

**2011–2017 Greenhouse Gas Reporting Program
Industrial Profile: Petroleum and Natural Gas Systems**

October 2018

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PETROLEUM AND NATURAL GAS SYSTEMS

Introduction

In Fall 2018, the U.S. Environmental Protection Agency (EPA) released 2017 greenhouse gas (GHG) data for Petroleum and Natural Gas Systems¹ collected under the Greenhouse Gas Reporting Program (GHGRP). The GHGRP, which was required by Congress in the Fiscal Year 2008 Consolidated Appropriations Act, requires facilities to report data from large emission sources across a range of industry sectors, as well as from suppliers of certain greenhouse gases and products that would emit GHGs if released or combusted.

The data show 2017 GHG emissions from 2,253 facilities conducting Petroleum and Natural Gas Systems activities, such as production, gathering and boosting, processing, transmission, and distribution. In total, these facilities accounted for GHG emissions of 284 million metric tons of carbon dioxide equivalent (CO₂e). In 2017, reported GHG emissions from Petroleum and Natural Gas Systems represented 9.8% of emissions reported to the GHGRP.

All emissions presented here reflect the most recent information reported to EPA as of 8/19/2018. The reported emissions exclude biogenic CO₂. GHG data displayed here in units of carbon dioxide equivalent (CO₂e) reflect the global warming potential (GWP) values from [Table A-1](#) of 40 CFR 98, which is generally based on the [IPCC AR4](#), with the addition of GWPs from the IPCC [AR5](#) for fluorinated GHGs that did not have GWPs in the AR4.

When reviewing these data and comparing them to other data sets or published literature, it is important to understand the GHGRP reporting requirements and the impacts of these requirements on the reported data. Facilities used uniform methods prescribed by the EPA to calculate GHG emissions, such as direct measurement, engineering calculations, or emission factors derived from direct measurement. In some cases, facilities had a choice of calculation methods for an emission source.

Petroleum and Natural Gas Systems is one of the more complex source categories within the GHGRP because of the number of emission sources covered, technical complexity, variability in the calculation methods used for a particular emission source, and variability across facilities. It is expected that there can be differences in reported emissions from one facility to another. As described in more detail below, there is a reporting threshold, and the reporting requirements do not cover certain emission sources. Thus the data do not represent the entire universe of emissions from Petroleum and Natural Gas Systems. Starting with data reported for 2016, facilities reported emissions from select emission sources in gathering and boosting systems, blowdown emissions from natural gas transmission pipelines, emissions from oil well completions and workovers with hydraulic fracturing, and well identification numbers for onshore production wells. While changes in the total number of reporting facilities can cause changes in total reported emissions from year-to-year, a number of factors, such as those detailed above, contribute to differences as well. All of these factors could impact cross-segment, cross-source, or cross-facility comparisons.

There are also considerations to keep in mind when drawing conclusions about the deferred activity data reported for 2011-2013, as part of the reporting year 2014 submissions. While many facilities in this sector submitted deferred data, certain facilities might not have reported this

¹ The implementing regulations of the Petroleum and Natural Gas Systems source category of the GHGRP are located at 40 CFR Part 98 Subpart W.

information for legitimate reasons. These include changes in ownership and not having reported to the GHGRP in a previous year for a valid reason. In addition, the reporting requirements were significantly revised in 2014, so some activity data reported in 2015 and later reporting years are not available for previous years. It is important to be aware of these limitations and differences when using this data, particularly when attempting to draw broad conclusions about emissions and activities from this sector.

