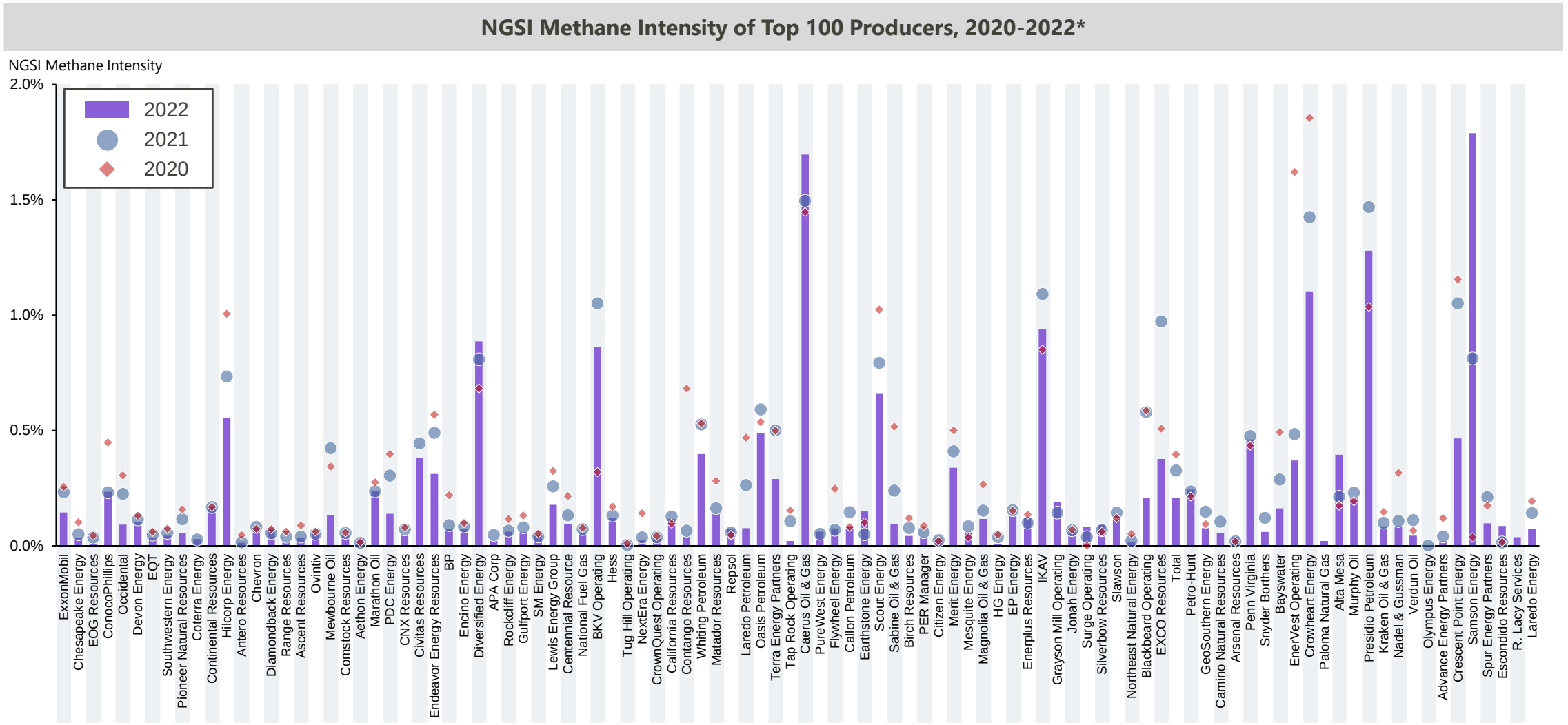
GHGRP Hydrocarbon Production & Emissions Contributions



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 seven and eight companies, respectively. However, the 198 companies that fall outside the top 100 are responsible for 24% of reported GHG emissions but only 9% of total hydrocarbon production.

Note: Reflects unpublished data submitted by NextEra Energy currently under EPA review. Southwestern Energy reflects assets purchased in 2021 that were allocated to GeoSouthern in current EPA data; EQT reflects assets purchased in 2021 that were allocated to ARD Operating; IKAV reflects assets purchased in 2020 that were allocated to BP; Hilcorp reflects assets purchased in 2020 that were allocated to BP; Presidio Petroleum reflects assets purchased in 2019 that were allocated to Apache.

2020-2022 Trends Analysis: Change in Methane Intensity, by Top 100 Producer



*10 of the top 100 producers in 2022 were not in the EPA database for all three years and may not have data for 2020 and/or 2021.

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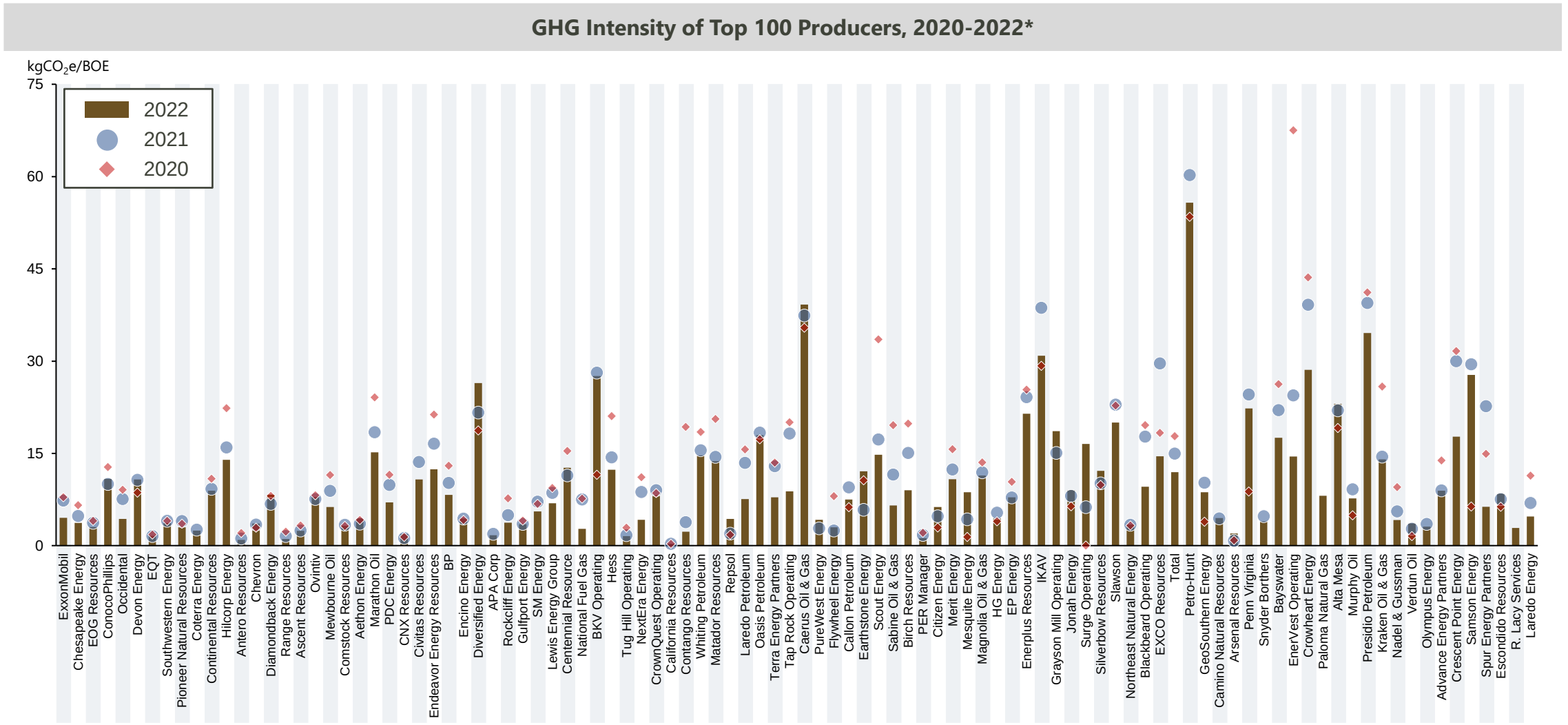
2020-2022 Trends Analysis: Change in GHG Intensity, by Top 100 Producer



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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	504,554	1,503	38,278	2,294,708	0.14%	4.55	4	6	6	32	64
2	Chesapeake Energy	478,702	2,445	21,639	1,774,451	0.03%	3.71	1	9	10	84	76
3	EOG Resources	456,514	918	2,082	1,384,423	0.01%	3.03	7	66	15	97	84
4	ConocoPhillips	433,940	762	53,629	4,717,168	0.23%	10.87	15	4	1	23	33
5	Occidental	372,667	785	18,219	1,626,020	0.09%	4.36	12	13	12	46	69
6	Devon Energy	372,541	766	19,948	4,016,200	0.10%	10.78	13	11	2	42	35
7	EQT	372,297	2,026	12,654	596,243	0.04%	1.60	2	20	37	83	95
8	Southwestern Energy	369,643	1,832	14,411	1,355,407	0.04%	3.67	3	18	16	74	77
9	Pioneer Natural Resources	338,579	624	5,626	1,007,221	0.06%	2.97	18	36	20	69	86
10	Coterra Energy	326,435	1,382	8,049	800,936	0.03%	2.45	5	29	29	87	89
11	Continental Resources	283,778	732	24,706	2,540,642	0.17%	8.95	16	8	4	29	40
12	Hilcorp Energy	276,271	838	78,008	3,858,624	0.55%	13.97	9	1	3	9	24
13	Antero Resources	268,867	1,158	2,592	256,557	0.01%	0.95	6	60	72	96	99
14	Chevron	235,106	529	10,160	850,316	0.08%	3.62	19	24	28	53	79
15	Diamondback Energy	199,798	344	7,365	1,657,545	0.07%	8.30	29	31	11	61	46
16	Range Resources	194,805	813	2,100	209,598	0.02%	1.08	11	65	76	95	98
17	Ascent Resources	188,930	894	5,861	458,807	0.04%	2.43	8	35	48	81	90
18	Ovintiv	159,926	357	4,999	1,263,337	0.05%	7.90	28	40	18	71	50
19	Mewbourne Oil	151,316	300	9,445	951,503	0.13%	6.29	32	25	21	35	60
20	Comstock Resources	145,297	763	6,171	471,435	0.05%	3.24	14	33	44	72	82
21	Aethon Energy	142,678	821	4,062	630,257	0.03%	4.42	10	47	35	88	68
22	Marathon Oil	141,553	302	16,475	2,149,839	0.24%	15.19	31	14	7	22	18
23	PDC Energy	127,686	343	9,385	899,145	0.14%	7.04	30	26	25	33	56
24	CNX Resources	121,884	635	5,063	229,728	0.04%	1.88	17	39	75	75	93
25	Civitas Resources	118,503	226	21,350	1,275,099	0.38%	10.76	42	10	17	15	36
26	Endeavor Energy Resources	115,221	174	19,906	1,429,452	0.31%	12.41	49	12	14	19	27
27	BP	113,827	465	7,578	941,099	0.07%	8.27	21	30	23	57	47
28	Encino Energy	92,872	361	4,634	412,057	0.07%	4.44	26	43	53	60	67
29	Diversified Energy	92,712	461	71,952	2,452,001	0.89%	26.45	22	2	5	6	8
30	APA Corp	92,320	293	1,227	158,300	0.02%	1.71	35	79	82	90	94
31	Rockcliff Energy	91,753	490	5,340	344,449	0.06%	3.75	20	38	62	64	75
32	Gulfport Energy	85,993	416	4,477	300,846	0.06%	3.50	23	45	65	67	80
33	SM Energy	83,563	201	2,338	466,527	0.05%	5.58	45	61	46	73	62
34	Lewis Energy Group	80,145	365	10,686	553,777	0.18%	6.91	25	23	40	28	57

Note: Southwestern Energy reflects assets purchased in 2021 that were allocated to GeoSouthern in current EPA data; EQT reflects assets purchased in 2021 that were allocated to Ard Operating; Hilcorp reflects assets purchased in 2020 that were allocated to BP

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	Centennial Resource	74,602	168	5,457	943,901	0.09%	12.65	51	37	22	44	26
36	National Fuel Gas	72,562	402	3,987	199,279	0.05%	2.75	24	48	79	70	88
37	BKV Operating	71,294	357	52,590	1,967,226	0.86%	27.59	27	5	8	7	7
38	Hess	70,958	118	3,176	876,712	0.12%	12.36	61	55	27	38	28
39	Tug Hill Operating	70,099	277	199	109,262	0.00%	1.56	36	98	88	99	96
40	NextEra Energy	67,244	300	1,877	281,915	0.03%	4.19	33	70	70	89	72
41	Crow nQuest Operating	66,994	123	1,096	548,009	0.03%	8.18	58	82	41	86	48
42	California Resources	65,526	95	519	20,344	0.12%	0.31	70	93	100	40	100
43	Contango Resources	65,422	297	2,849	148,053	0.04%	2.26	34	58	84	78	91
44	Whiting Petroleum	60,419	98	8,828	885,945	0.40%	14.66	69	28	26	13	20
45	Matador Resources	56,002	118	4,587	769,491	0.14%	13.74	63	44	31	34	25
46	Repsol	53,177	261	3,819	231,627	0.07%	4.36	38	50	74	59	70
47	Laredo Petroleum	52,897	132	2,326	401,820	0.08%	7.60	57	62	54	55	54
48	Oasis Petroleum	50,752	90	9,274	911,960	0.49%	17.97	75	27	24	10	14
49	Terra Energy Partners	50,438	245	12,175	396,900	0.29%	7.87	39	21	55	20	52
50	Tap Rock Operating	49,834	91	608	440,517	0.02%	8.84	74	90	52	91	42
51	Caerus Oil & Gas	49,572	227	63,664	1,943,295	1.70%	39.20	41	3	9	2	2
52	PureWest Energy	48,084	237	2,643	202,011	0.06%	4.20	40	59	78	65	71
53	Flyw heel Energy	47,136	265	3,686	141,734	0.08%	3.01	37	51	85	56	85
54	Callon Petroleum	46,395	80	2,228	347,540	0.09%	7.49	81	63	61	50	55
55	Earthstone Energy	46,227	110	3,273	558,623	0.15%	12.08	66	54	39	31	30
56	Scout Energy	46,135	152	16,418	681,605	0.66%	14.77	55	15	32	8	19
57	Sabine Oil & Gas	43,998	224	3,645	288,358	0.09%	6.55	43	52	69	45	58
58	Birch Resources	43,859	65	919	394,917	0.04%	9.00	85	85	56	77	39
59	PER Manager	43,730	197	1,182	53,581	0.04%	1.23	46	80	96	82	97
60	Citizen Energy	43,647	153	887	274,043	0.03%	6.28	54	87	71	85	61
61	Merit Energy	43,534	208	13,137	471,148	0.34%	10.82	44	19	45	18	34
62	Mesquite Energy	42,198	117	1,527	367,213	0.06%	8.70	64	75	58	63	43
63	Magnolia Oil & Gas	40,396	101	2,857	461,489	0.12%	11.42	67	57	47	41	32
64	HG Energy	38,694	190	300	174,361	0.01%	4.51	47	97	80	98	65
65	EP Energy	38,413	83	2,877	302,549	0.13%	7.88	79	56	64	36	51
66	Enerplus Resources	36,839	46	1,763	790,705	0.12%	21.46	89	73	30	39	11
67	IKAV	36,274	186	29,470	1,120,587	0.94%	30.89	48	7	19	5	4

Note: Reflects unpublished data submitted by NextEra Energy currently under EPA review. IKAV reflects assets purchased in 2020 that were allocated to BP.

Emissions & Emissions Intensities of the Top 100 Producers

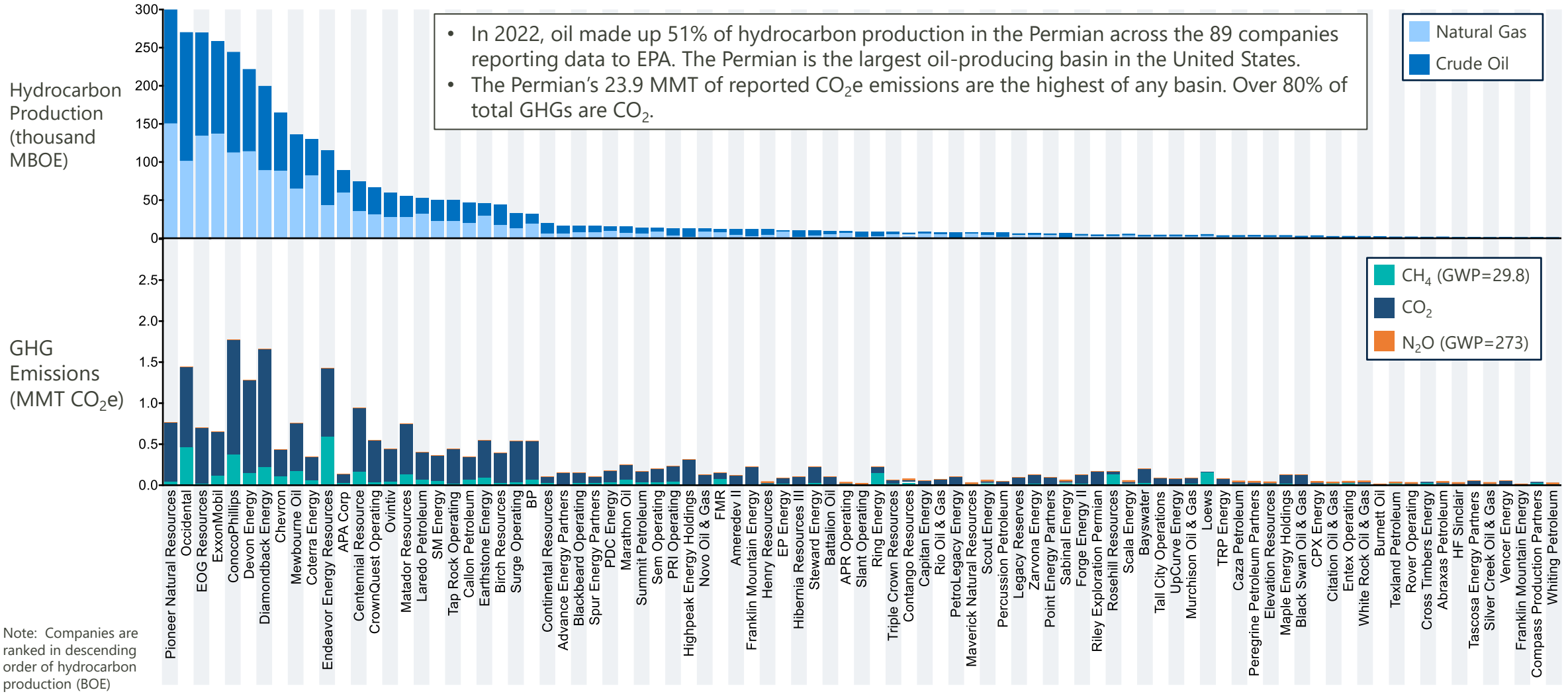
		Production		Emissions		Intensity		Metric Rank (among top 100 producers) 1=highest, 100= lowest				
Rank	Company	Total MBOE	Gas (bcf)	MT CH4	MT GHG	NGSI Intensity	GHG Intensity	Gas (bcf)	CH4 Emissions	GHG Emissions	NGSI Intensity	GHG Intensity
68	Grayson Mill Operating	35,259	55	1,940	656,293	0.19%	18.61	87	69	33	27	13
69	Jonah Energy	34,280	160	1,871	310,254	0.07%	9.05	53	71	63	62	38
70	Surge Operating	32,550	47	1,158	538,069	0.08%	16.53	88	81	42	52	17
71	Silverbow Resources	32,146	120	1,942	390,608	0.09%	12.15	60	68	57	47	29
72	Slawson	31,740	31	1,338	635,878	0.13%	20.03	93	76	34	37	12
73	Northeast Natural Energy	31,128	169	527	106,083	0.02%	3.41	50	92	89	94	81
74	Blackbeard Operating	30,543	91	3,360	293,289	0.21%	9.60	73	53	67	26	37
75	EXCO Resources	30,433	143	11,534	441,809	0.38%	14.52	56	22	50	16	21
76	Total	30,381	163	6,040	362,878	0.21%	11.94	52	34	60	25	31
77	Petro-Hunt	26,197	37	2,104	1,460,618	0.24%	55.76	90	64	13	21	1
78	GeoSouthern Energy	23,690	118	1,587	205,595	0.08%	8.68	62	74	77	54	44
79	Camino Natural Resources	23,381	92	897	105,193	0.06%	4.50	72	86	90	68	66
80	Arsenal Resources	22,602	123	874	45,141	0.04%	2.00	59	88	98	79	92
81	Penn Virginia	22,092	26	4,873	493,104	0.46%	22.32	96	42	43	12	10
82	Snyder Borthers	21,426	100	1,001	84,493	0.06%	3.94	68	84	92	66	74
83	Bayswater	20,815	32	1,788	365,333	0.16%	17.55	92	72	59	30	16
84	EnerVest Operating	20,657	83	4,372	299,207	0.37%	14.48	78	46	66	17	22
85	Crow heart Energy	20,475	85	15,748	585,279	1.10%	28.58	77	16	38	4	5
86	Paloma Natural Gas	20,035	111	428	162,269	0.02%	8.10	65	96	81	92	49
87	Alta Mesa	19,124	57	4,964	441,147	0.39%	23.07	86	41	51	14	9
88	Murphy Oil	17,707	22	2,030	135,858	0.21%	7.67	98	67	86	24	53
89	Presidio Petroleum	17,701	66	14,629	611,768	1.28%	34.56	84	17	36	3	3
90	Kraken Oil & Gas	17,466	20	553	245,255	0.08%	14.04	99	91	73	51	23
91	Nadel & Gussman	17,294	88	1,326	71,875	0.09%	4.16	76	77	93	49	73
92	Verdun Oil	17,249	36	451	62,473	0.04%	3.62	91	94	95	76	78
93	Olympus Energy	17,113	93	24	52,922	0.00%	3.09	71	100	97	100	83
94	Advance Energy Partners	16,778	27	183	149,995	0.02%	8.94	95	99	83	93	41
95	Crescent Point Energy	16,378	18	3,870	290,283	0.47%	17.72	100	49	68	11	15
96	Samson Energy	16,187	24	6,201	449,319	1.79%	27.76	97	32	49	1	6
97	Spur Energy Partners	16,113	30	800	101,676	0.10%	6.31	94	89	91	43	59
98	Escondido Resources	15,482	81	1,243	131,016	0.09%	8.46	80	78	87	48	45
99	R. Lacy Services	15,041	71	444	43,288	0.04%	2.88	83	95	99	80	87
100	Laredo Energy	14,790	79	1,036	70,107	0.07%	4.74	82	83	94	58	63

Note: Presidio Petroleum reflects assets purchased in 2019 that were allocated to Apache.

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.