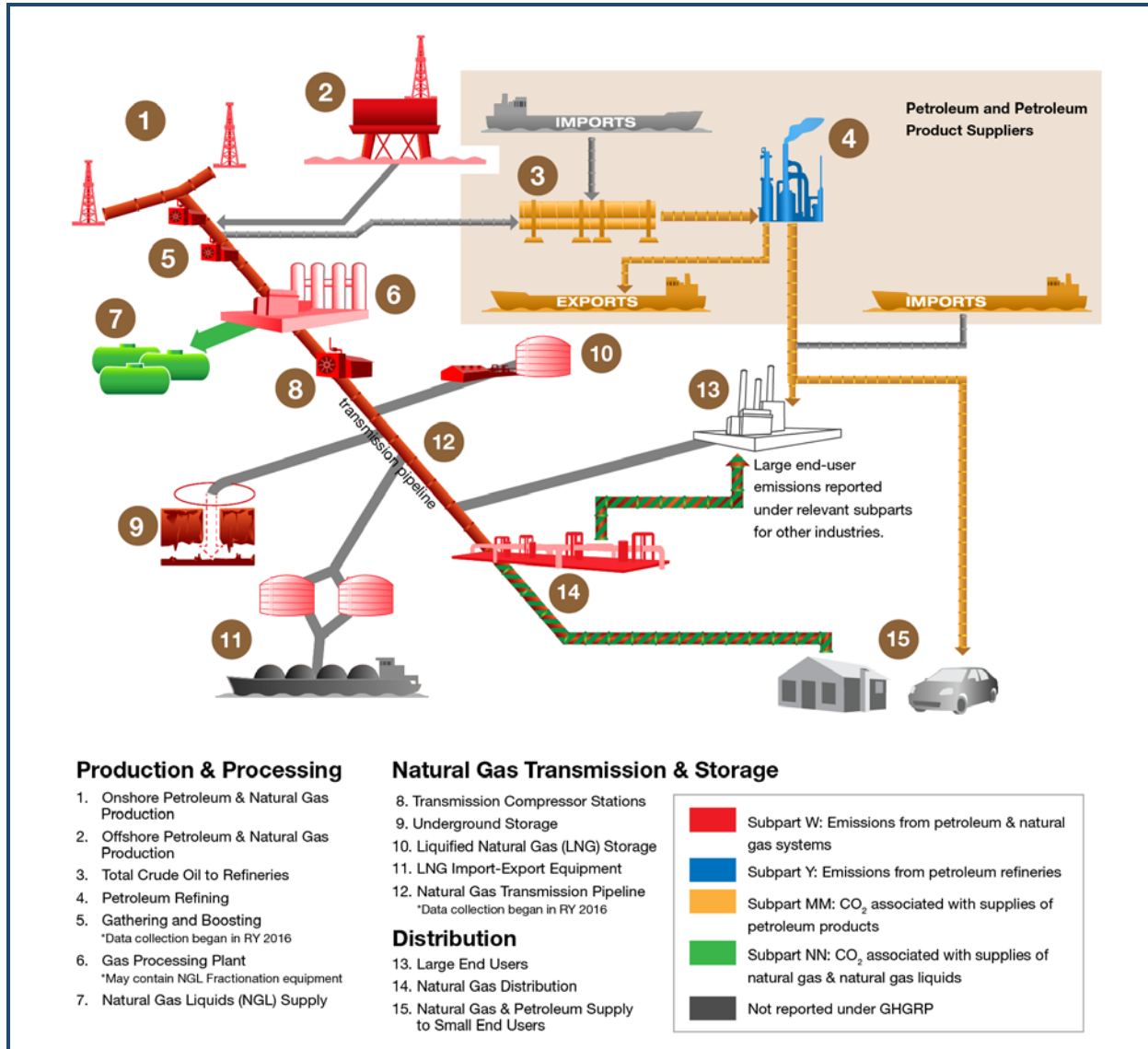
Petroleum and Natural Gas Systems in the GHG Reporting Program

The Petroleum and Natural Gas Systems source category of the GHGRP (Subpart W) requires reporting from the following 10 industry segments for 2017:

- Onshore Production – Production of petroleum and natural gas associated with onshore production wells and related equipment;
- Offshore Production – Production of petroleum and natural gas from offshore production platforms;
- Gathering and Boosting – Gathering pipelines and other equipment that collect petroleum/natural gas from onshore production gas or oil wells and then compress, dehydrate, sweeten, or transport the petroleum and/or natural gas;
- Natural Gas Processing – Processing of field-quality gas to produce pipeline-quality natural gas;
- Natural Gas Transmission Compression – Compressor stations used to transfer natural gas through transmission pipelines;
- Natural Gas Transmission Pipeline – A rate-regulated interstate or intrastate pipeline, or a pipeline that falls under the “Hinshaw Exemption” of the Natural Gas Act;
- Underground Natural Gas Storage – Facilities that store natural gas in underground formations;
- Liquefied Natural Gas (LNG) Import/Export – Liquefied Natural Gas import and export terminals;
- LNG Storage – Liquefied Natural Gas storage equipment; and
- Natural Gas Distribution – Distribution systems that deliver natural gas to customers.