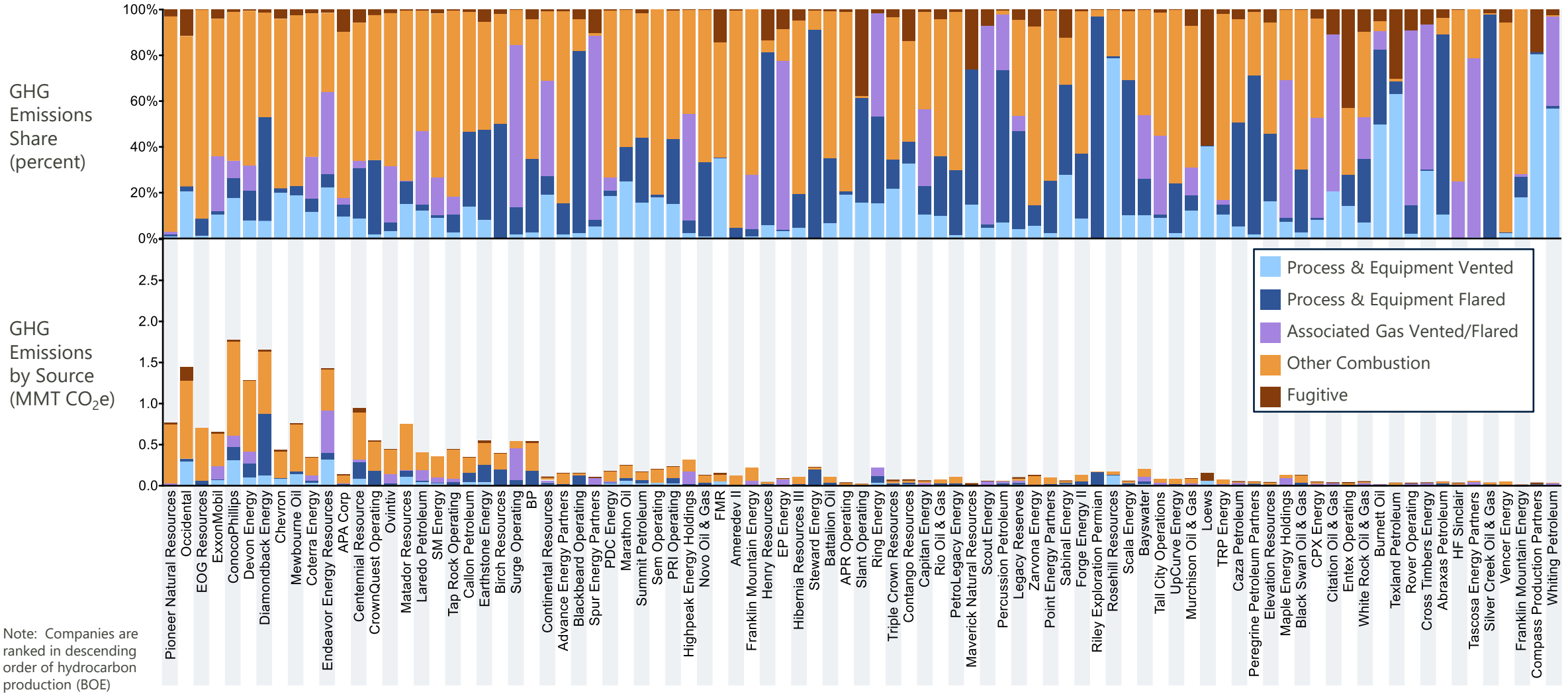
Hydrocarbon Production & Emissions (100-year GWP)



- In 2022, oil made up 51% of hydrocarbon production in the Permian across the 89 companies reporting data to EPA. The Permian is the largest oil-producing basin in the United States.
- The Permian's 23.9 MMT of reported CO_2e emissions are the highest of any basin. Over 80% of total GHGs are CO_2.

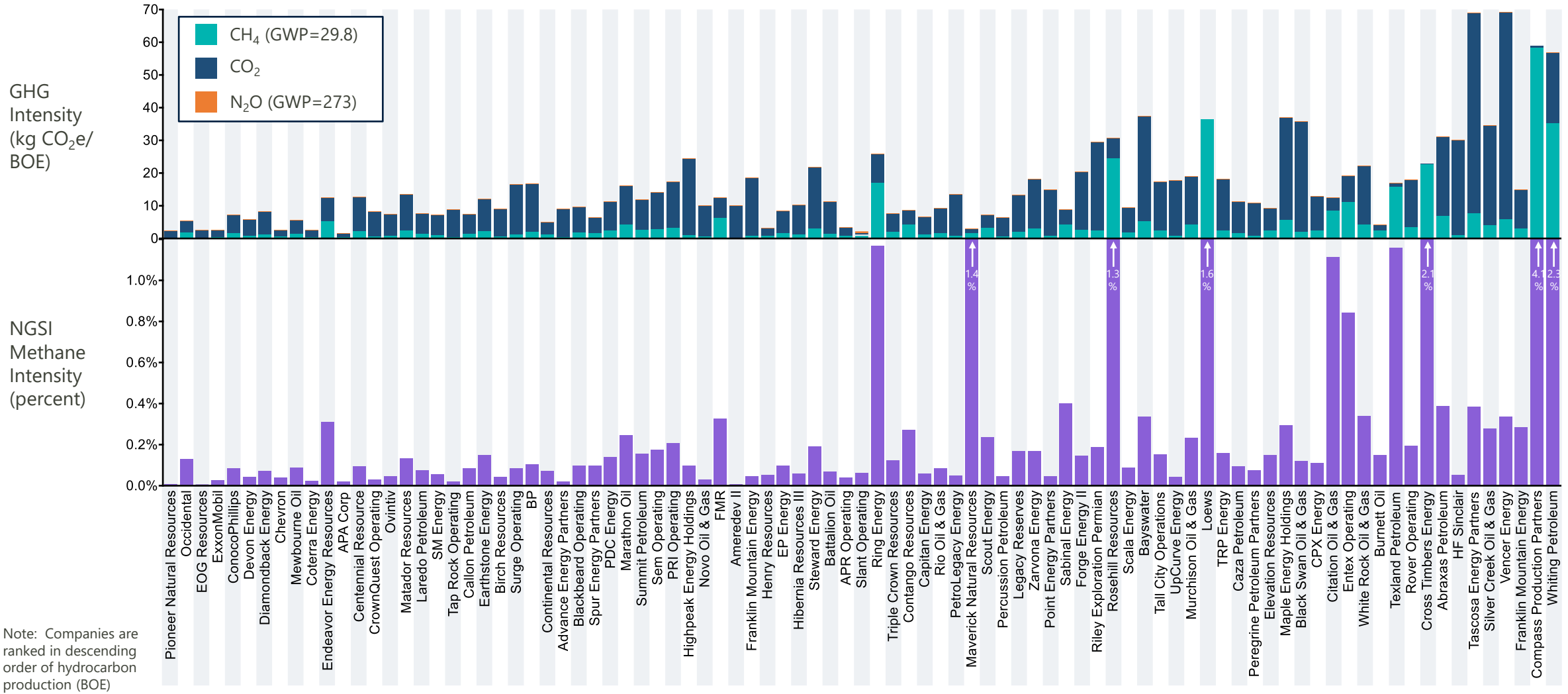
Note: Companies are ranked in descending order of hydrocarbon production (BOE) within basin

GHG Emissions by Source (100-year GWP)



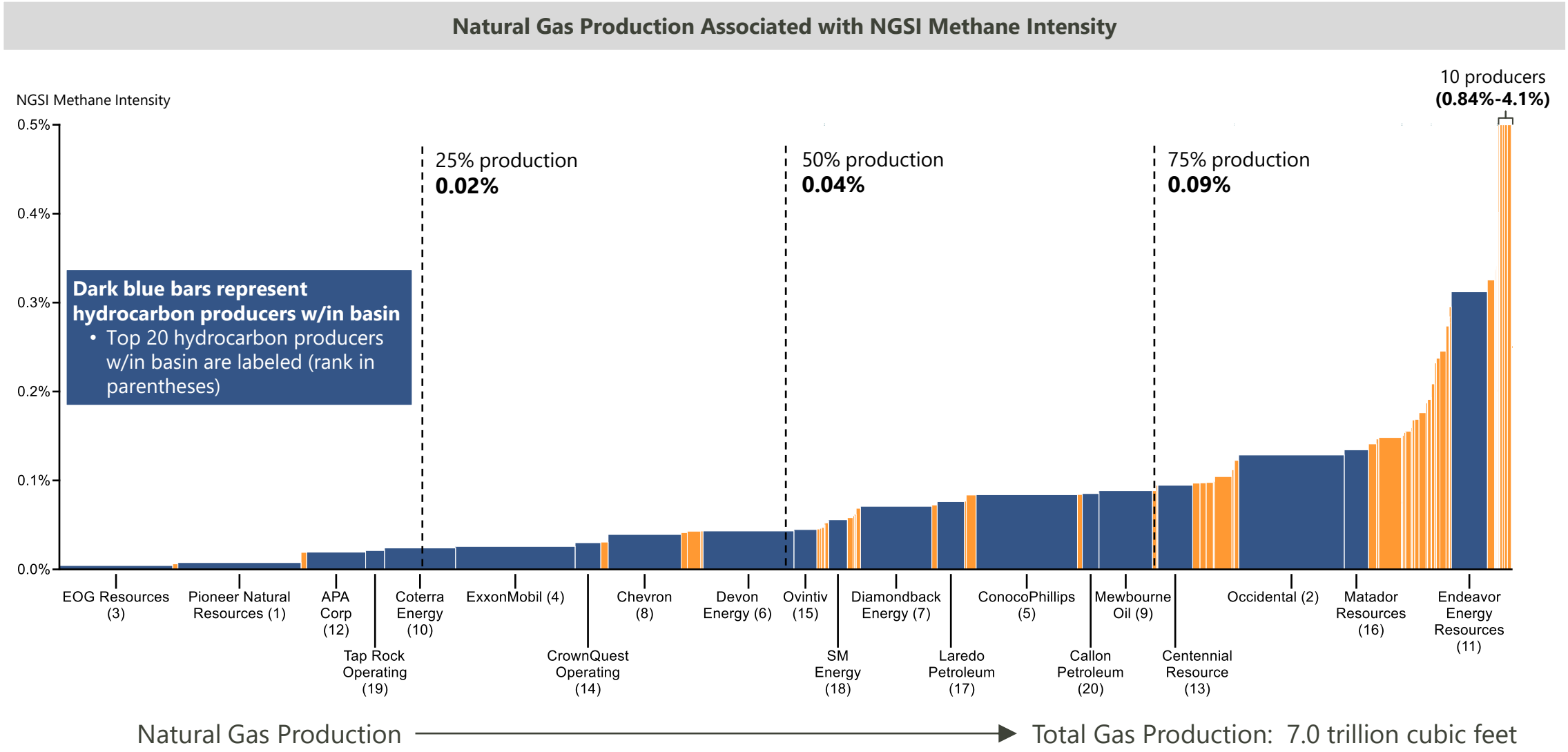
Note: Companies are ranked in descending order of hydrocarbon production (BOE) within basin

Methane & GHG Intensity (100-year GWP)

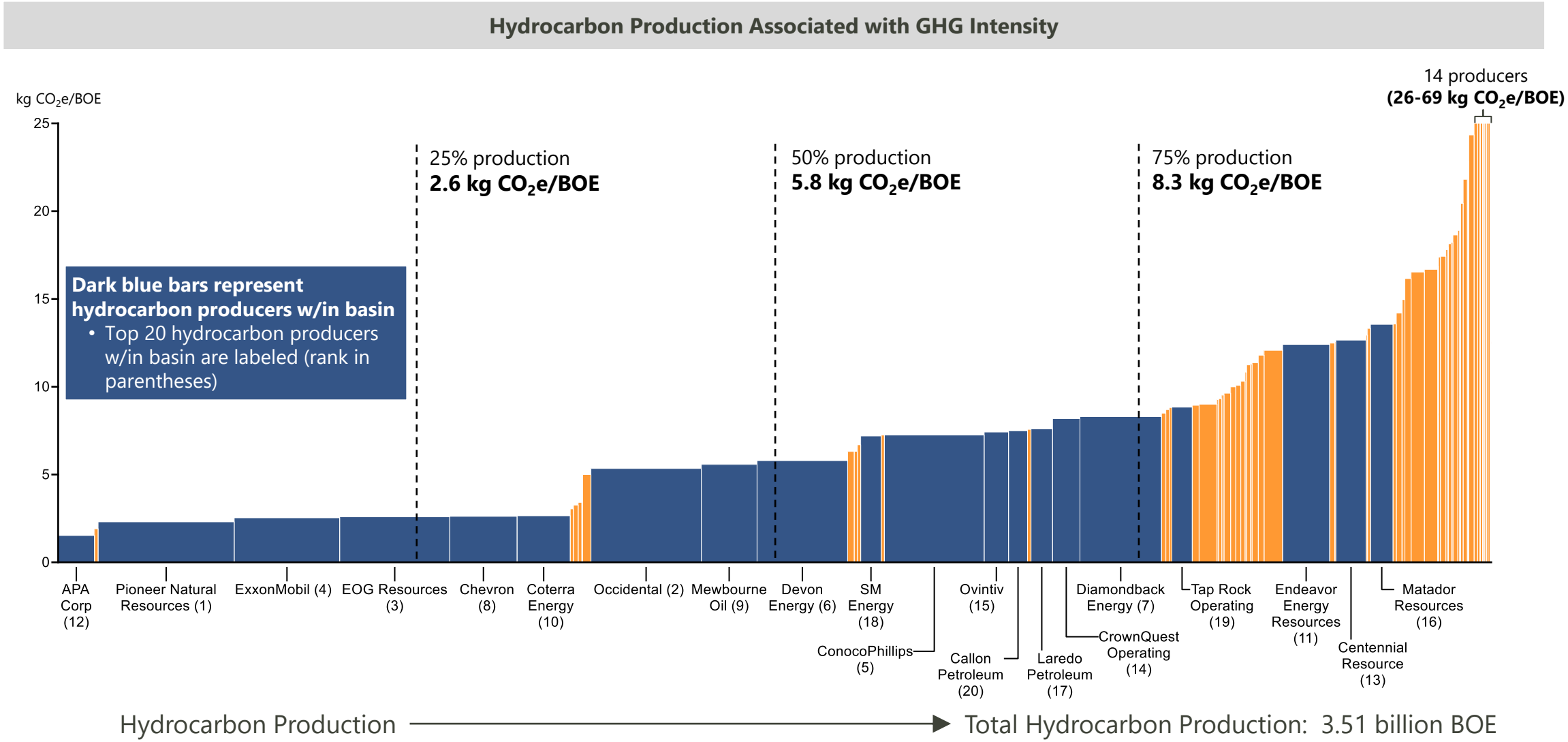


Note: Companies are ranked in descending order of hydrocarbon production (BOE) within basin

Total GHGRP Natural Gas Production, by Methane Intensity



Total GHGRP Hydrocarbon Production, by GHG Intensity

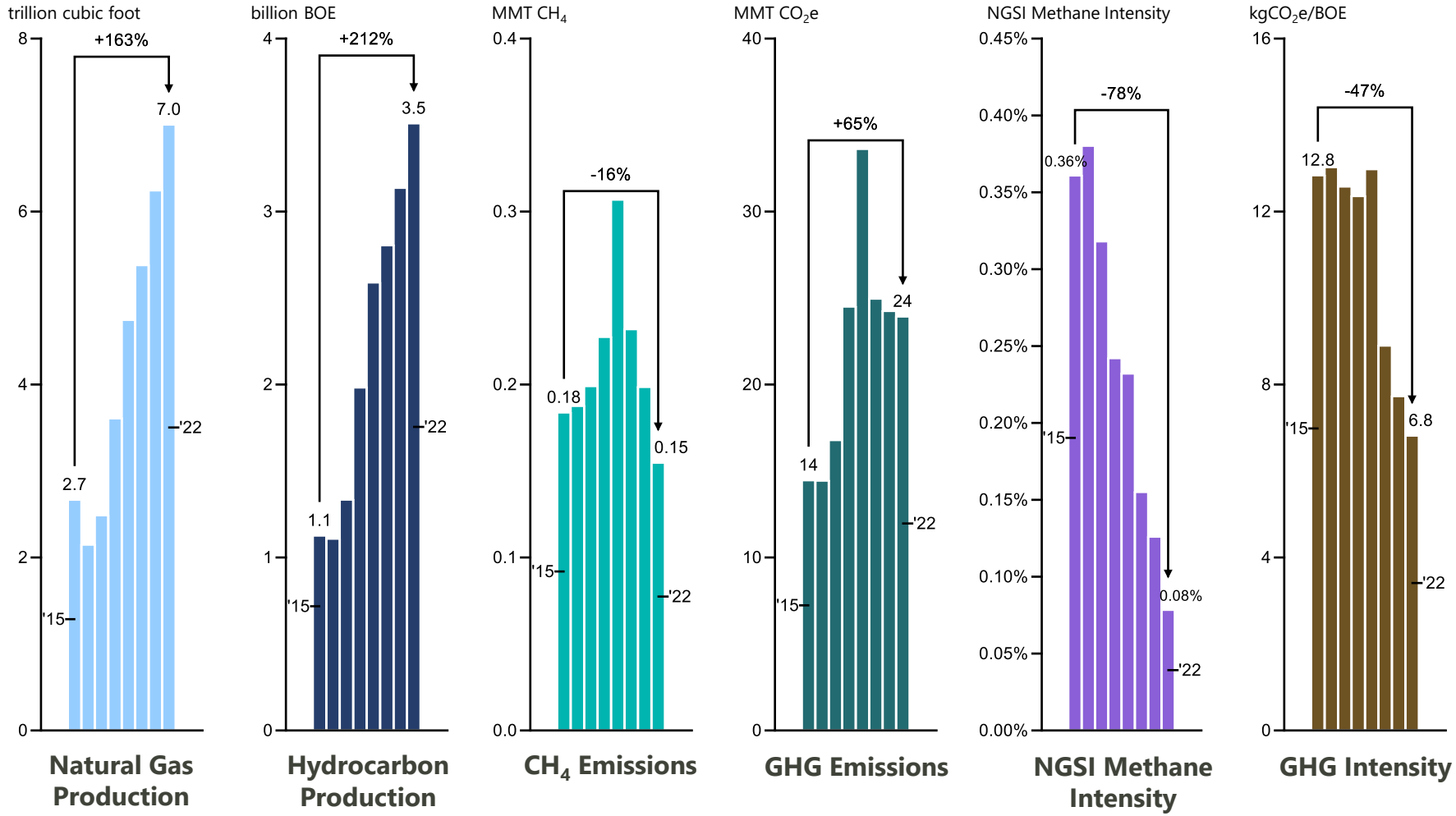


Permian Basin Producers

2015-2022 Trends Analysis: Production & Emissions Metrics

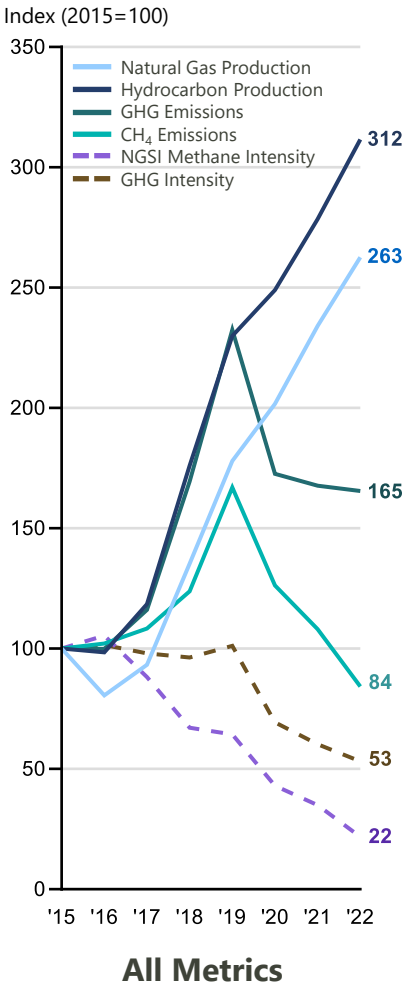
GHGRP Data Trends, 2015-2022

Permian Basin



Combined Data Metrics

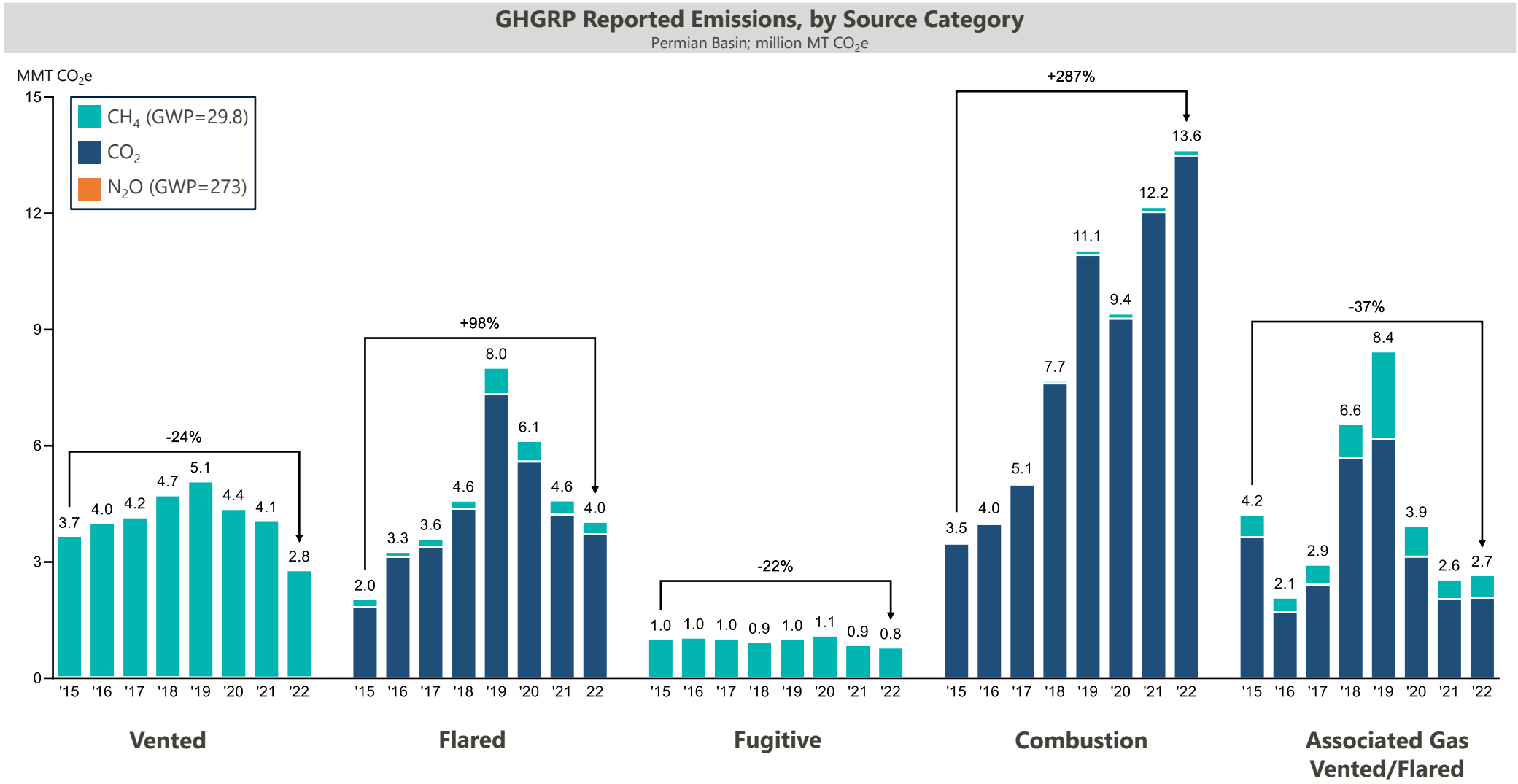
Indexed; 2015 = 100



Permian Basin Producers

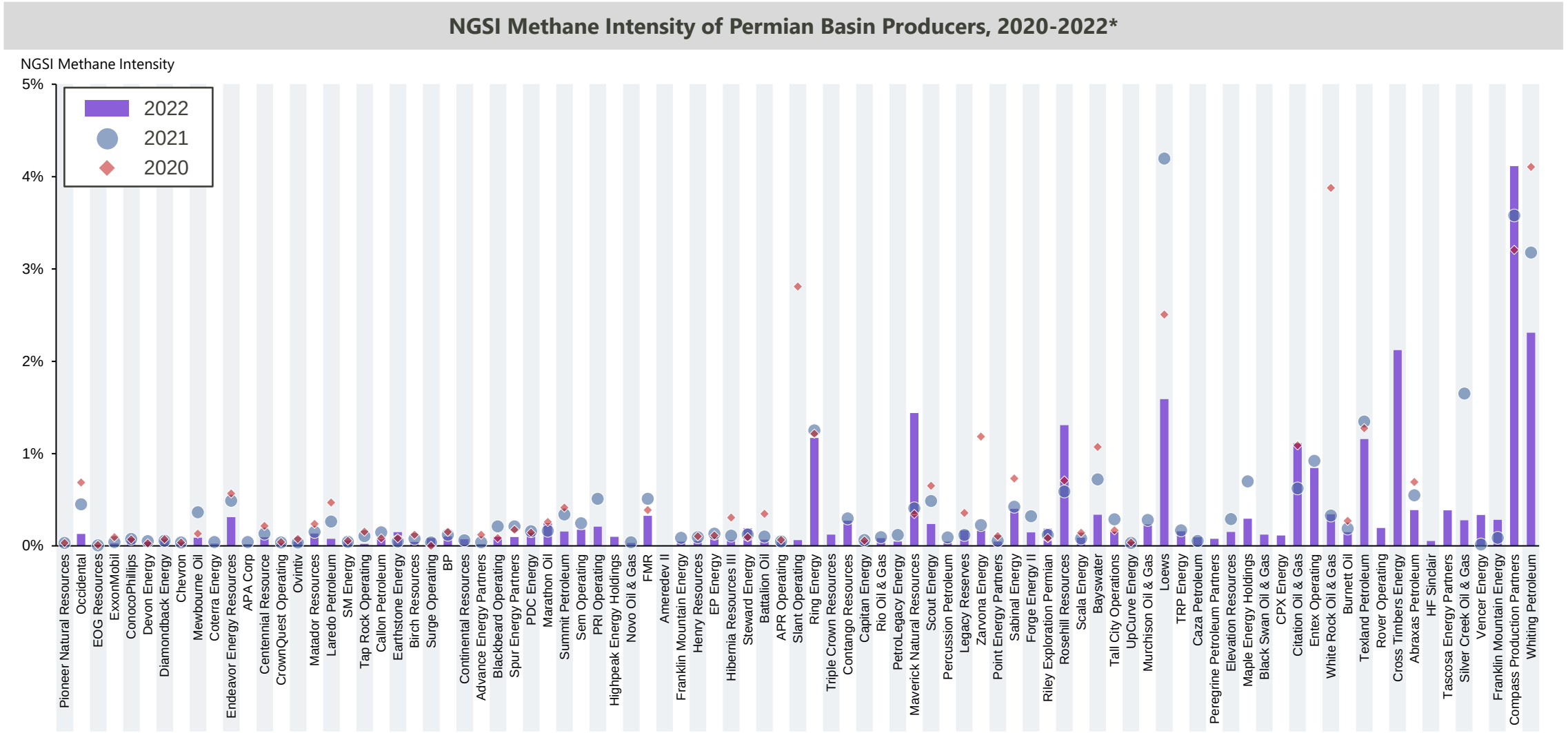
2015-2022 Trends Analysis: Emissions Sources