Figure 1 below illustrates the segments of the Petroleum and Natural Gas Systems source category that were required to report under the GHGRP for 2017.

Figure 1: Petroleum and Natural Gas operations covered by the GHG Reporting Program



Note: Certain petroleum and/or natural gas operations are covered by subparts of the GHGRP other than Subpart W or began reporting GHG data starting with the 2016 reporting year.

Other segments of the petroleum and natural gas industry are covered by the GHGRP but not included in the Petroleum and Natural Gas Systems (Subpart W) source category, such as Petroleum Refineries (Subpart Y), Petrochemical Production (Subpart X), Suppliers of Petroleum Products (Subpart MM), and Suppliers of Natural Gas and Natural Gas Liquids (Subpart NN).

As noted above, the GHGRP also includes reporting of stationary fuel combustion emissions from facilities that are associated with the petroleum and natural gas industry, but that do not report process emissions from any of the above source categories, such as certain facilities that have a North American Industry Classification System (NAICS) code beginning with 211 (the general NAICS for oil and gas extraction). These facilities are referred to as “Other Oil and Gas Combustion” in this document.

The GHGRP covers a subset of national emissions from Petroleum and Natural Gas Systems. A facility in the Petroleum and Natural Gas Systems source category is required to submit annual reports if total emissions are 25,000 metric tons carbon dioxide equivalent (CO₂e) or more.

The EPA has a multi-step data verification process, including automatic checks during data-entry, statistical analyses on completed reports, and staff review of the reported data.² Based on the results of the verification process, the EPA follows up with facilities to resolve mistakes that may have occurred during the reporting period.

The EPA has made available the optional use of best available monitoring methods (BAMM) for targeted circumstances where the EPA made recent changes to GHGRP monitoring requirements for Petroleum and Natural Gas Systems.³ In certain previous reporting years, in order to provide facilities with time to adjust to the requirements of the GHGRP, the EPA made available the optional use of BAMM for unique or unusual circumstances. Where a facility used BAMM for any reporting year, it was required to follow emission calculations specified by the EPA but allowed to use alternative methods for determining inputs to calculate emissions. Examples of BAMM include monitoring methods used by the facility that do not meet the specifications of 40 CFR Part 98 Subpart W, supplier data, engineering calculations, and other company records. As of reporting year 2017, no facilities are approved to use BAMM any longer.

Reported GHG Emissions from Petroleum and Natural Gas Systems

The following section provides information on reported GHG emissions by industry segment, greenhouse gas, and combustion and process emissions for the 2017 calendar year.

Reported Emissions by Industry Segment

The 2017 calendar year was the seventh year that GHG emissions from Petroleum and Natural Gas Systems activities were required to be collected. Annual reports were due to the EPA by April 2, 2018. The EPA received reports from 2,253 facilities⁴ with Petroleum and Natural Gas Systems activities, with total reported GHG emissions of 284 million metric tons (MMT) CO₂e.

Table 1 presents number of facilities and reported emissions in 2017 by industry segment. The largest industry segment in terms of reported GHG emissions was onshore production, with a total of 94 MMT CO₂e, followed by gathering and boosting, with reported emissions of 75 MMT CO₂e. Natural gas processing accounted for 56 MMT CO₂e. The next largest segment was natural gas transmission compression, with reported emissions of 24 MMT CO₂e. Reported emissions from natural gas distribution totaled 13 MMT CO₂e. The remaining segments accounted for total reported emissions of approximately 22 MMT CO₂e.

² [Access more information on verification.](#)

³ [Access more information on BAMM.](#)

⁴ In general, a “facility” for purposes of the GHGRP means all co-located emission sources that are commonly owned or operated. However, the GHGRP has developed specialized facility definitions for onshore production, gathering and boosting, natural gas transmission pipeline, and natural gas distribution. For onshore production, the “facility” includes all emissions associated with wells owned or operated by a single company in a specific hydrocarbon producing basin (as defined by the geologic provinces published by the American Association of Petroleum Geologists). For gathering and boosting, a “facility” means all gathering pipelines and other equipment located along those pipelines that are under common ownership or common control by a gathering and boosting system owner or operator and that are located in a single hydrocarbon basin. For natural gas transmission pipeline, a “facility” means the total U.S. mileage of natural gas transmission pipelines, owned and operated by an onshore natural gas transmission pipeline owner or operator. For natural gas distribution, a “facility” is a local distribution company as regulated by a single state public utility commission.

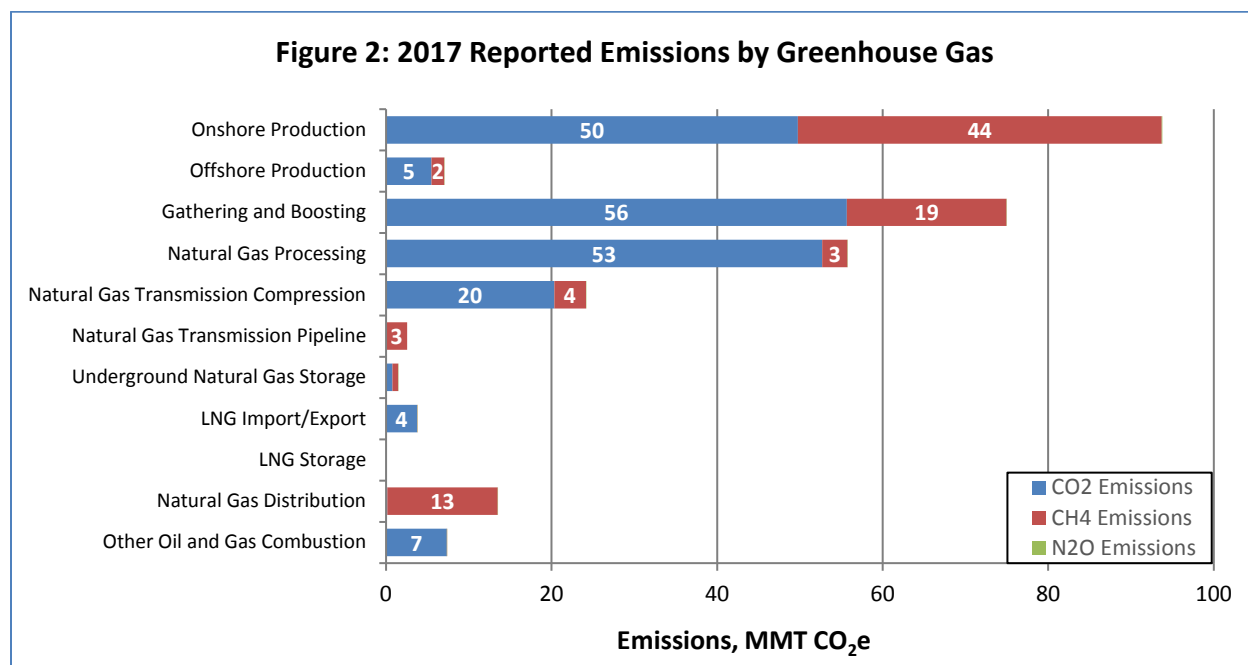
Table 1: 2017 Reported Emissions by Industry Segment

Industry Segment	Number of Facilities	Reported Emissions (Million Metric Tons CO ₂ e)
Onshore Production	497	94
Offshore Production	141	7
Gathering and Boosting	321	75
Natural Gas Processing	449	56
Natural Gas Transmission Compression	529	24
Natural Gas Transmission Pipeline	33	3
Underground Natural Gas Storage	48	1
LNG Import/Export	6	4
LNG Storage	6	<1
Natural Gas Distribution	169	13
Other Oil and Gas Combustion	79	7
Total	2,253	284

Note: The total number of facilities that reported to the GHGRP for 2017 is smaller than the sum of facilities from each segment because some facilities reported under multiple segments. A facility is included in the count of number of facilities if it reported emissions (even if the reported emissions were zero) under a given segment.