GHG Emissions (MMT CO_2e)



Permian Basin Producers

2020-2022 Trends Analysis: Change in Methane Intensity, by Top Producer

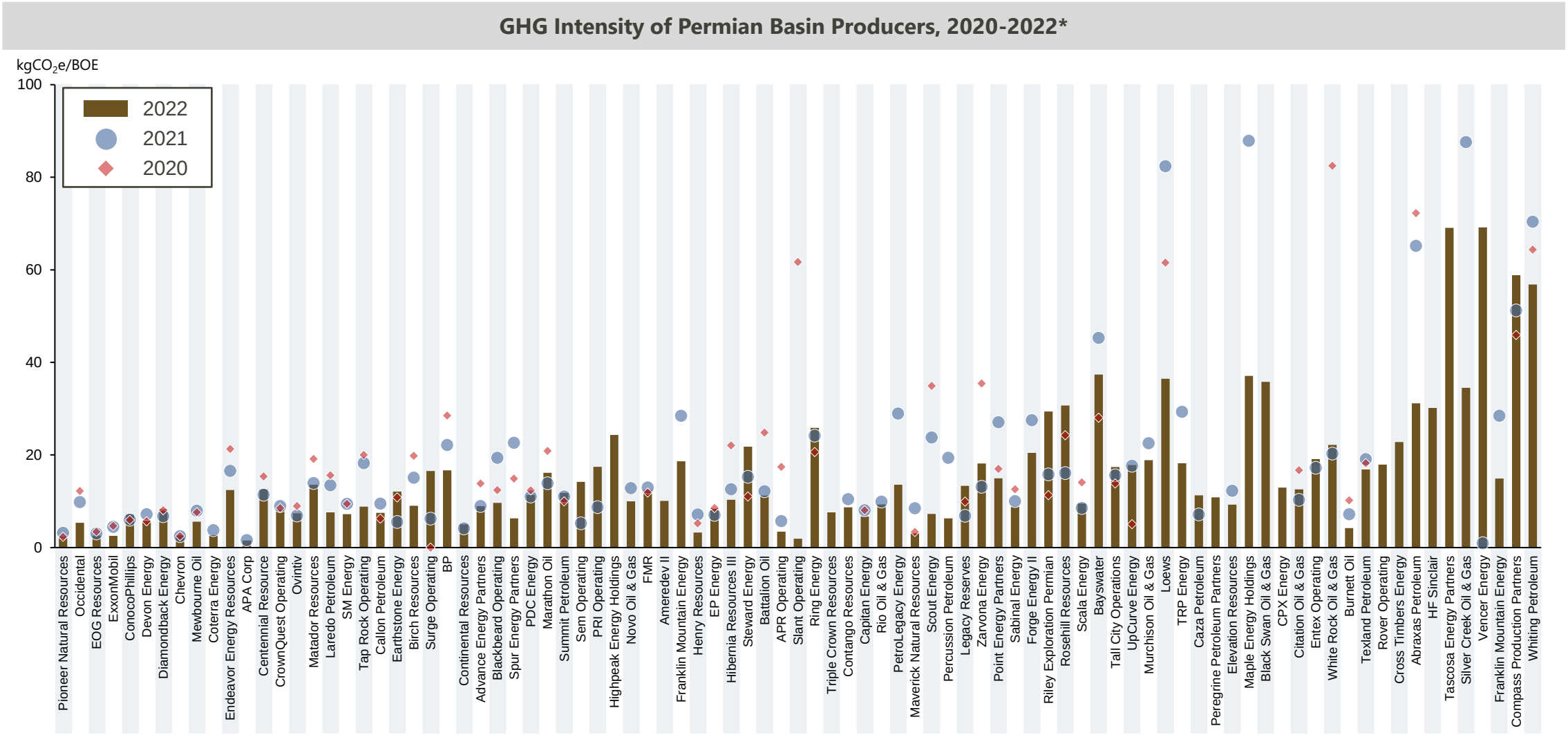


*Note that some producers in 2022 were not in the EPA database for all three years and may not have data for 2020 and/or 2021.

Note: BP reflects assets purchased in 2020 that were allocated to BHP Minerals.

Permian Basin Producers

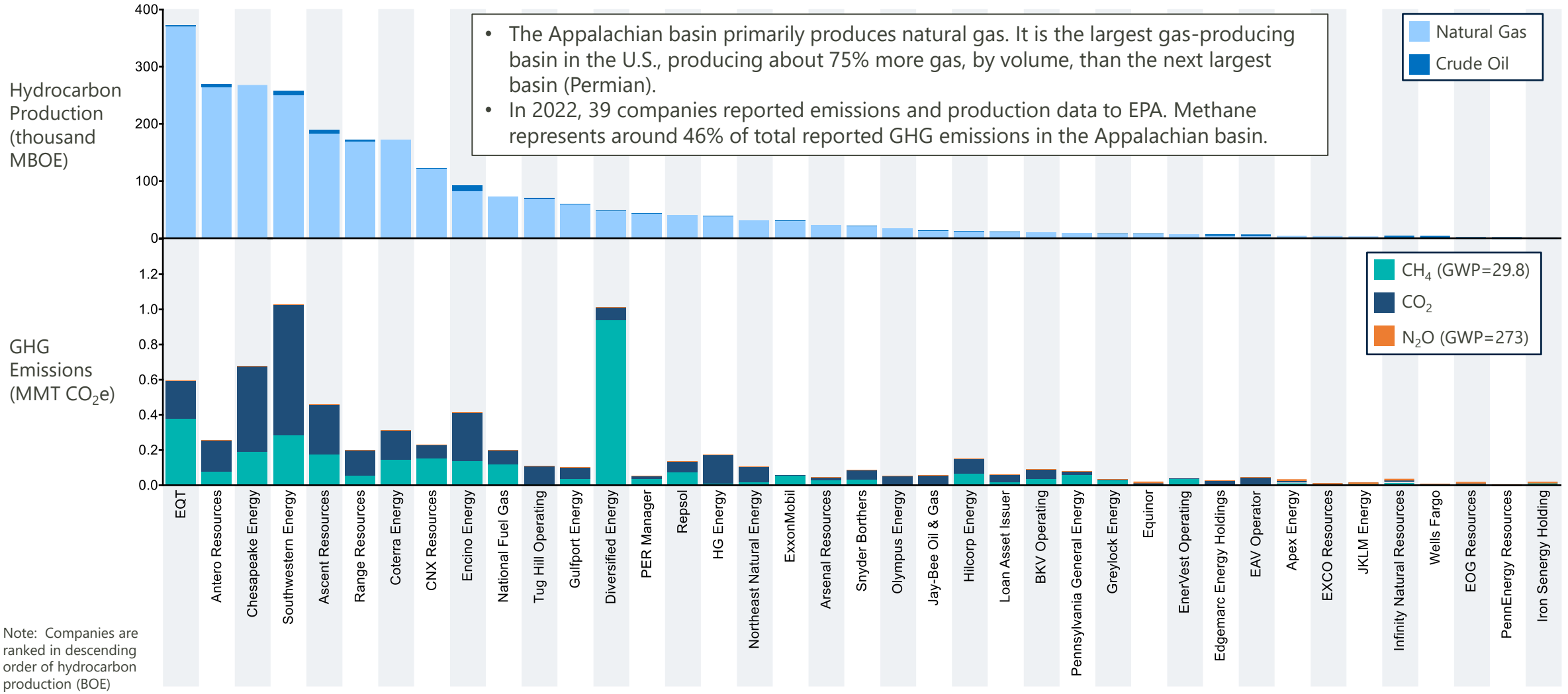
2020-2022 Trends Analysis: Change in GHG Intensity, by Top Producer



*Note that some producers in 2022 were not in the EPA database for all three years and may not have data for 2020 and/or 2021.

Note: BP reflects assets purchased in 2020 that were allocated to BHP Minerals.

Hydrocarbon Production & Emissions (100-year GWP)

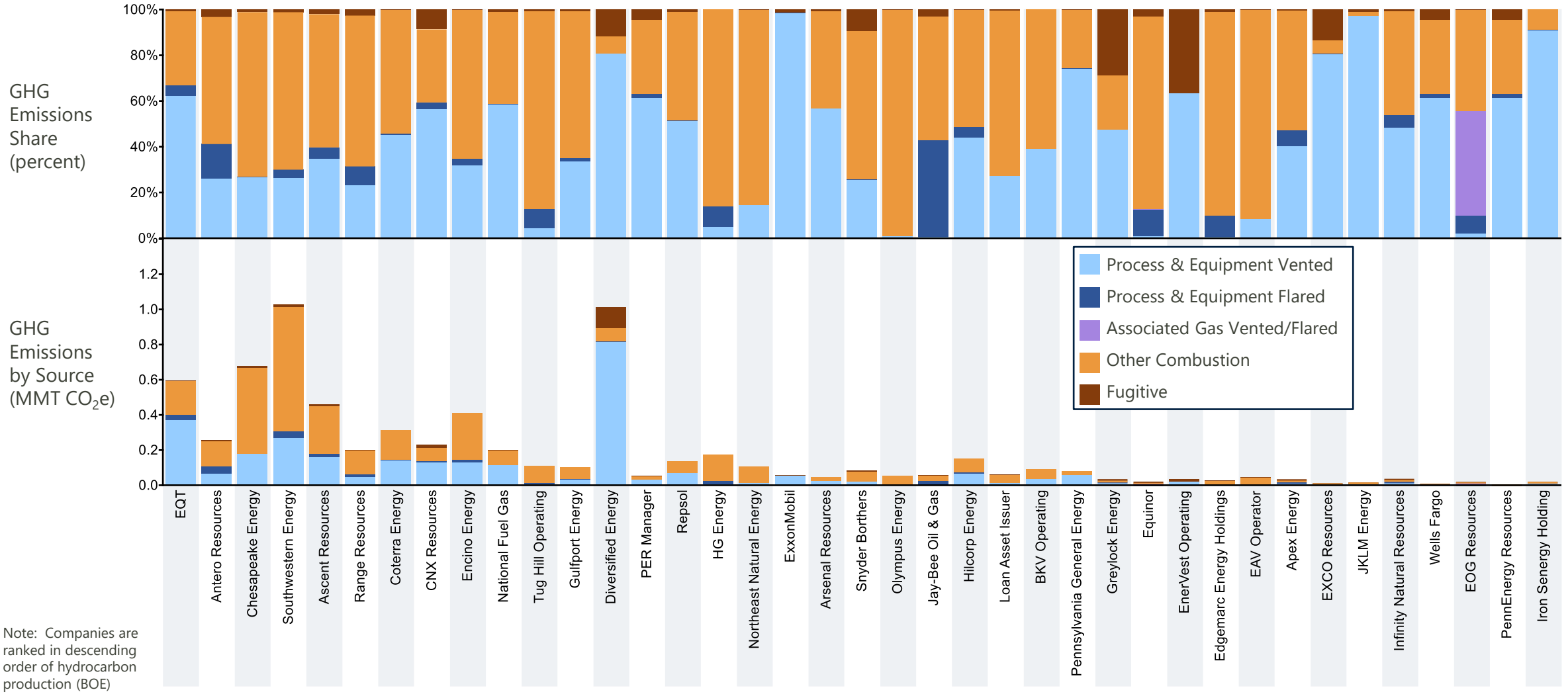


- The Appalachian basin primarily produces natural gas. It is the largest gas-producing basin in the U.S., producing about 75% more gas, by volume, than the next largest basin (Permian).
- In 2022, 39 companies reported emissions and production data to EPA. Methane represents around 46% of total reported GHG emissions in the Appalachian basin.

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

Note: EQT reflects assets purchased in 2021 that were allocated to ARD Operating.

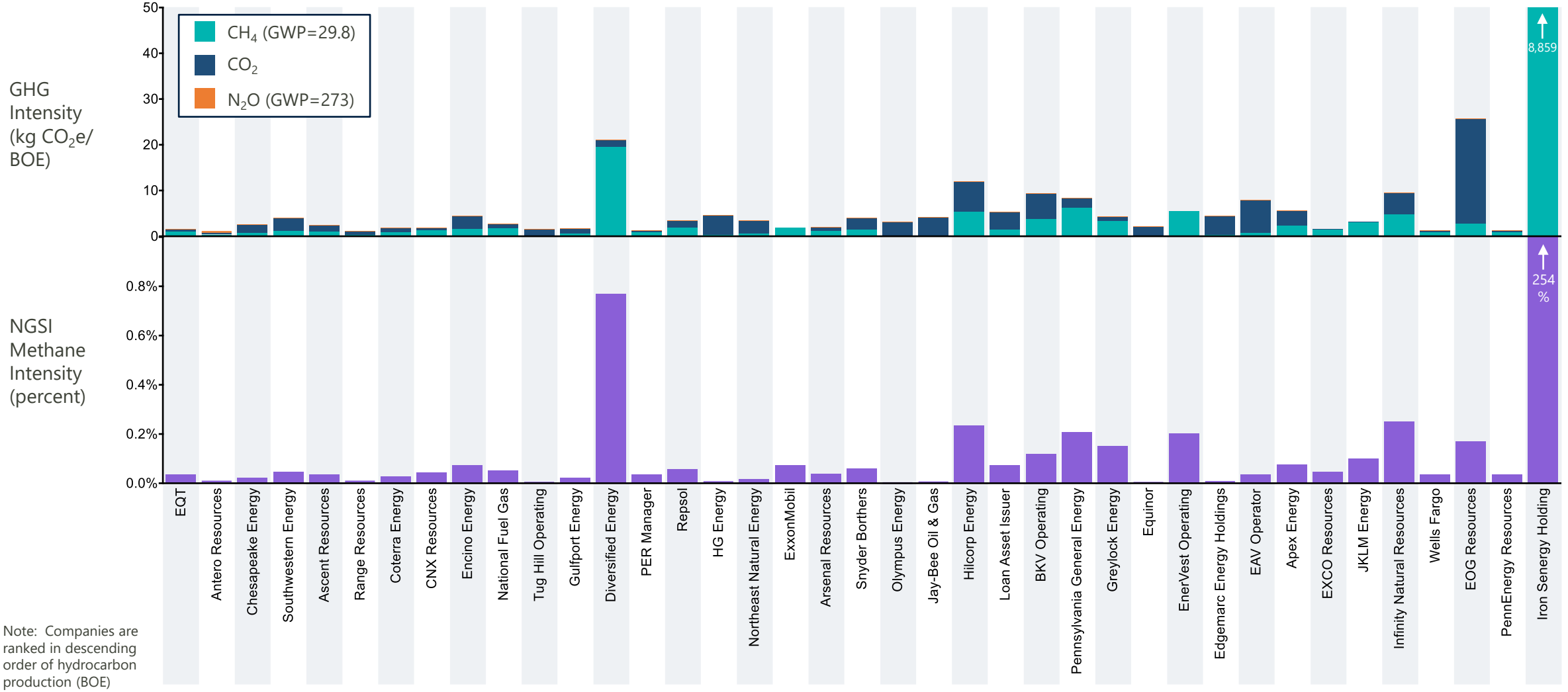
GHG Emissions by Source (100-year GWP)



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

Note: EQT reflects assets purchased in 2021 that were allocated to ARD Operating.

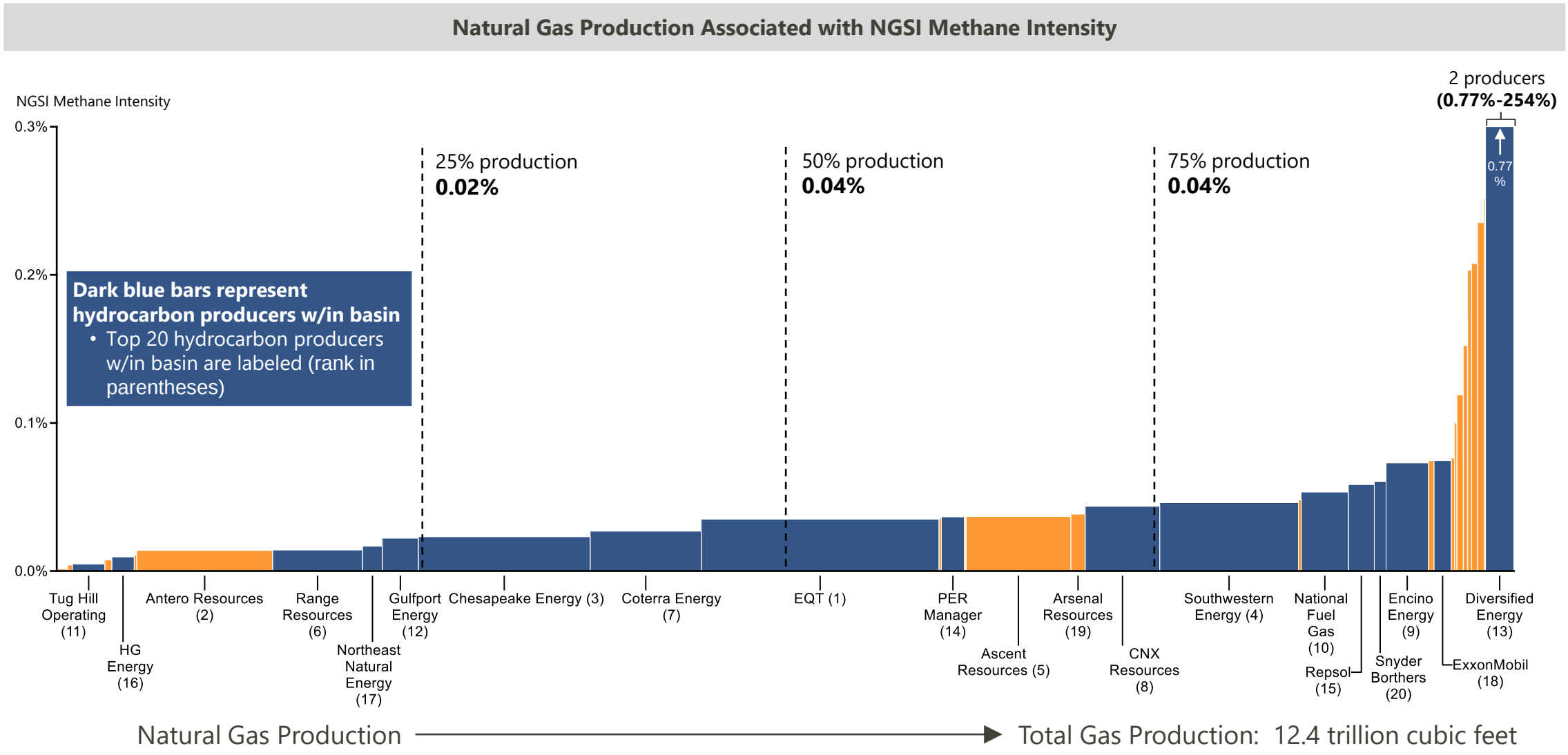
Methane & GHG Intensity (100-year GWP)



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

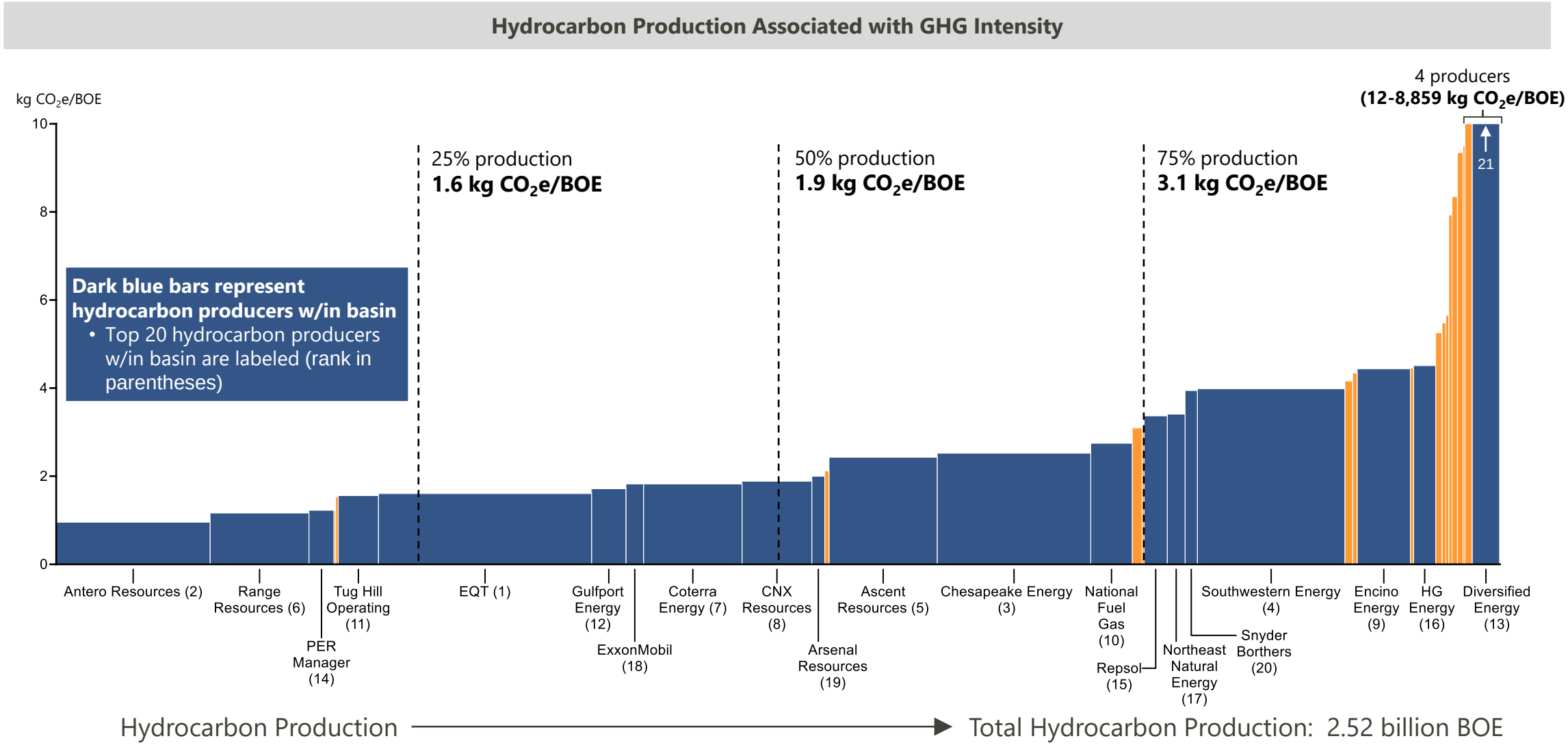
Note: EQT reflects assets purchased in 2021 that were allocated to ARD Operating.