Reported Emissions by Greenhouse Gas

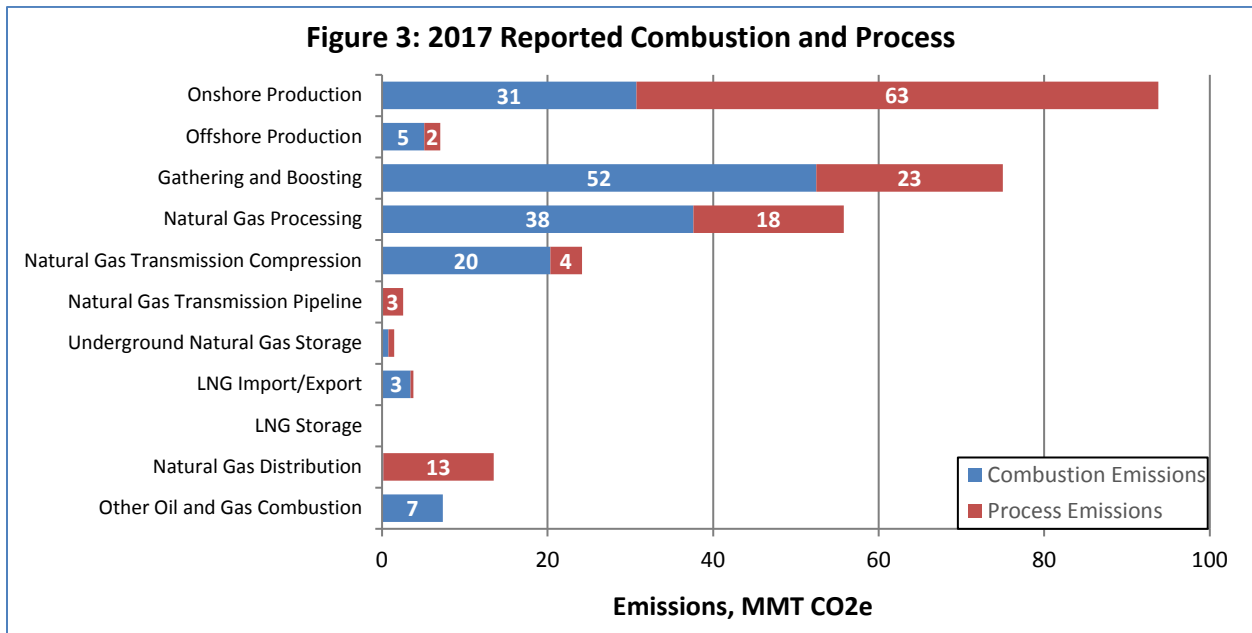
Figure 2 presents reported emissions in 2017 by industry segment and greenhouse gas. For all segments combined, carbon dioxide (CO₂) emissions accounted for 196 MMT CO₂e of reported emissions and methane (CH₄) emissions accounted for 88 MMT CO₂e of reported emissions. Nitrous oxide (N₂O) emissions accounted for 0.1 MMT CO₂e of reported emissions.