Total GHGRP Natural Gas Production, by Methane Intensity



Note: EQT reflects assets purchased in 2021 that were allocated to ARD Operating.

Total GHGRP Hydrocarbon Production, by GHG Intensity



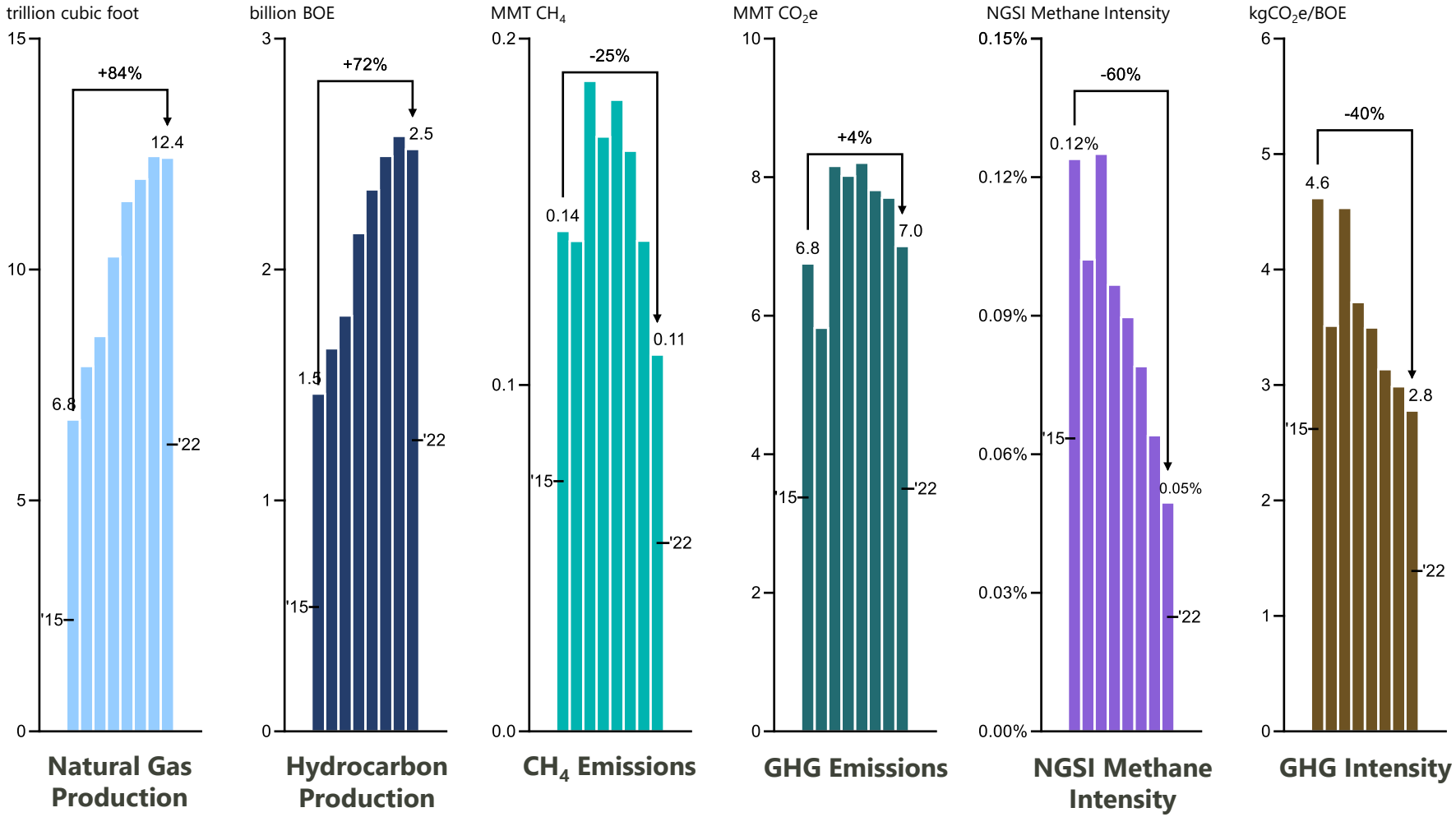
Note: EQT reflects assets purchased in 2021 that were allocated to ARD Operating.

Appalachian Basin Producers

2015-2022 Trends Analysis: Production & Emissions Metrics

GHGRP Data Trends, 2015-2022

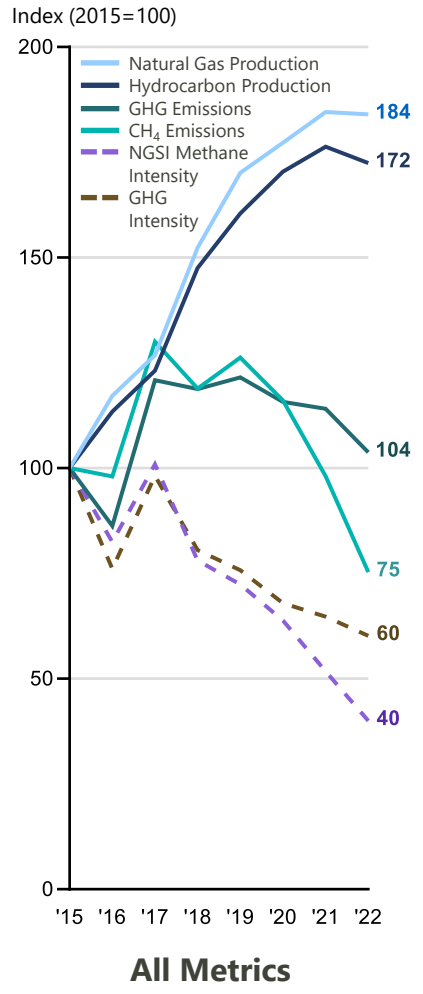
Appalachian Basin



Natural Gas Production | **Hydrocarbon Production** | **CH_4 Emissions** | **GHG Emissions** | **NGSI Methane Intensity** | **GHG Intensity**

Combined Data Metrics

Indexed; 2015 = 100

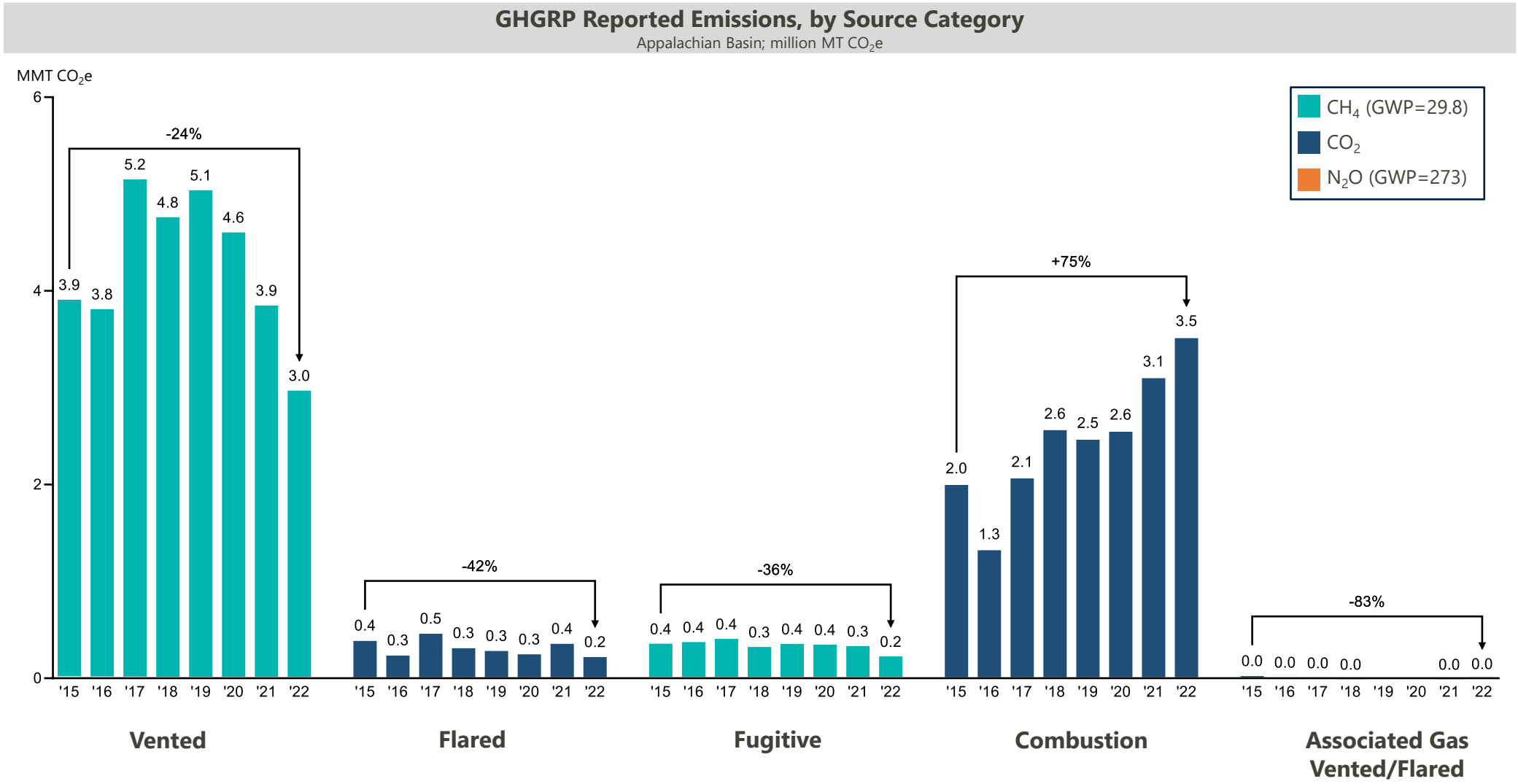


All Metrics

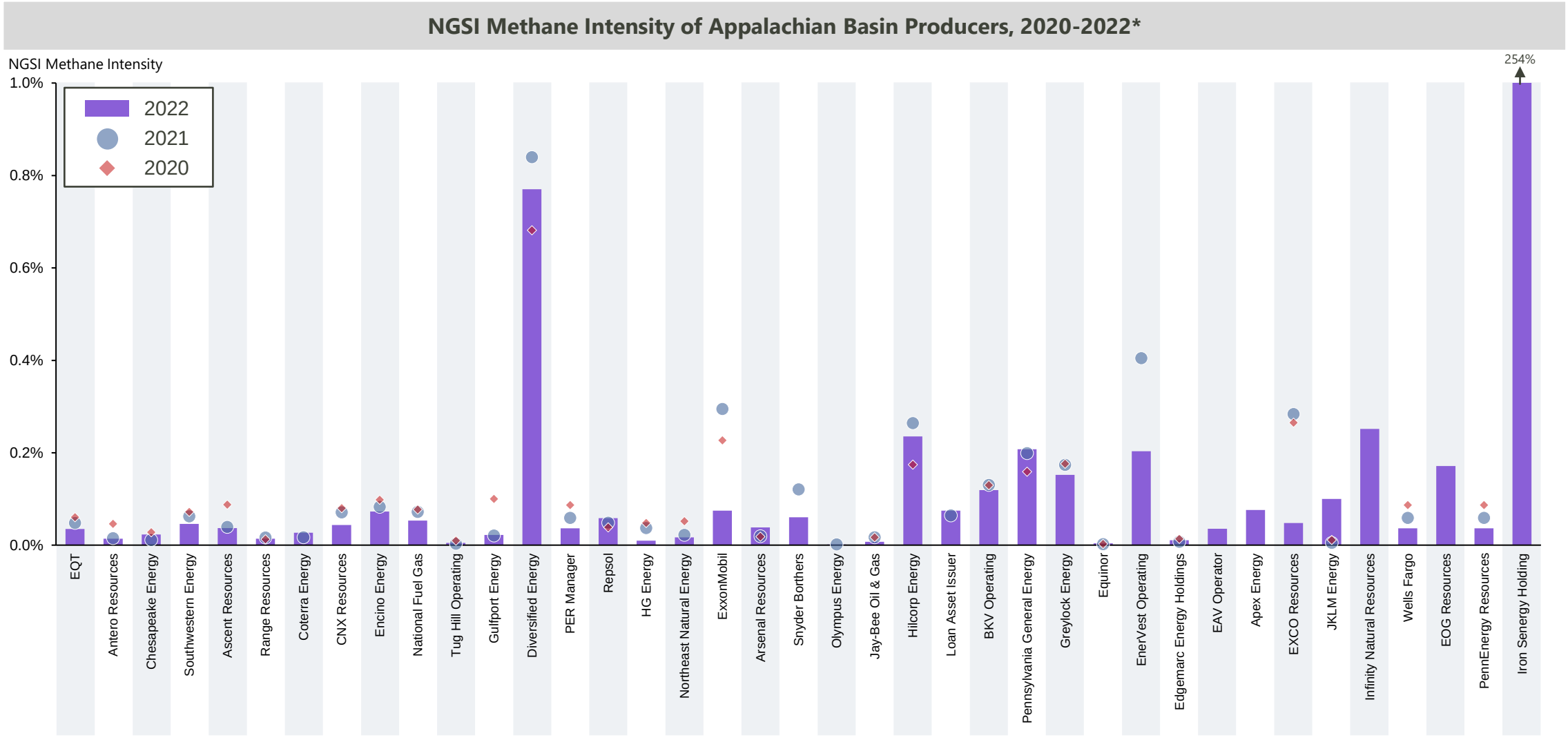
Appalachian Basin Producers

2015-2022 Trends Analysis: Emissions Sources

GHG Emissions (MMT CO_2e)



2020-2022 Trends Analysis: Change in Methane Intensity, by Top Producer

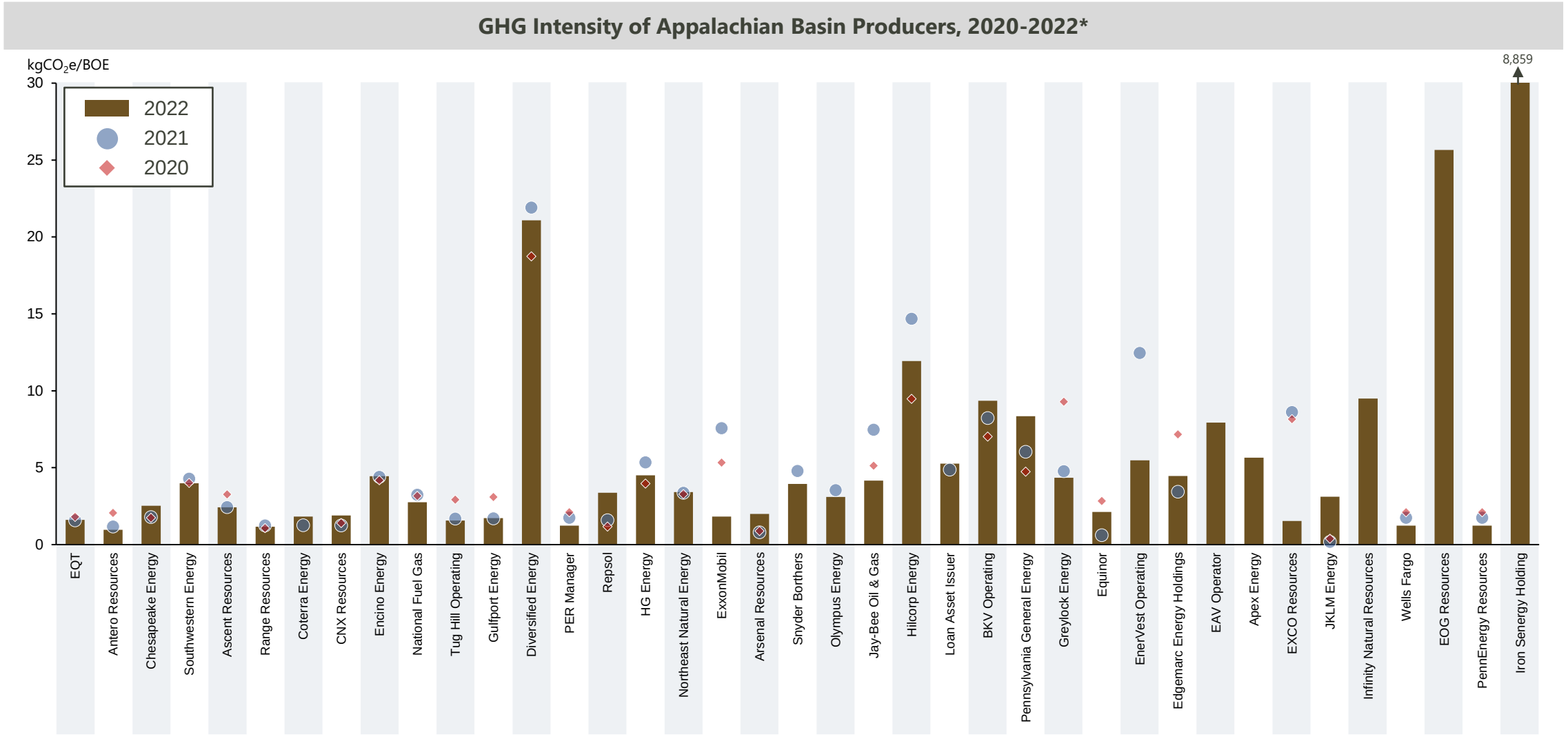


*Note that some producers in 2022 were not in the EPA database for all three years and may not have data for 2020 and/or 2021.

Note: EQT reflects assets purchased in 2021 that were allocated to ARD Operating.

Appalachian Basin Producers

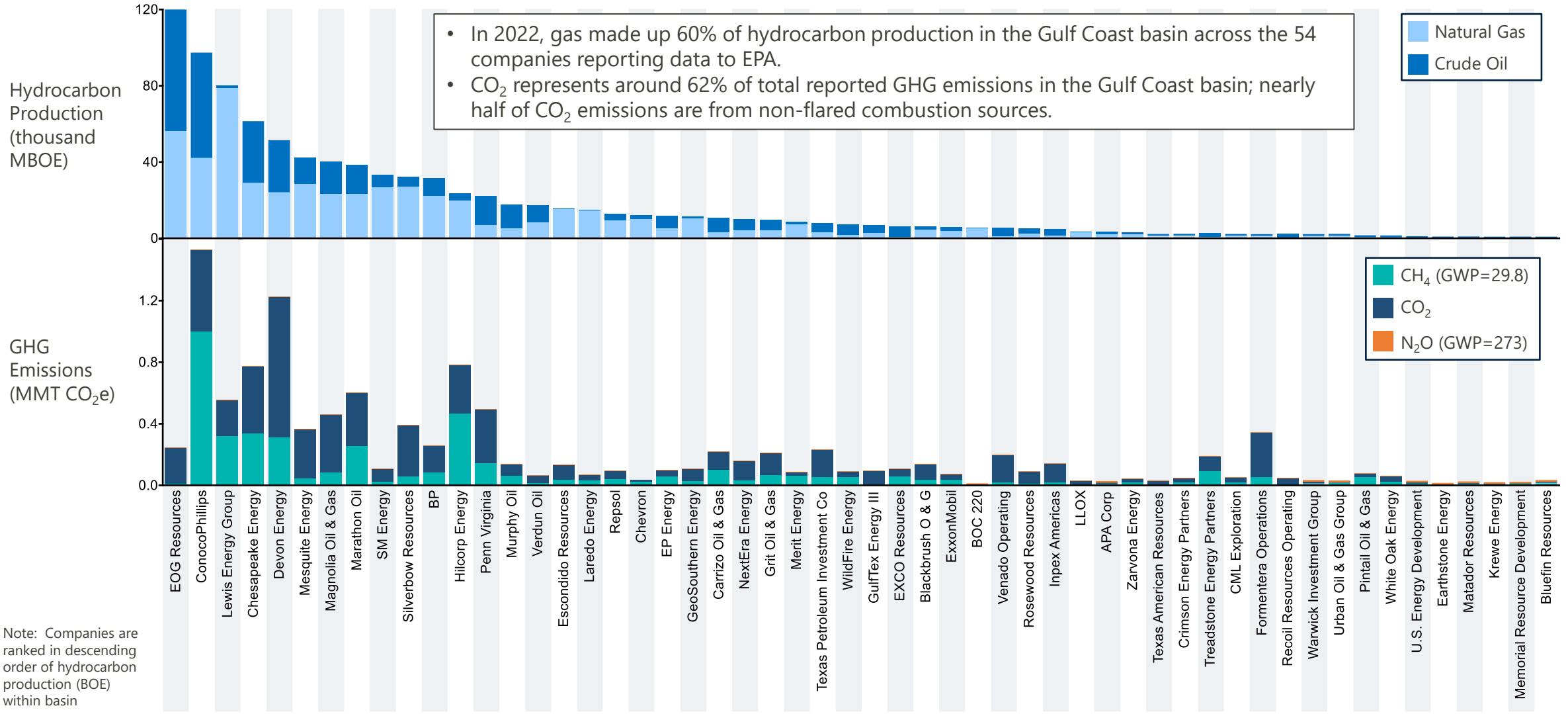
2020-2022 Trends Analysis: Change in GHG Intensity, by Top Producer



*Note that some producers in 2022 were not in the EPA database for all three years and may not have data for 2020 and/or 2021.

Note: EQT reflects assets purchased in 2021 that were allocated to ARD Operating.

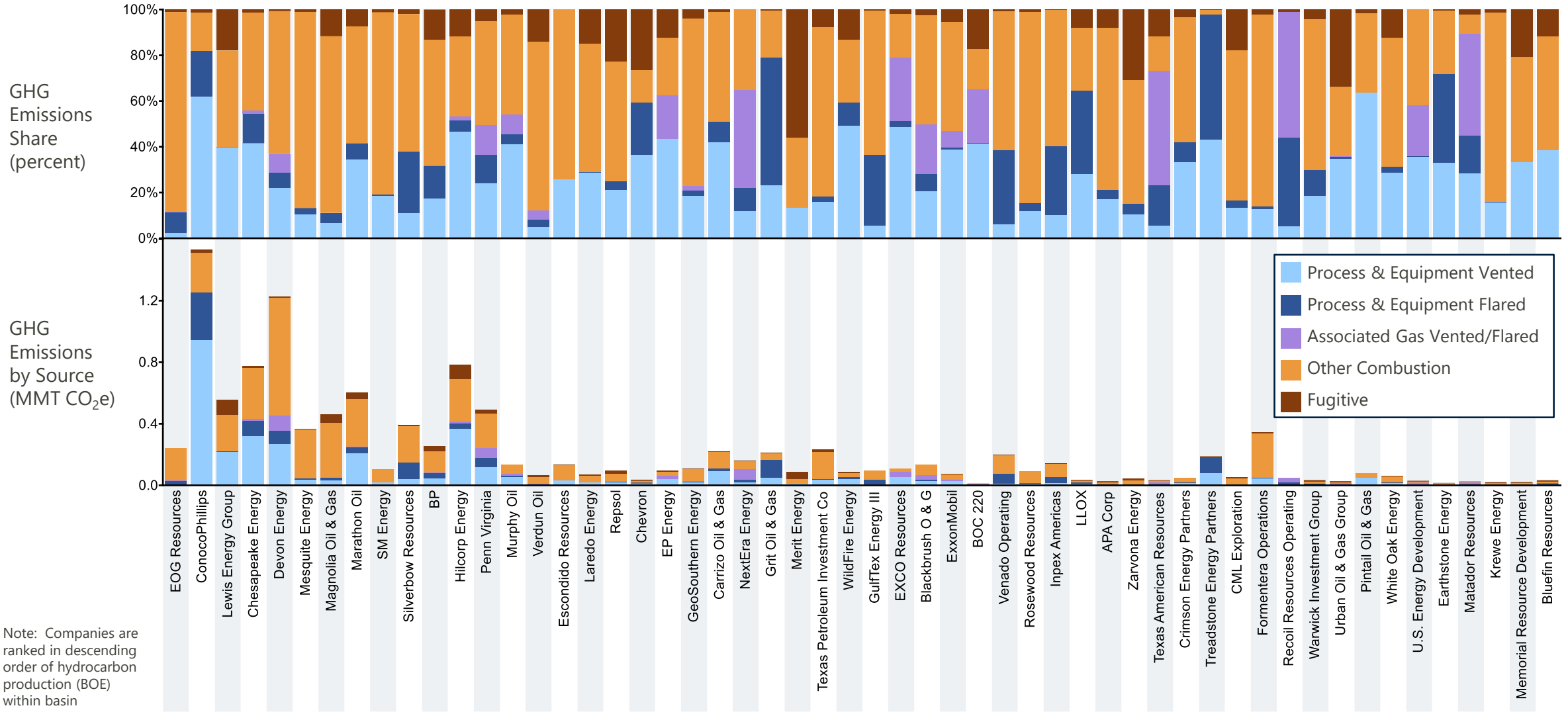
Hydrocarbon Production & Emissions (100-year GWP)



- In 2022, gas made up 60% of hydrocarbon production in the Gulf Coast basin across the 54 companies reporting data to EPA.
- CO_2 represents around 62% of total reported GHG emissions in the Gulf Coast basin; nearly half of CO_2 emissions are from non-flared combustion sources.

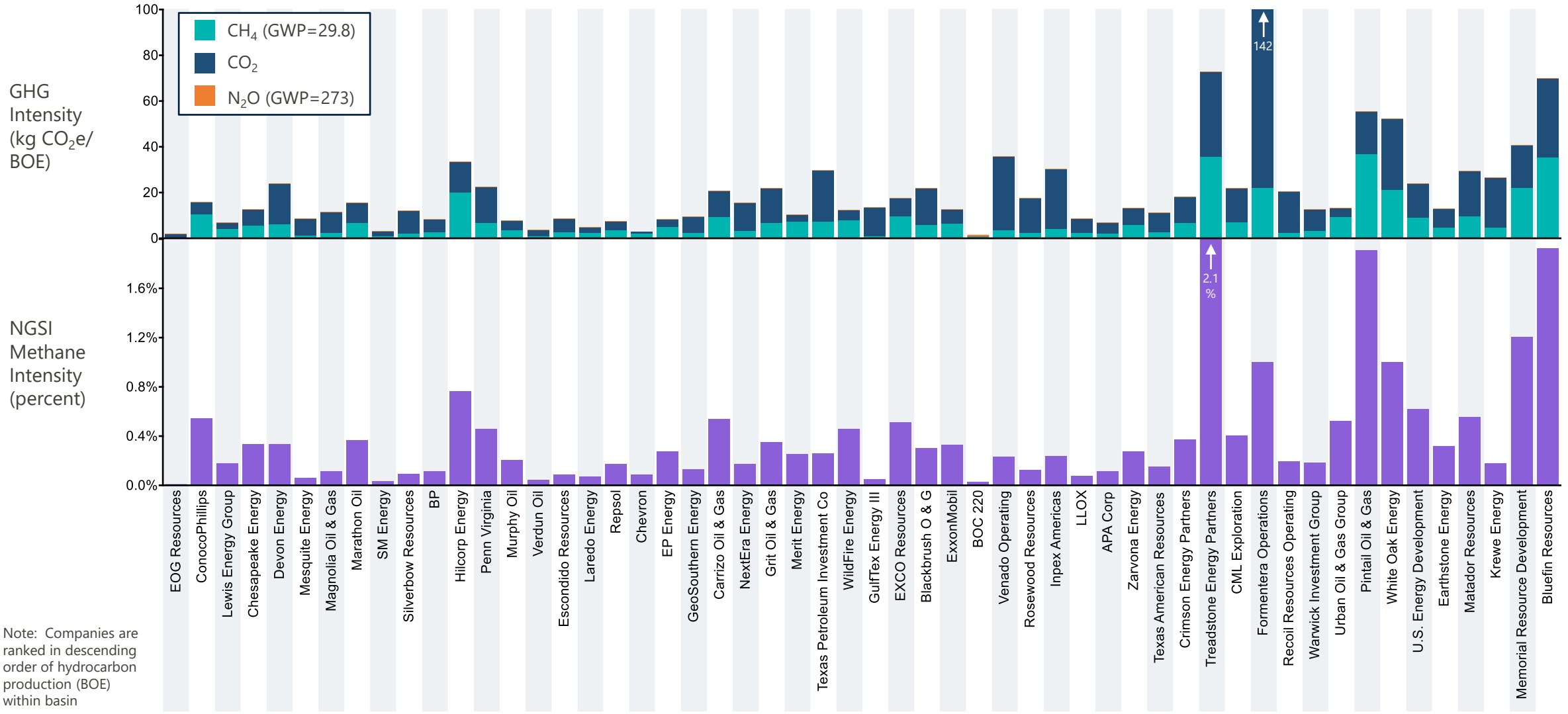
Note: Companies are ranked in descending order of hydrocarbon production (BOE) within basin

GHG Emissions by Source (100-year GWP)



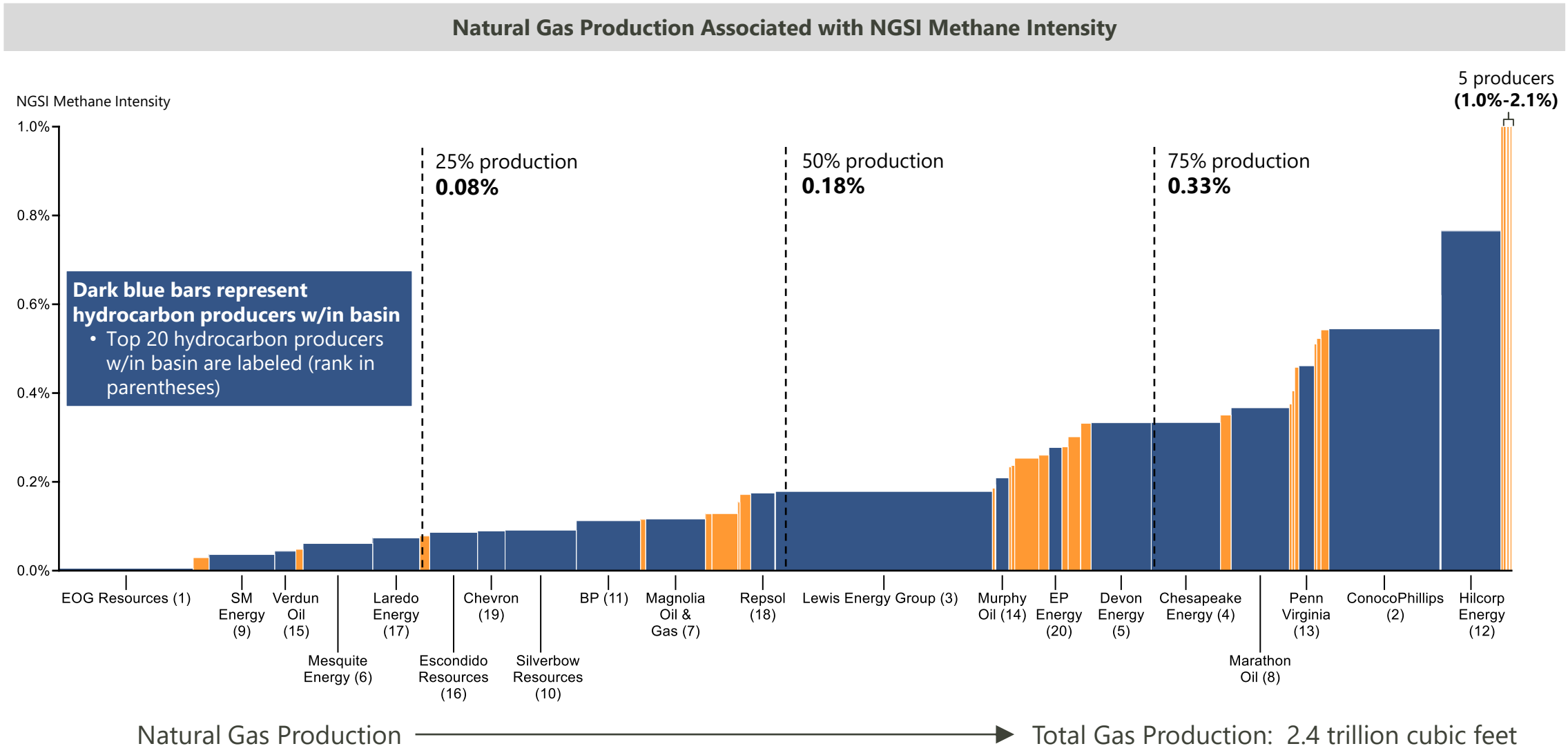
Note: Companies are ranked in descending order of hydrocarbon production (BOE) within basin

Methane & GHG Intensity (100-year GWP)



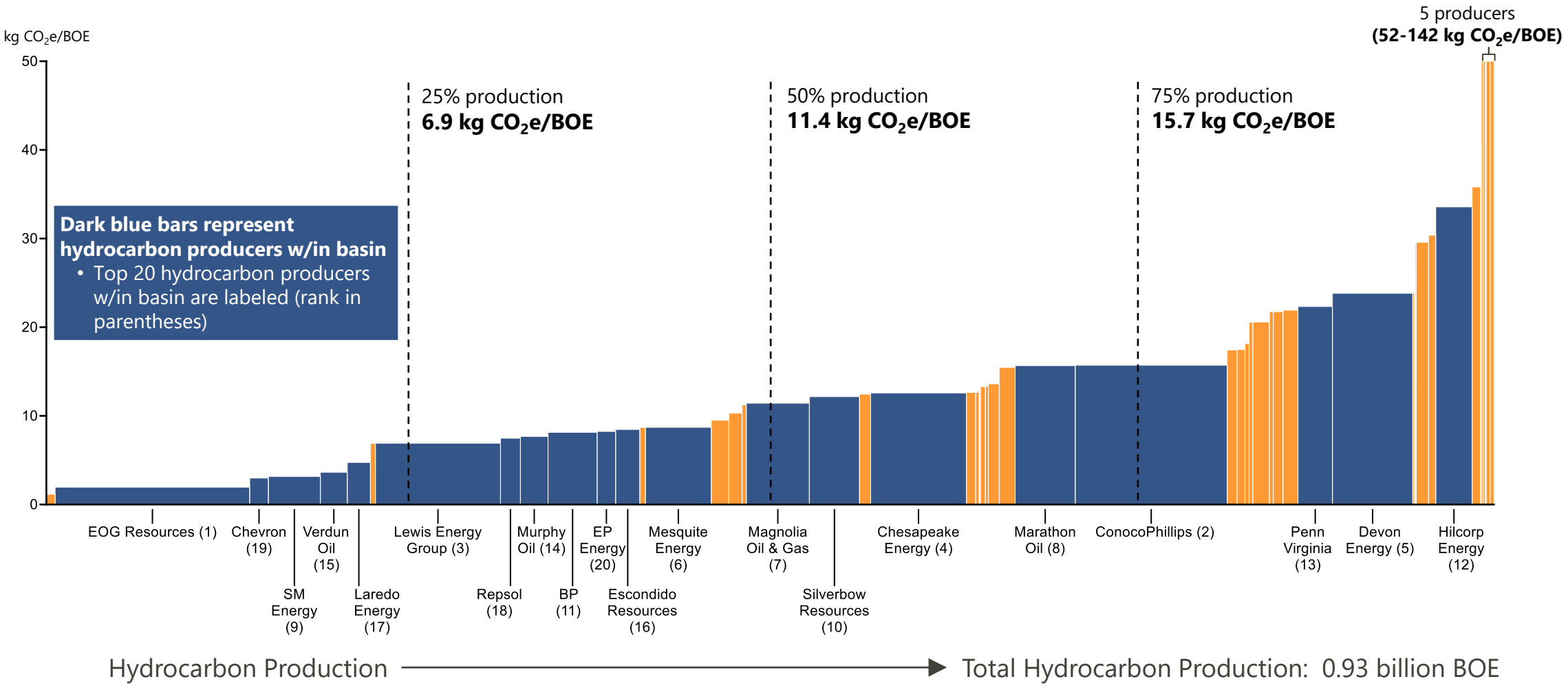
Note: Companies are ranked in descending order of hydrocarbon production (BOE) within basin

Total GHGRP Natural Gas Production, by Methane Intensity



Total GHGRP Hydrocarbon Production, by GHG Intensity

Hydrocarbon Production Associated with GHG Intensity

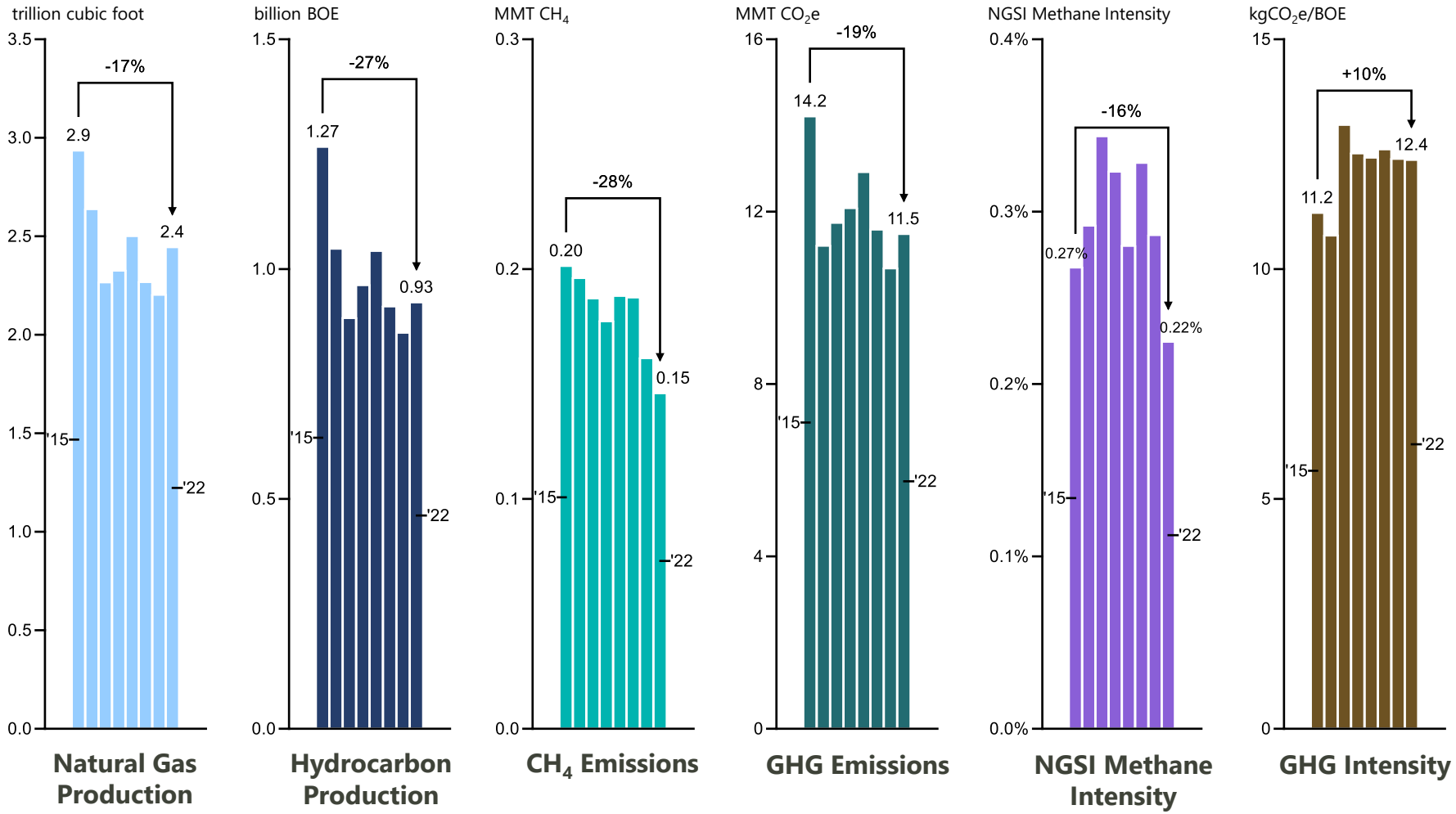


Gulf Coast Basin Producers

2015-2022 Trends Analysis: Production & Emissions Metrics

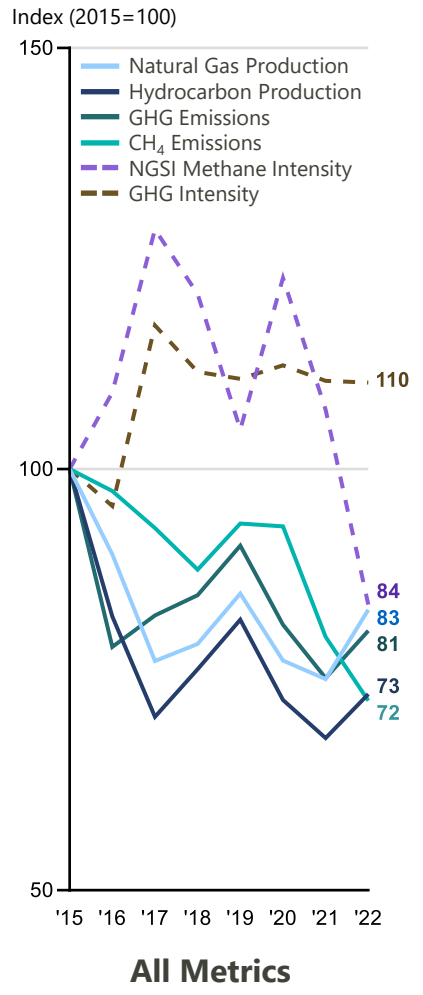
GHGRP Data Trends, 2015-2022

Gulf Coast Basin



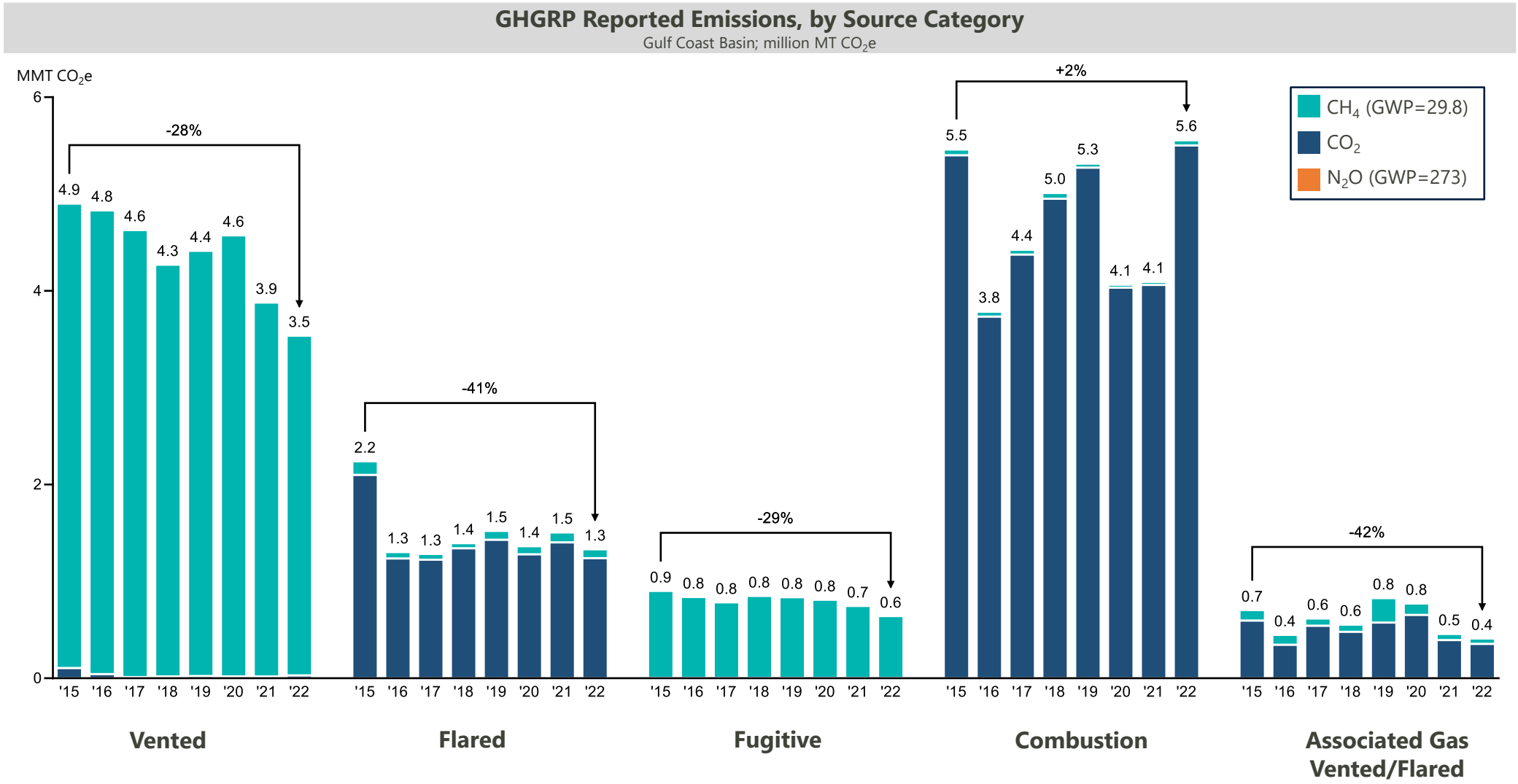
Combined Data Metrics

Indexed; 2015 = 100

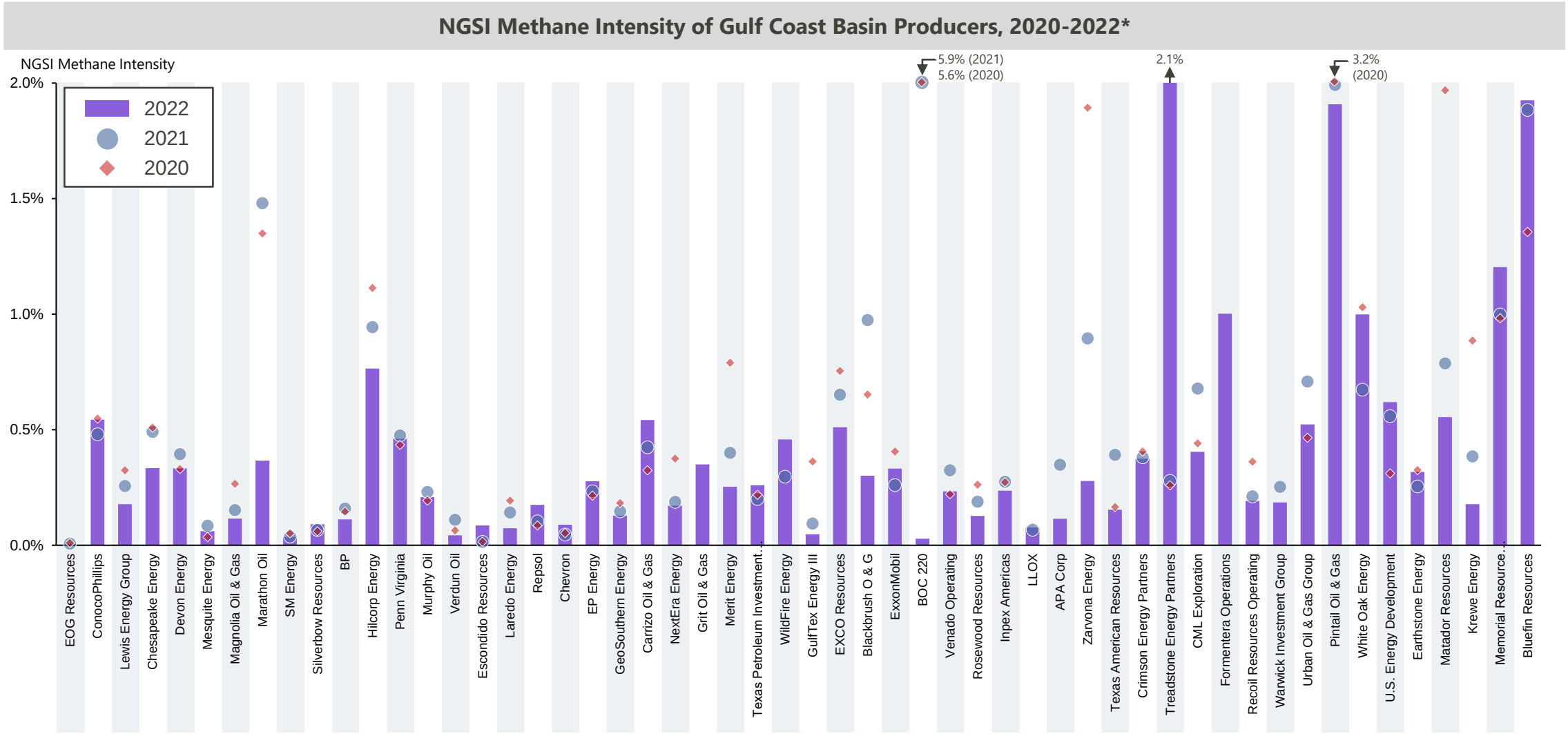


Gulf Coast Basin Producers

2015-2022 Trends Analysis: Emissions Sources



2020-2022 Trends Analysis: Change in Methane Intensity, by Top Producer

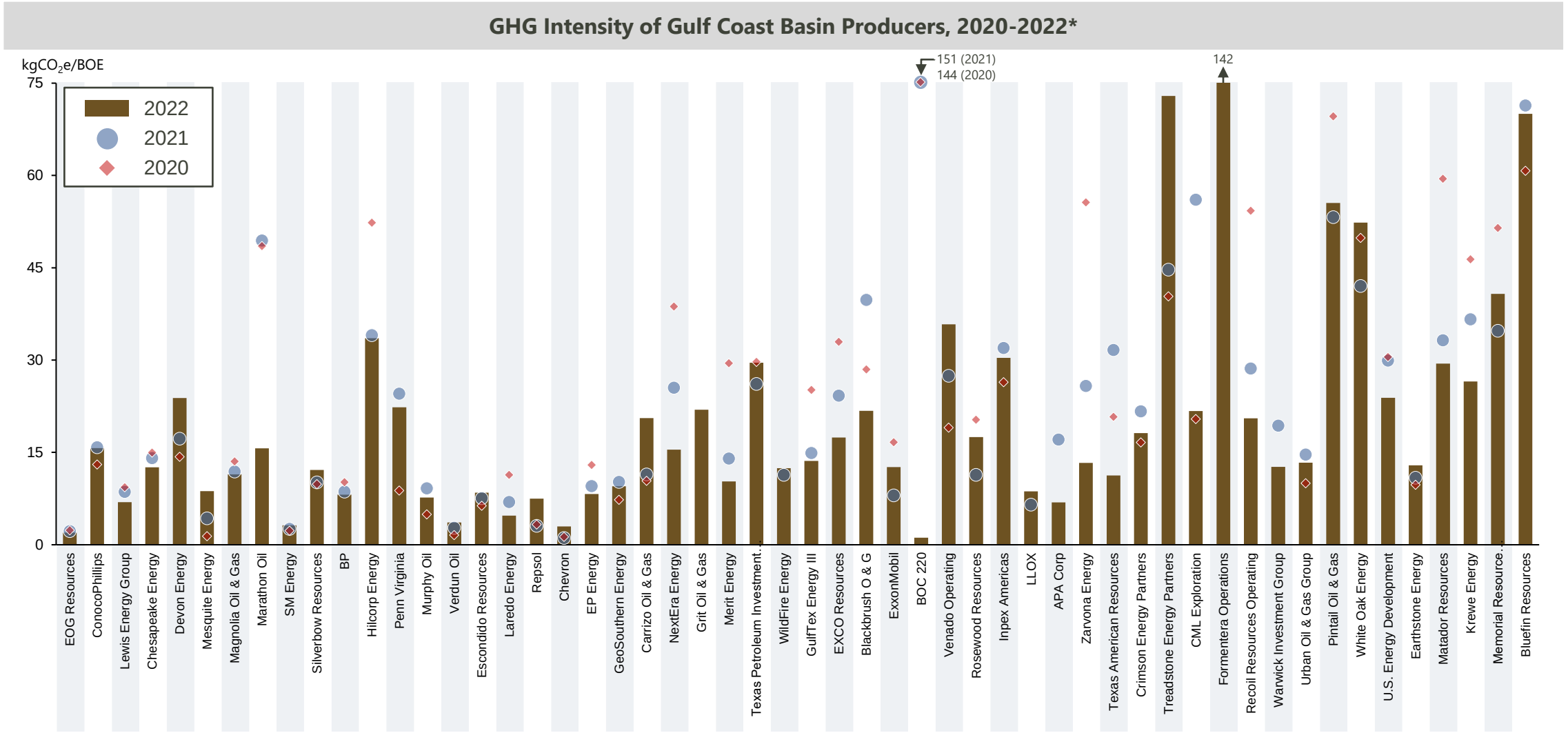


*Note that some producers in 2022 were not in the EPA database for all three years and may not have data for 2020 and/or 2021.

Note: Repsol reflects assets purchased in 2020 that were allocated to Equinor.

Gulf Coast Basin Producers

2020-2022 Trends Analysis: Change in GHG Intensity, by Top Producer

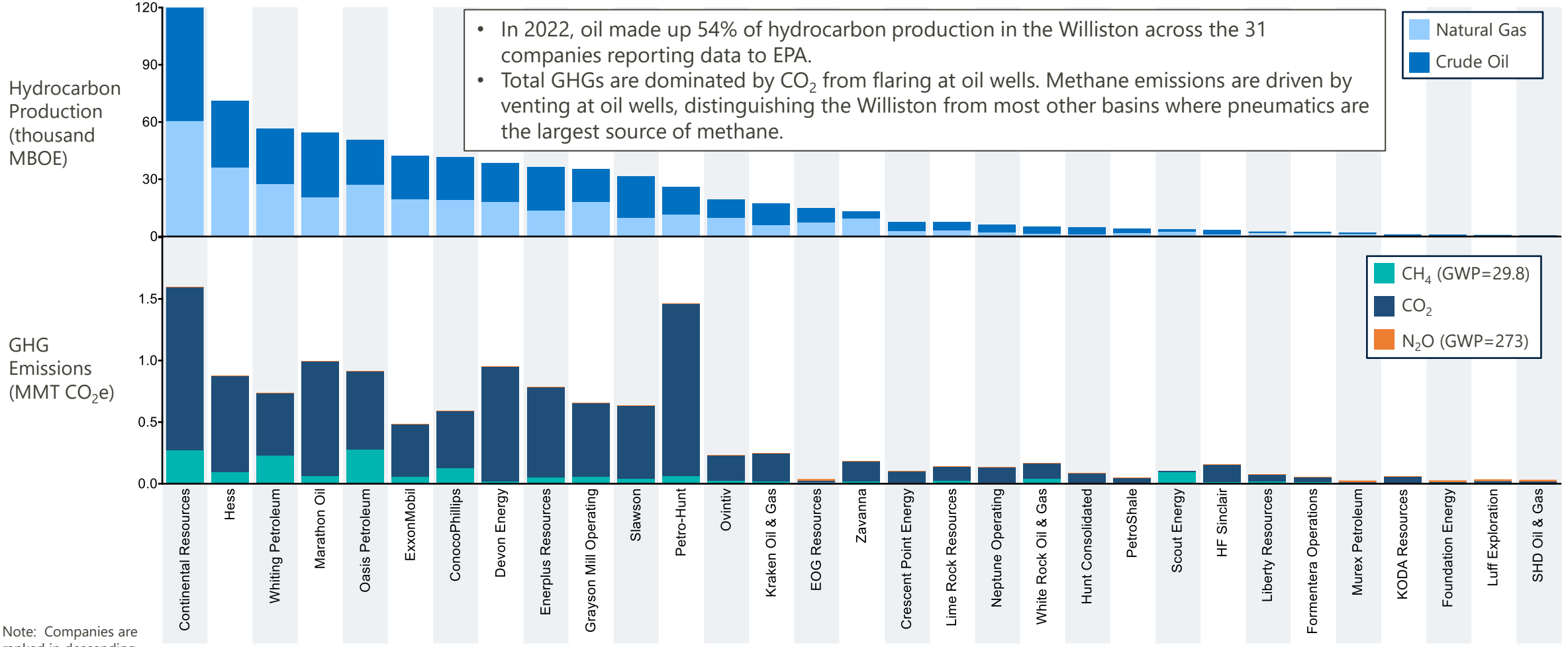


*Note that some producers in 2022 were not in the EPA database for all three years and may not have data for 2020 and/or 2021.

Note: Repsol reflects assets purchased in 2020 that were allocated to Equinor.

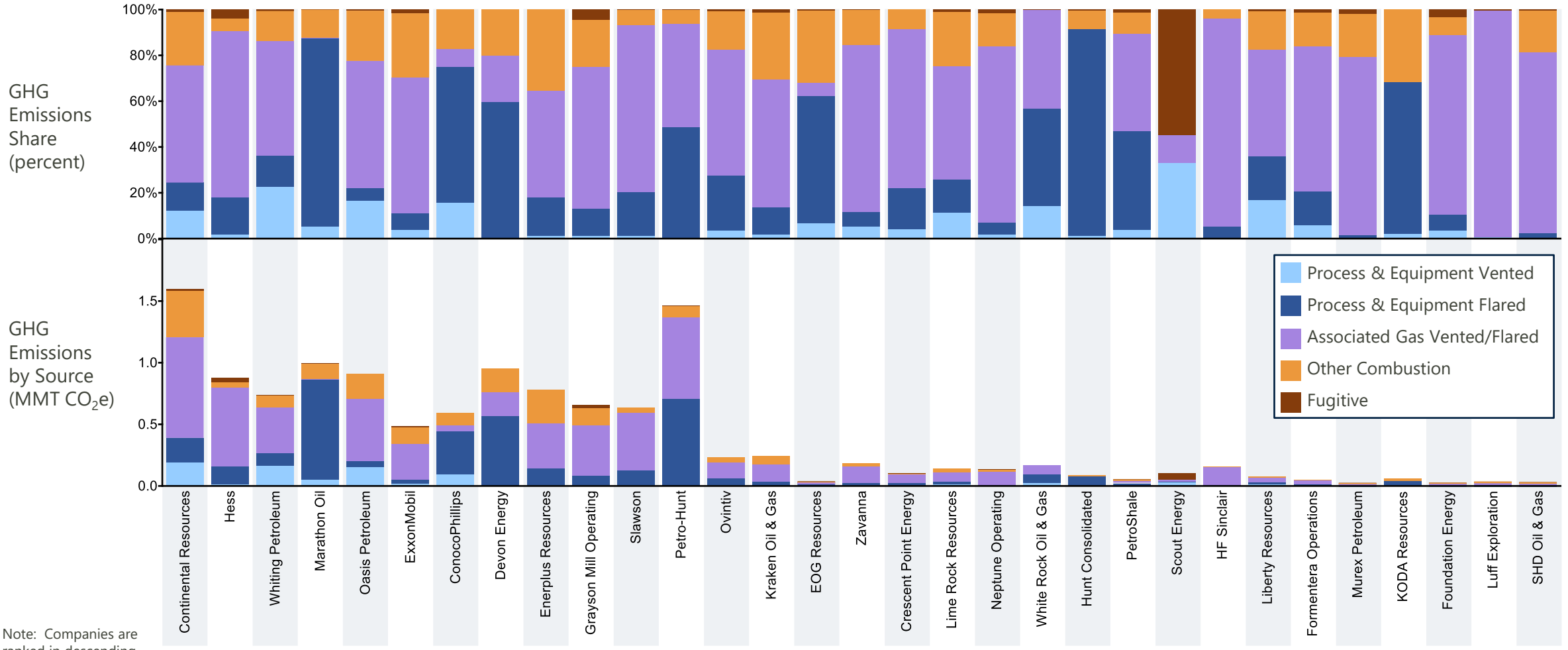
Hydrocarbon Production & Emissions (100-year GWP)

- In 2022, oil made up 54% of hydrocarbon production in the Williston across the 31 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.



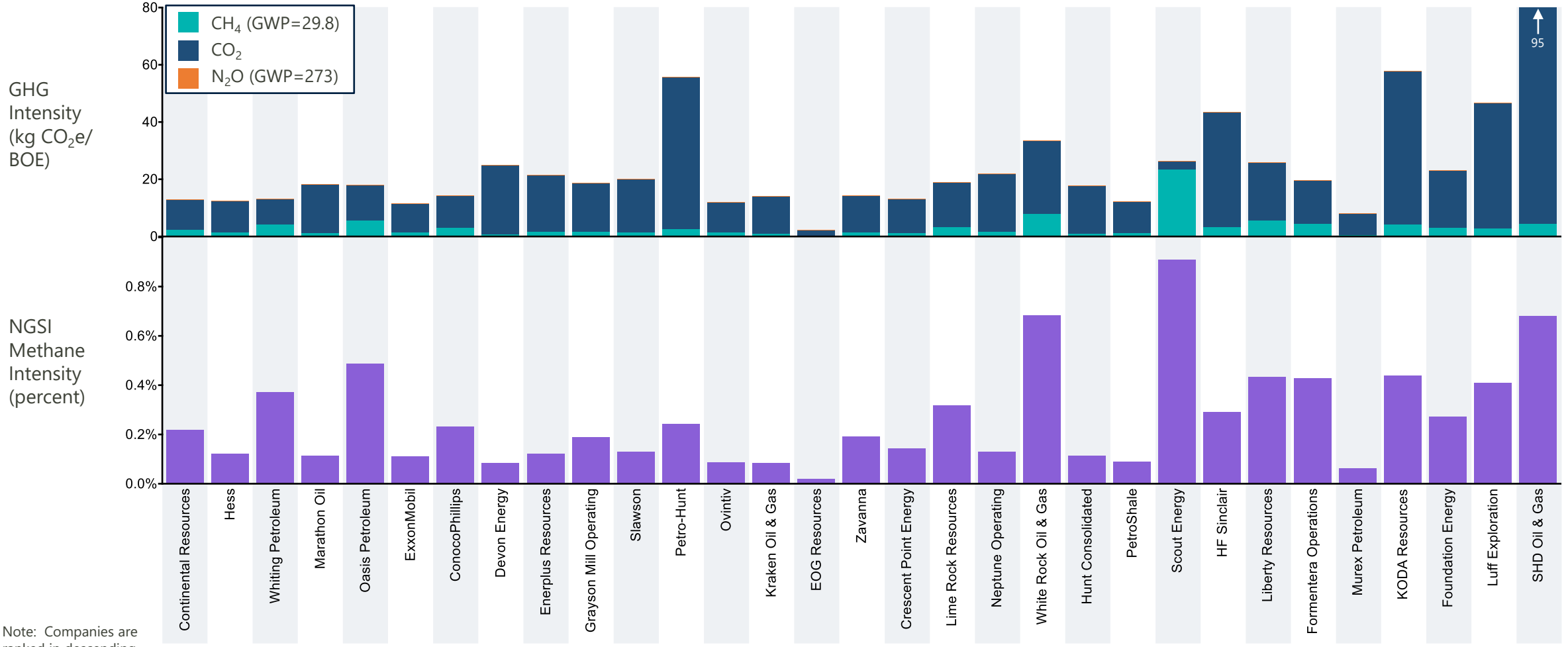
Note: Companies are ranked in descending order of hydrocarbon production (BOE) within basin

GHG Emissions by Source (100-year GWP)



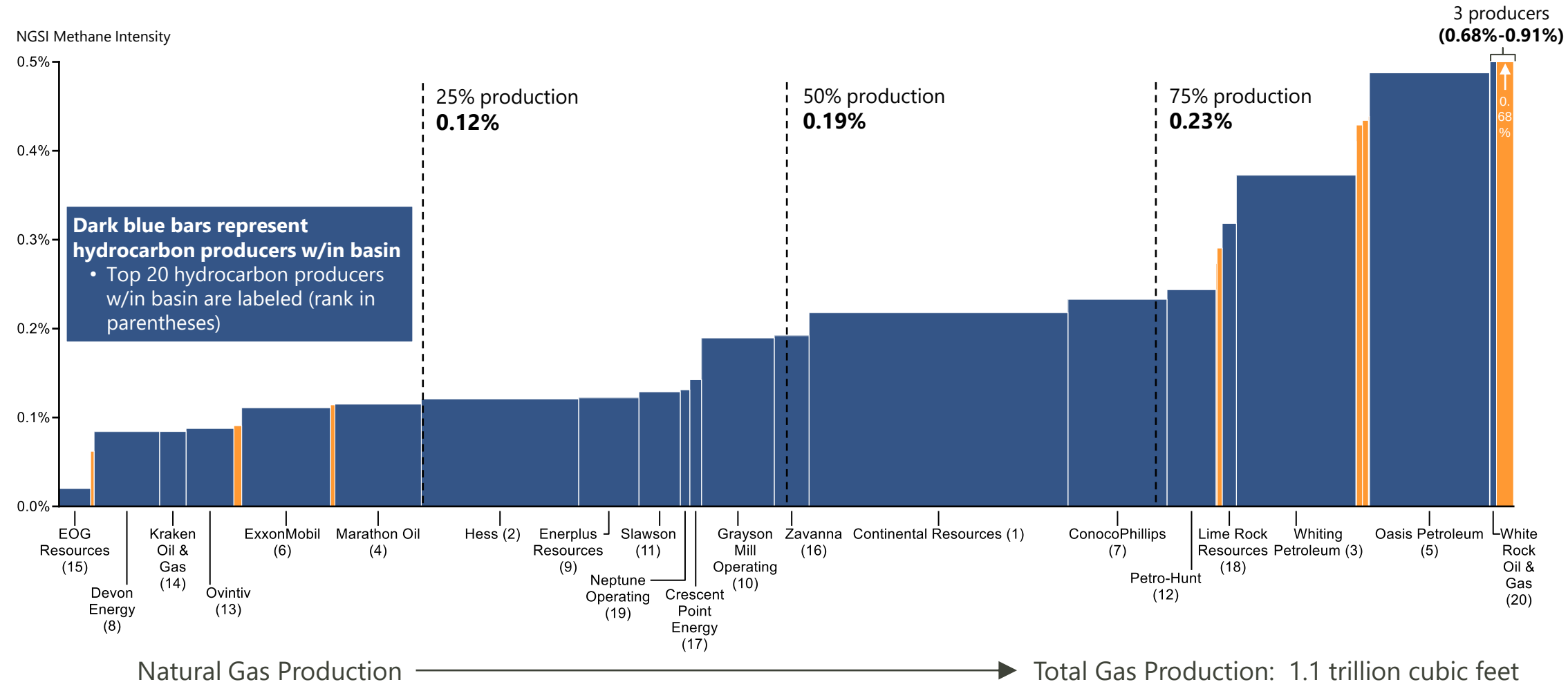
Note: Companies are ranked in descending order of hydrocarbon production (BOE) within basin

Methane & GHG Intensity (100-year GWP)

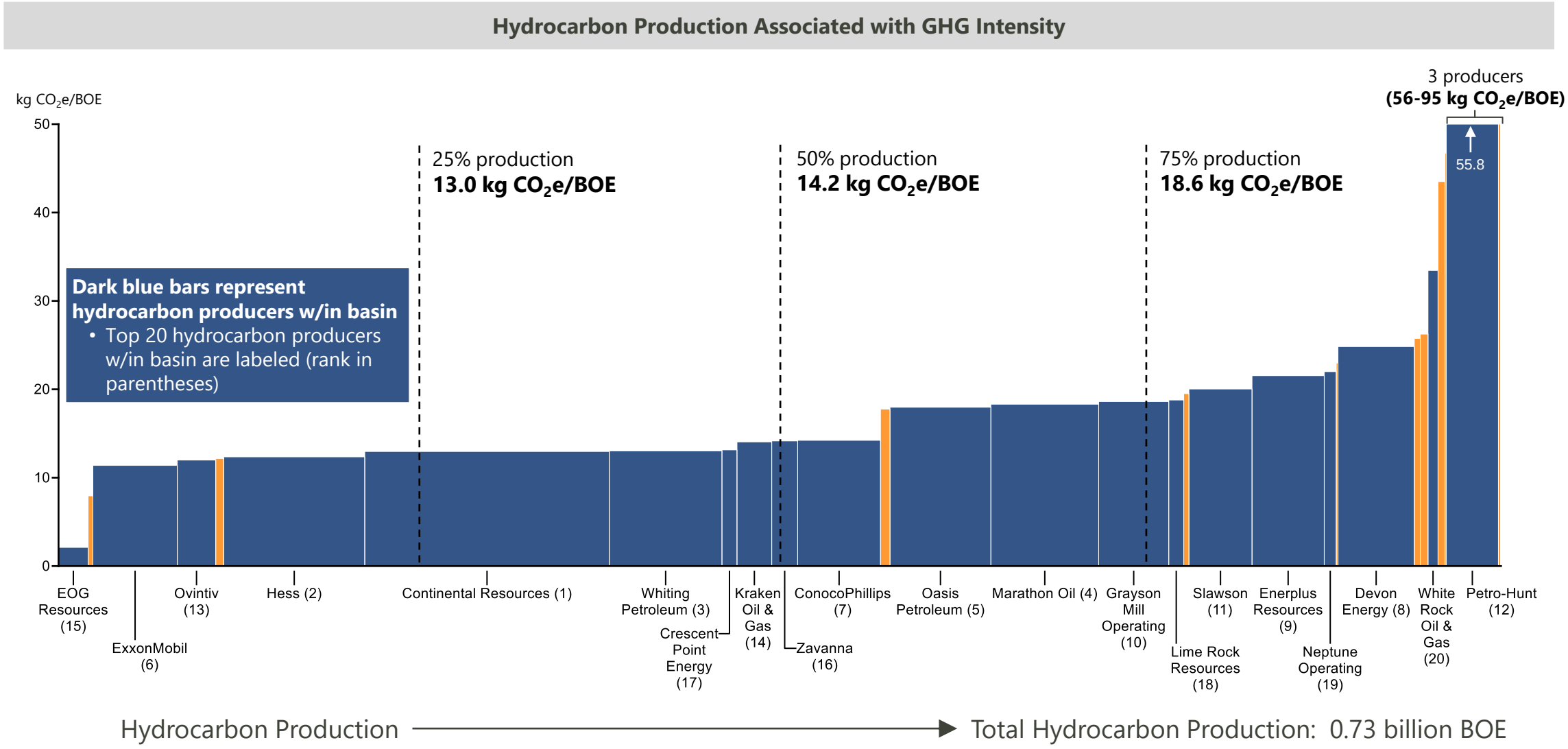


Note: Companies are ranked in descending order of hydrocarbon production (BOE) within basin

Total GHGRP Natural Gas Production, by Methane Intensity



Total GHGRP Hydrocarbon Production, by GHG Intensity

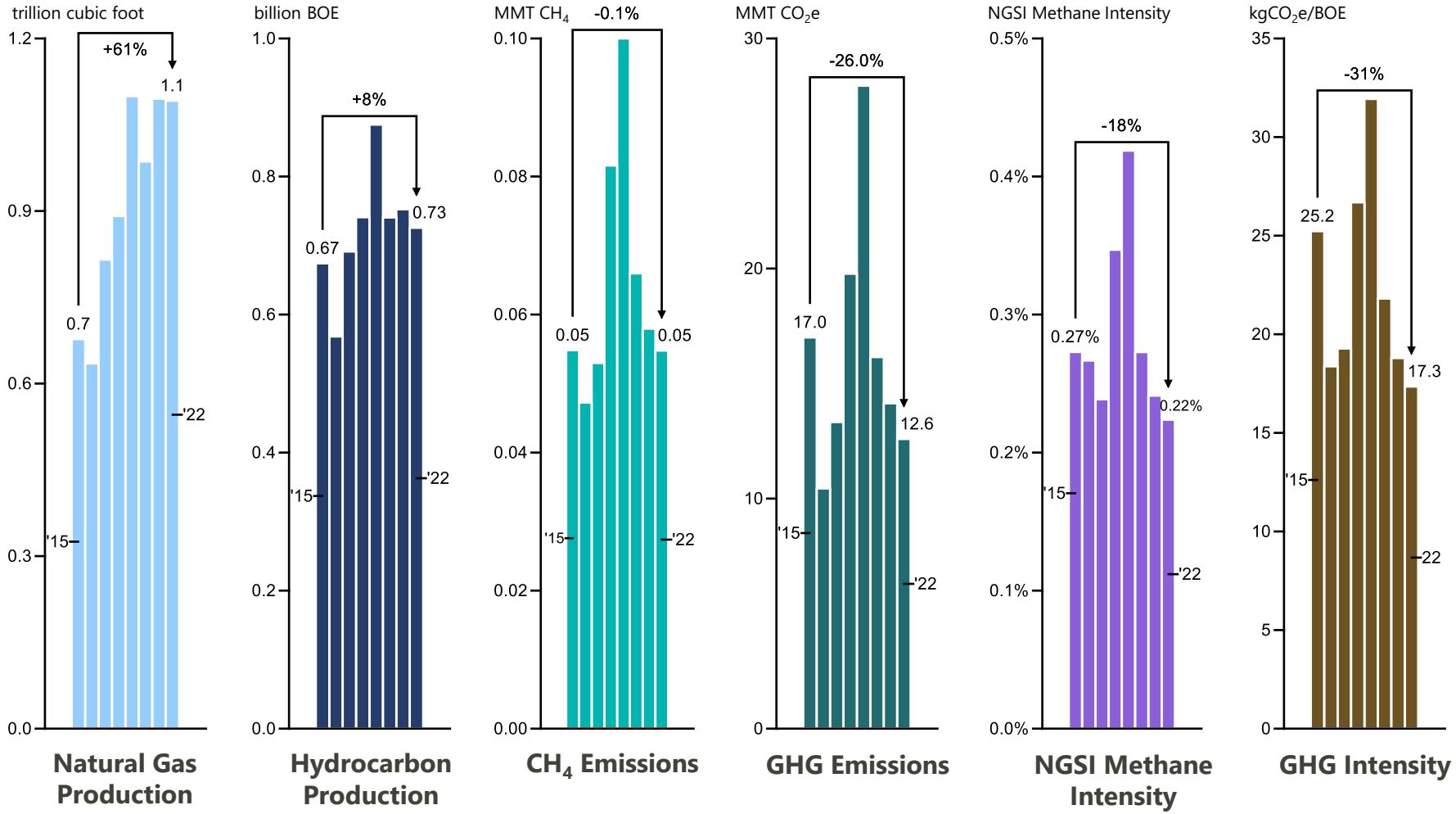


Williston Basin Producers

2015-2022 Trends Analysis: Production & Emissions Metrics

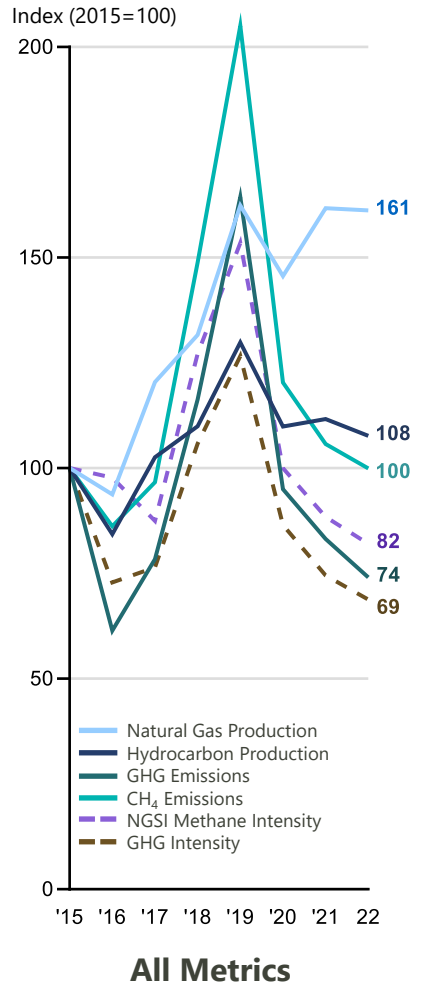
GHGRP Data Trends, 2015-2022

Williston Basin



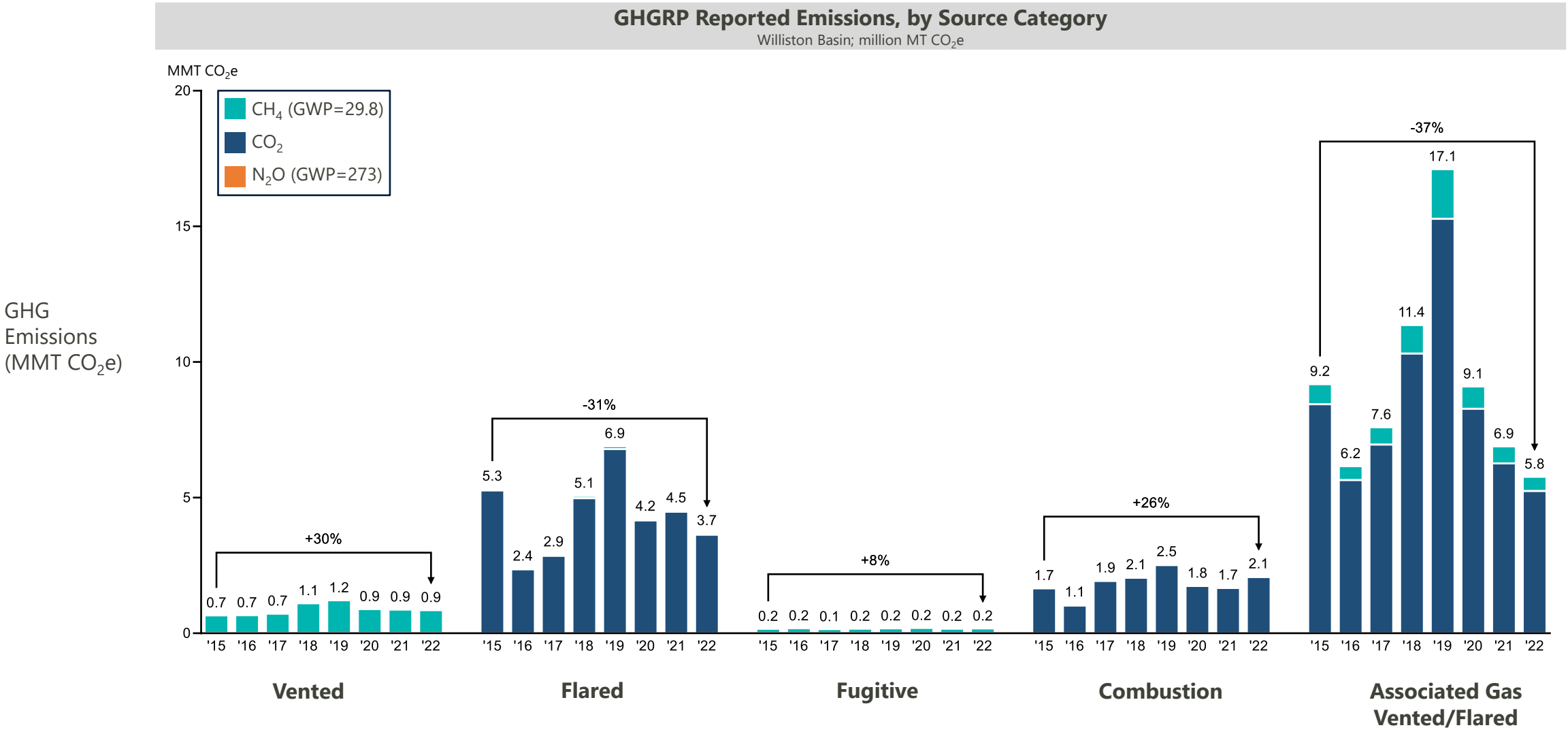
Combined Data Metrics

Indexed; 2015 = 100



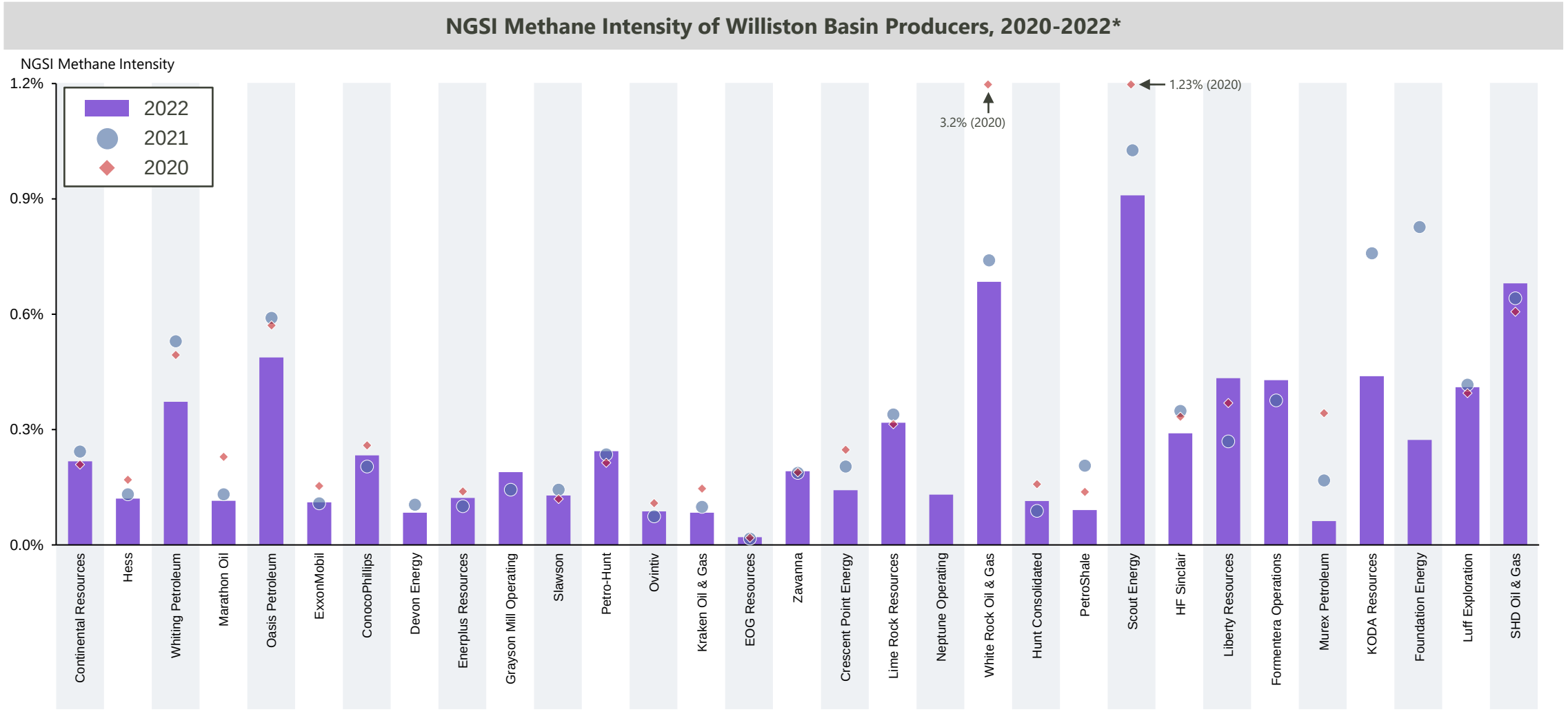
Williston Basin Producers

2015-2022 Trends Analysis: Emissions Sources



Williston Basin Producers

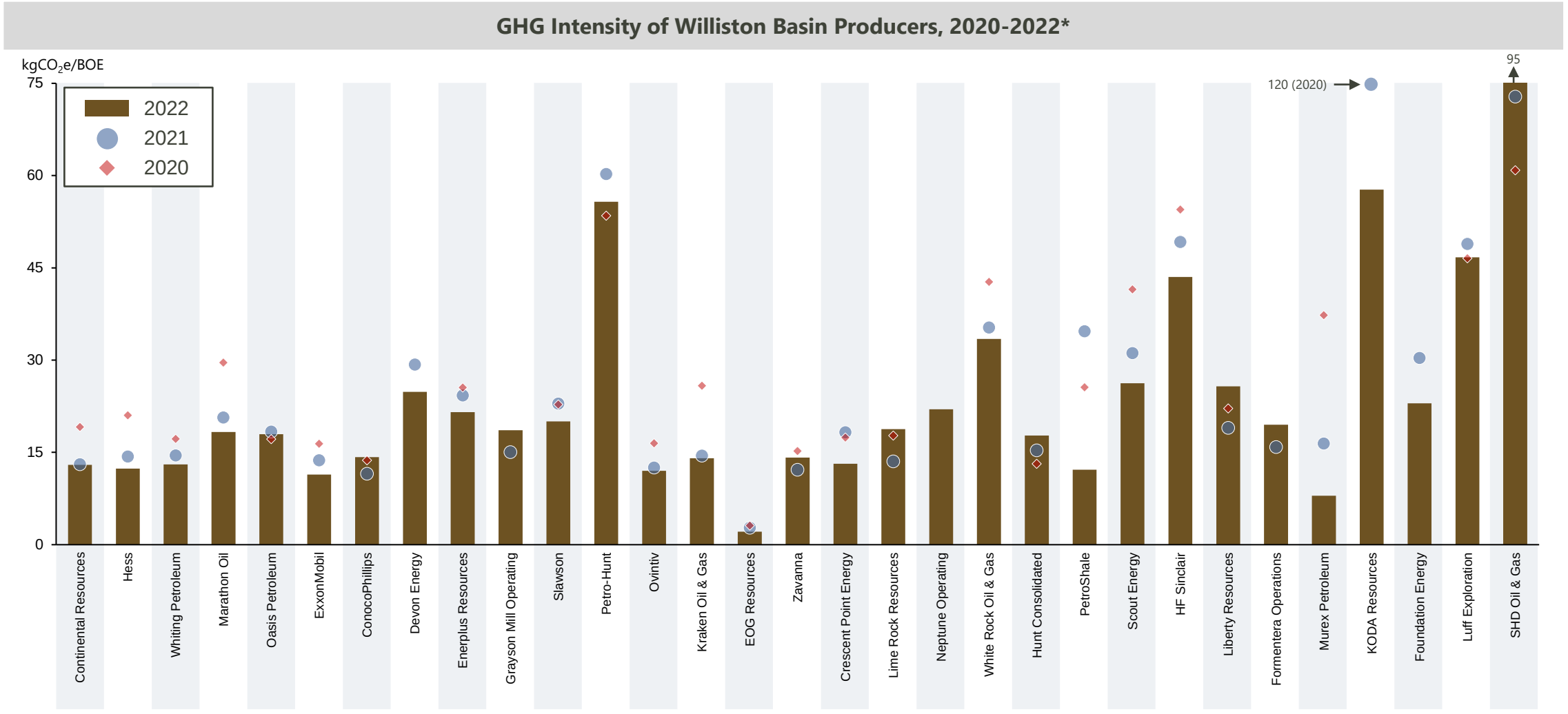
2020-2022 Trends Analysis: Change in Methane Intensity, by Top Producer



*Note that some producers in 2022 were not in the EPA database for all three years and may not have data for 2020 and/or 2021.

Williston Basin Producers

2020-2022 Trends Analysis: Change in GHG Intensity, by Top Producer



*Note that some producers in 2022 were not in the EPA database for all three years and may not have data for 2020 and/or 2021.

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 2024 report uses the same methodology as the 2023 report.

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 emissions factors that are applied to all companies; some emissions are based on direct measurements or company-specific emissions 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, 99.3 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 79. This report uses the following 2022 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 emissions 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 emissions 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 emissions factor, but Subpart W does not require reporting of the applicable activity factor).

For some of these sources, the GHG Inventory lists different emissions factors for natural gas and oil wells. Subpart W does not distinguish between natural gas and oil wells. This report uses the natural gas emissions factor for these sources. The GHG Inventory emissions factors are used in conjunction with activity data reported under Subpart W to calculate approximately 0.7 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 emissions 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 emissions 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 emissions factor to estimate emissions. Emissions from sources calculated using GHG Inventory emissions factors are small and generally account for a small percentage of total emissions from a company or basin.

Emissions factors for historic years may be updated in each annual GHG Inventory. This report uses the emissions factors published in the most recent GHG Inventory (2023 release) each respective year.

Emissions Source	GHG Inventory CH_4 Emissions Factor				GHG Inventory CO_2 Emissions Factor				Activity Factor (unit)
	2018	2019	2020	2021/ 2022*	2018	2019	2020	2021/ 2022*	
Vessel Blowdowns (applies to separators, heater-treaters, dehydrators, and in-line heaters)	1.6	1.6	1.6	1.6	0.2	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	76.6	8.5	8.5	8.6	8.6	Compressor count from GHGRP (kg/compressor)
Compressor Starts	171.7	171.6	171.4	171.4	19.0	19.1	19.2	19.2	Compressor count from GHGRP (kg/compressor)
Pressure Relief Valve Upsets	0.7	0.7	0.7	0.7	0.1	0.1	0.1	0.1	Valve count from GHGRP (kg/valve)
Well Drilling	51.3	51.2	51.2	51.2	6.7	6.7	6.7	6.7	Gas wells completed from GHGRP (kg/well)
Acid Gas Removal Units	598.3	598.3	598.3	598.3	Captured in GHGRP				AGRU count from GHGRP (kg/AGRU)

*Note that at the time of data finalization, the 2024 GHG Inventory was not released and 2022 factors were consequently not available; 2021 factors were applied in this report

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%	33%	67%	0%	0%
	Appalachian	41%	34%	10%	5%	10%
PADD 2	IN, IL, & KY	36%	41%	8%	9%	6%
	MN, WI, ND, & SD	30%	36%	15%	5%	14%
	OK, KS, & MO	41%	31%	10%	6%	12%
PADD 3	LA (Gulf)	39%	33%	12%	6%	10%
	N. LA & AR	19%	30%	13%	11%	28%
	NM	39%	32%	12%	5%	12%
	TX (Inland)	44%	30%	11%	5%	10%
PADD 4 (Rocky Mountain)		32%	35%	14%	6%	14%
PADD 5 (West Coast)		0%	11%	27%	12%	49%

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 emissions 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 2015-2022 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 emissions 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 2022 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 2022 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 2022 reporting year data are released in October 2024. 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 2024.

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 2024.

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.

Top-Down Studies

Evan Sherwin *et al*. "US oil and gas system emissions from nearly one million aerial site measurements." *Nature*, March 2024. https://www.nature.com/articles/s41586-024-07117-5.

Lu Shen *et al*. "Satellite quantification of oil and natural gas methane emissions in the US and Canada including contributions from individual basins." *Atmospheric Chemistry and Physics*, September 2022. https://acp.copernicus.org/articles/22/11203/2022/acp-22-11203-2022.pdf.

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.

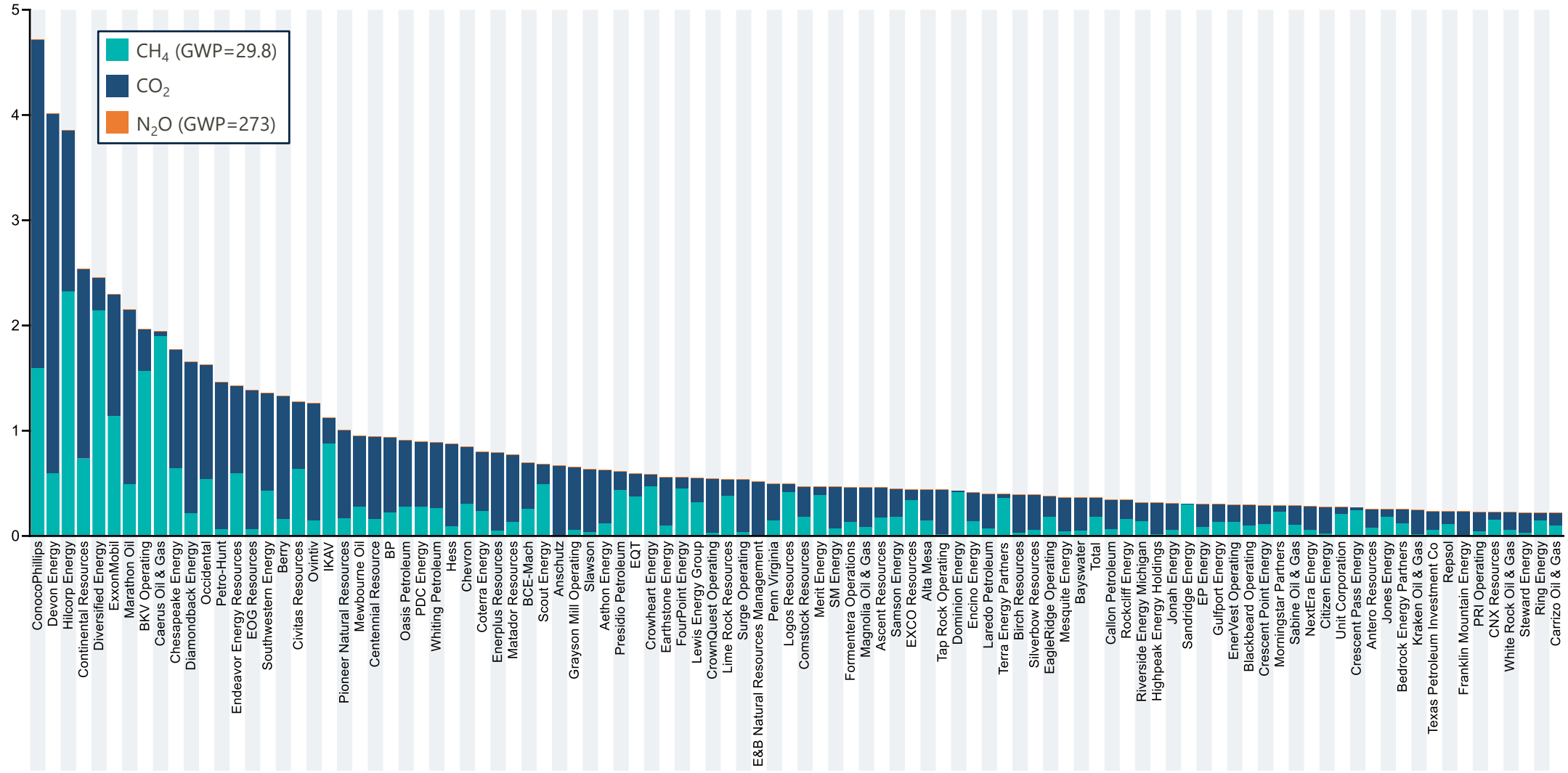
David Lyon *et al*. "Concurrent variation in oil and gas methane emissions and oil price during the COVID-19 pandemic." *Atmospheric Chemistry and Physics*, May 2021. https://doi.org/10.5194/acp-21-6605-2021.

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

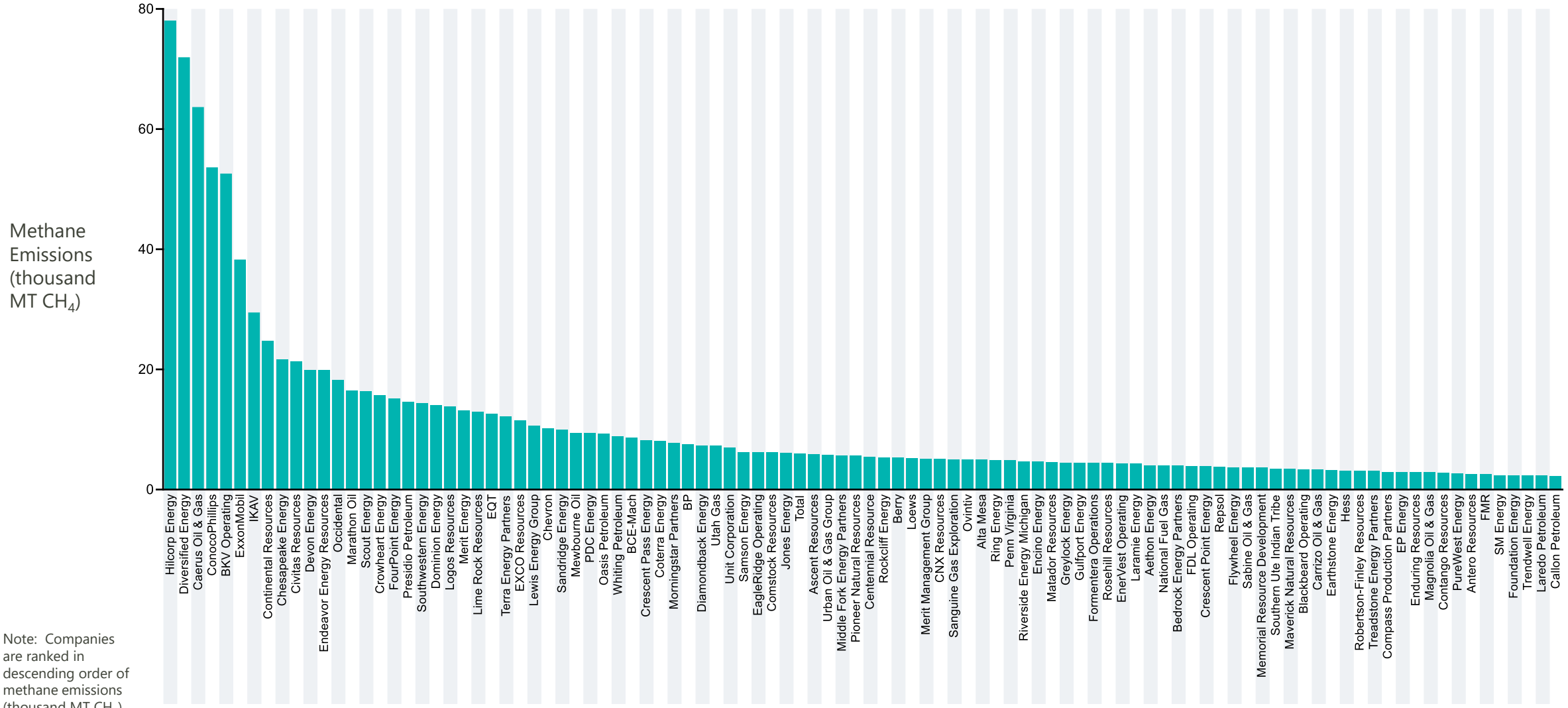
GHG Emissions (100-year GWP)



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

Note: Reflects unpublished data submitted by NextEra Energy currently under EPA review. Southwestern Energy reflects assets purchased in 2021 that were allocated to GeoSouthern in current EPA data; EQT reflects assets purchased in 2021 that were allocated to ARD Operating; IKAV reflects assets purchased in 2020 that were allocated to BP; Hilcorp reflects assets purchased in 2020 that were allocated to BP; Presidio Petroleum reflects assets purchased in 2019 that were allocated to Apache.

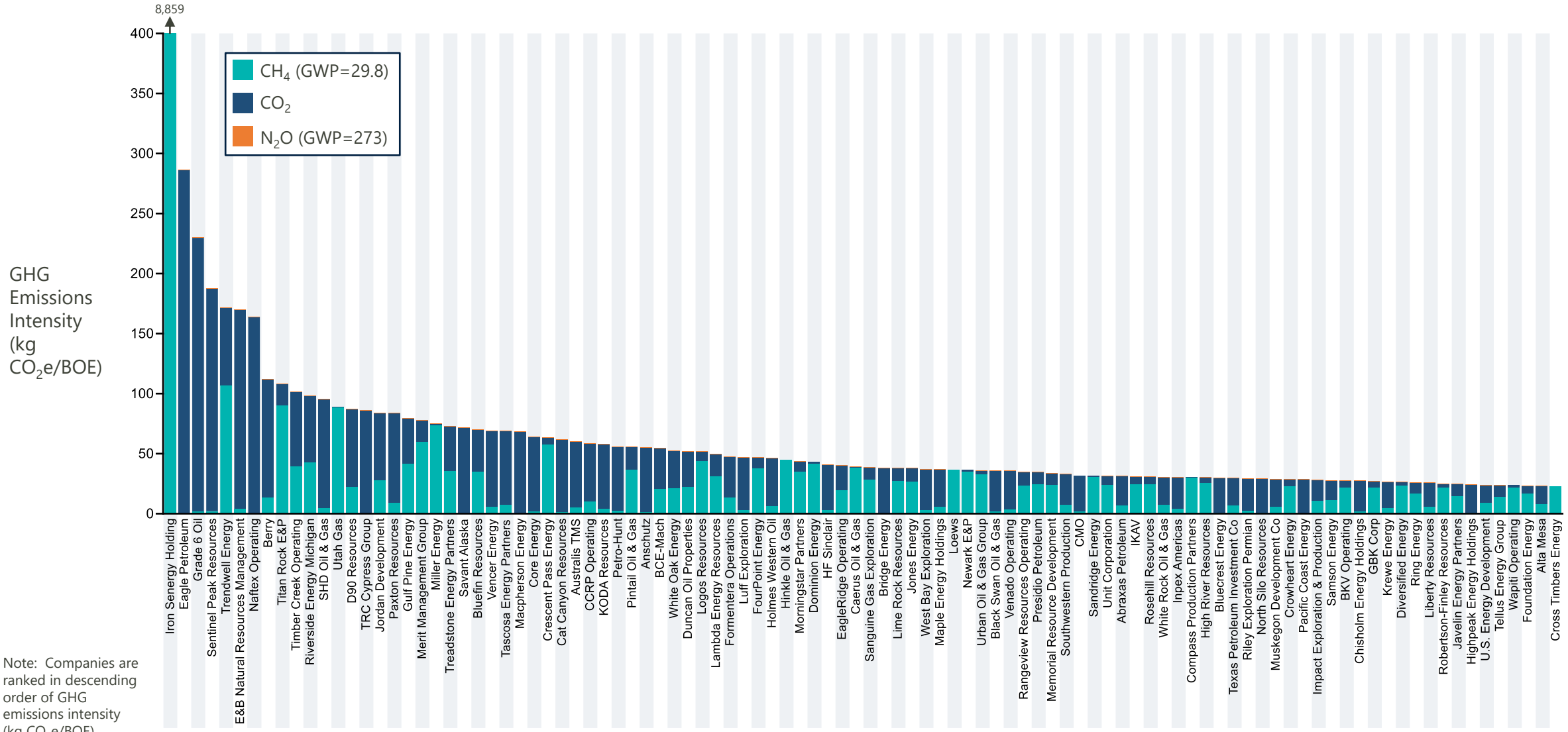
Methane Emissions



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

Note: Reflects unpublished data submitted by NextEra Energy currently under EPA review. Southwestern Energy reflects assets purchased in 2021 that were allocated to GeoSouthern in current EPA data; EQT reflects assets purchased in 2021 that were allocated to ARD Operating; IKAV reflects assets purchased in 2020 that were allocated to BP; Hilcorp reflects assets purchased in 2020 that were allocated to BP; Presidio Petroleum reflects assets purchased in 2019 that were allocated to Apache.

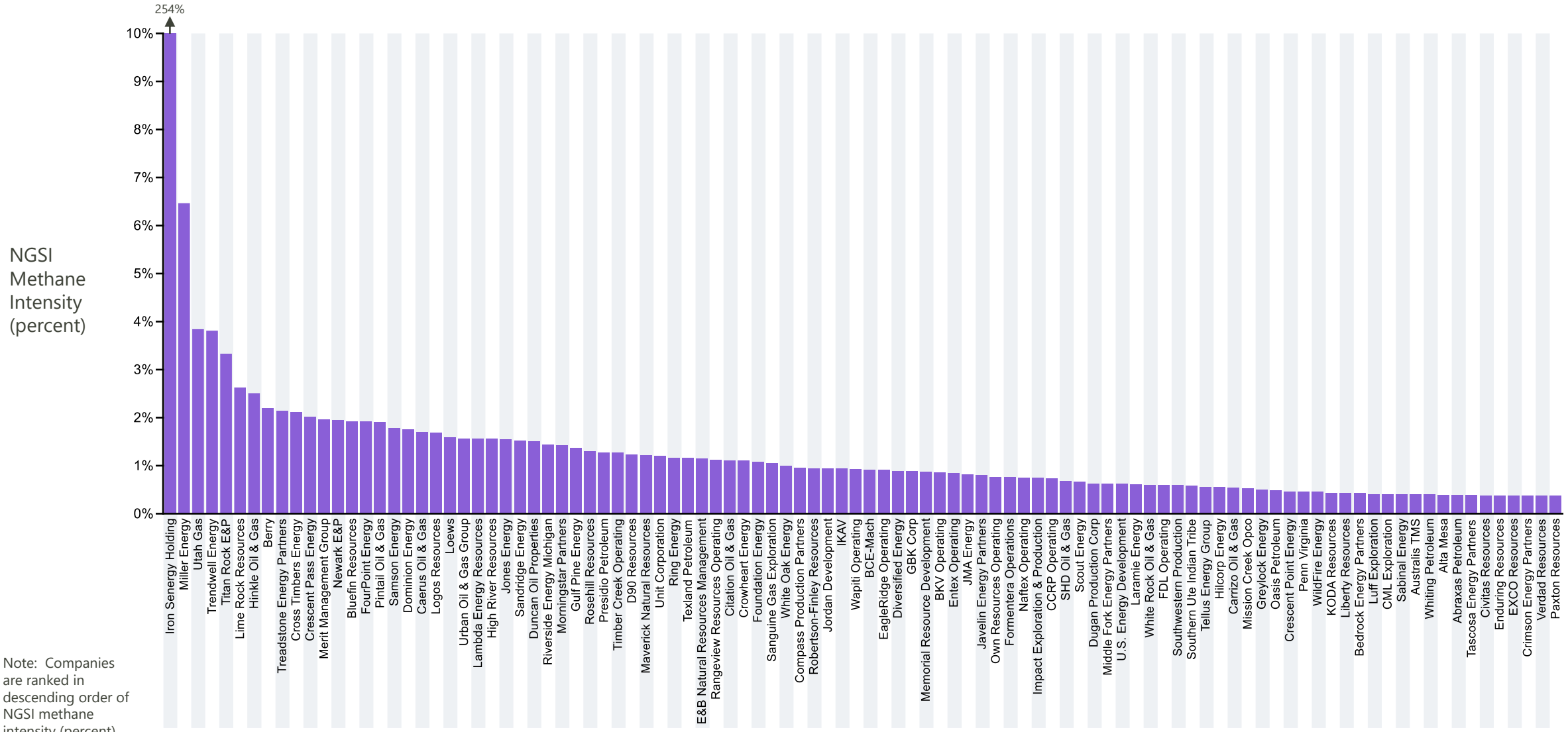
GHG Emissions Intensity



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

Note: Reflects unpublished data submitted by NextEra Energy currently under EPA review. Southwestern Energy reflects assets purchased in 2021 that were allocated to GeoSouthern in current EPA data; EQT reflects assets purchased in 2021 that were allocated to ARD Operating; IKAV reflects assets purchased in 2020 that were allocated to BP; Hilcorp reflects assets purchased in 2020 that were allocated to BP; Presidio Petroleum reflects assets purchased in 2019 that were allocated to Apache.

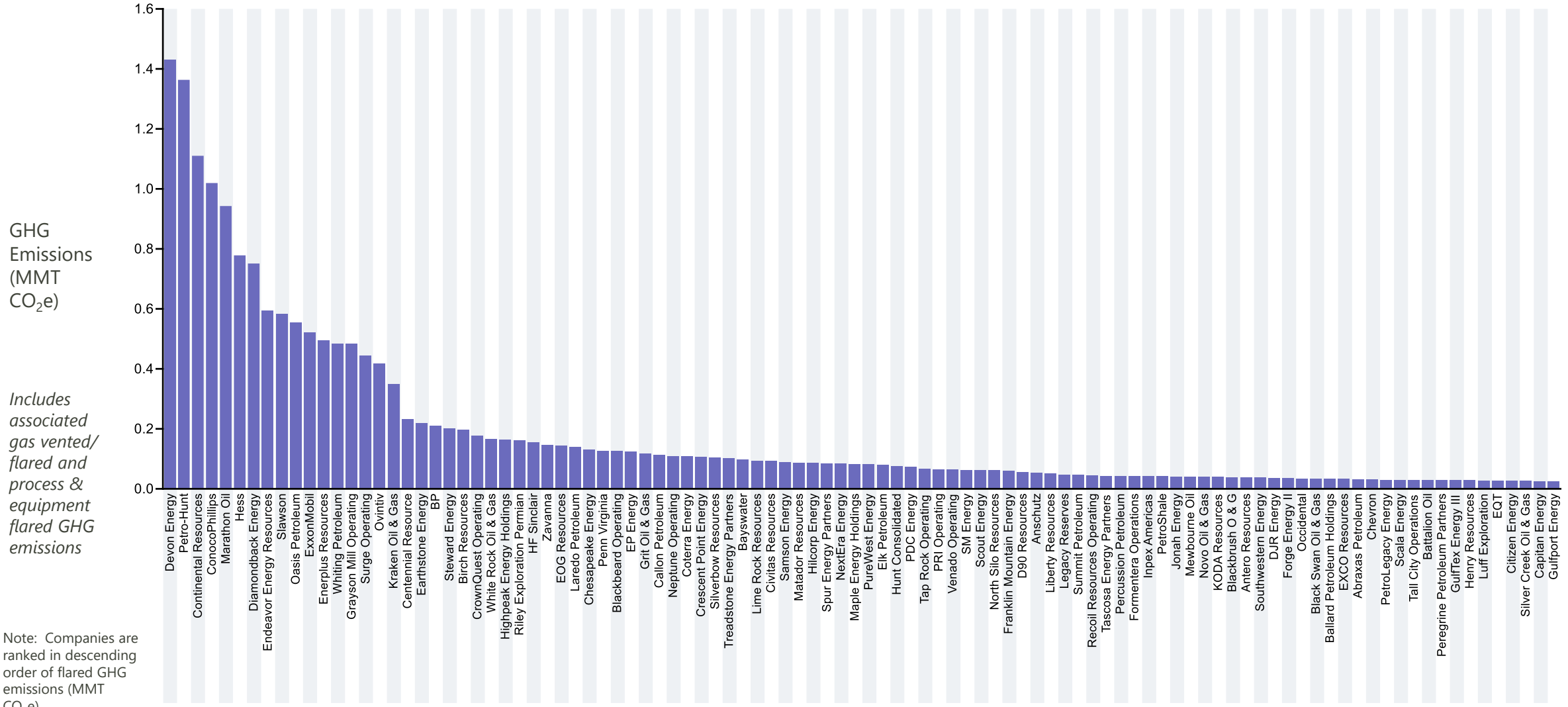
Methane Intensity



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

Note: Reflects unpublished data submitted by NextEra Energy currently under EPA review. Southwestern Energy reflects assets purchased in 2021 that were allocated to GeoSouthern in current EPA data; EQT reflects assets purchased in 2021 that were allocated to ARD Operating; IKAV reflects assets purchased in 2020 that were allocated to BP; Hilcorp reflects assets purchased in 2020 that were allocated to BP; Presidio Petroleum reflects assets purchased in 2019 that were allocated to Apache.

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

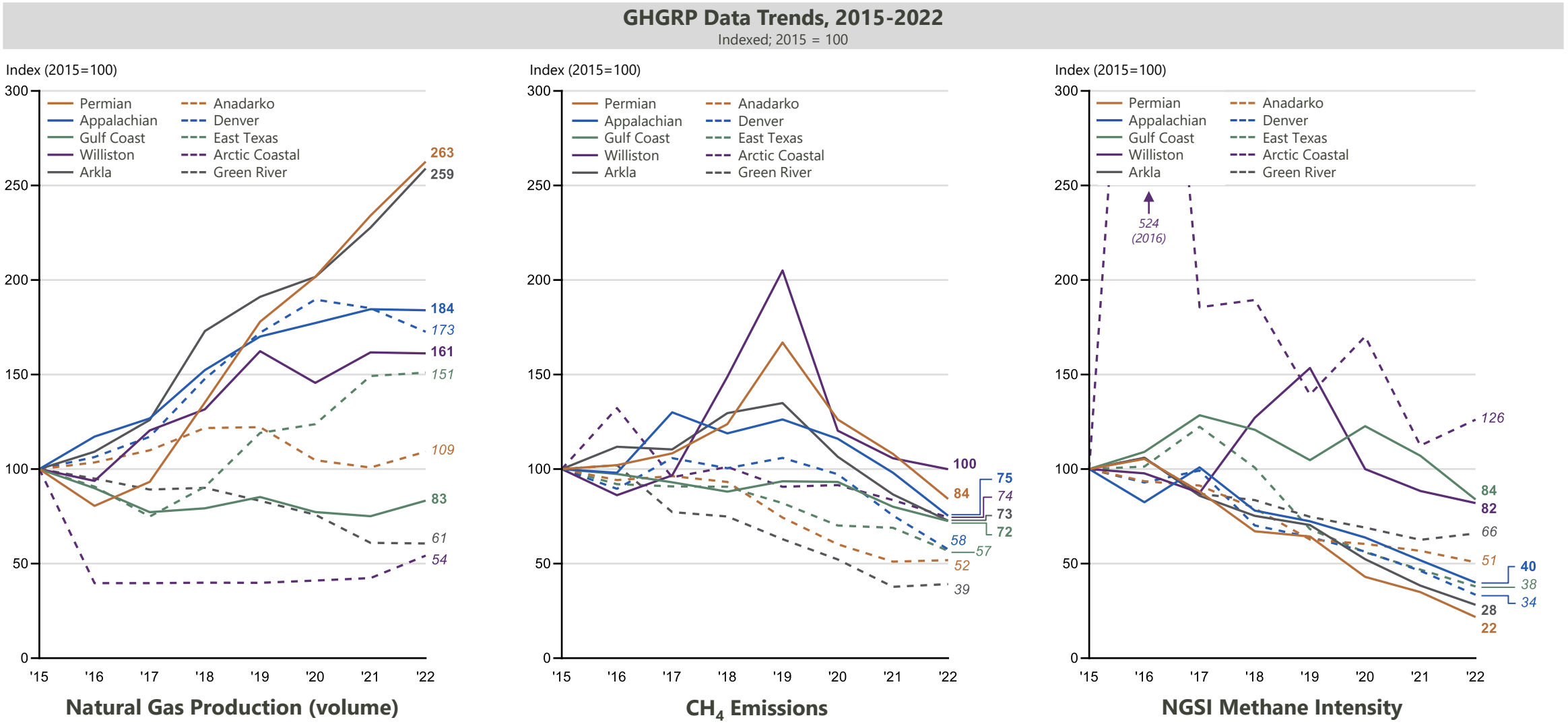


Includes associated gas vented/ flared and process & equipment flared GHG emissions

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

Note: Reflects unpublished data submitted by NextEra Energy currently under EPA review. Southwestern Energy reflects assets purchased in 2021 that were allocated to GeoSouthern in current EPA data; EQT reflects assets purchased in 2021 that were allocated to ARD Operating; IKAV reflects assets purchased in 2020 that were allocated to BP; Hilcorp reflects assets purchased in 2020 that were allocated to BP; Presidio Petroleum reflects assets purchased in 2019 that were allocated to Apache.

2015-2022 Trends Analysis: Production & Emissions Metrics of Top 10 Production Basins



2015-2022 Trends Analysis: Production & Emissions Metrics of Top 10 Production Basins