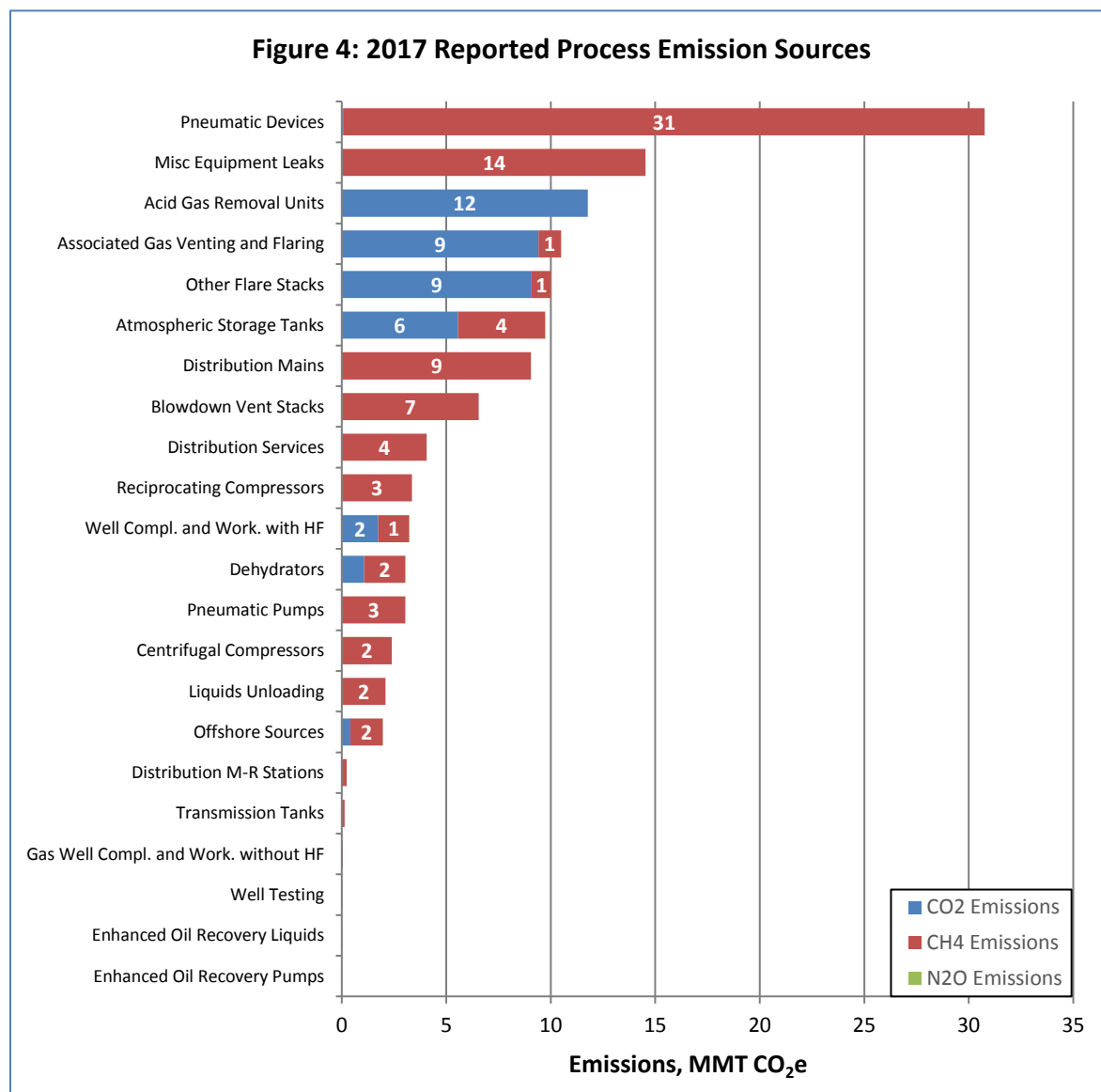
Note: Segment totals may not equal sum of individual GHGs due to independent rounding.

Reported Combustion and Process Emissions

Each segment of Petroleum and Natural Gas Systems includes a combination of emission sources. Emissions may result from the combustion of fossil fuels or from process sources that result in the direct emission of GHGs. Reported combustion emissions in Petroleum and Natural Gas Systems totaled 158 MMT CO₂e and reported process emissions totaled 127 MMT CO₂e. Figures 3 and 4 present reported combustion and process emissions in 2017 by industry segment and emission source, respectively.



Note: Segment totals may not equal sum of process and combustion emissions due to independent rounding.



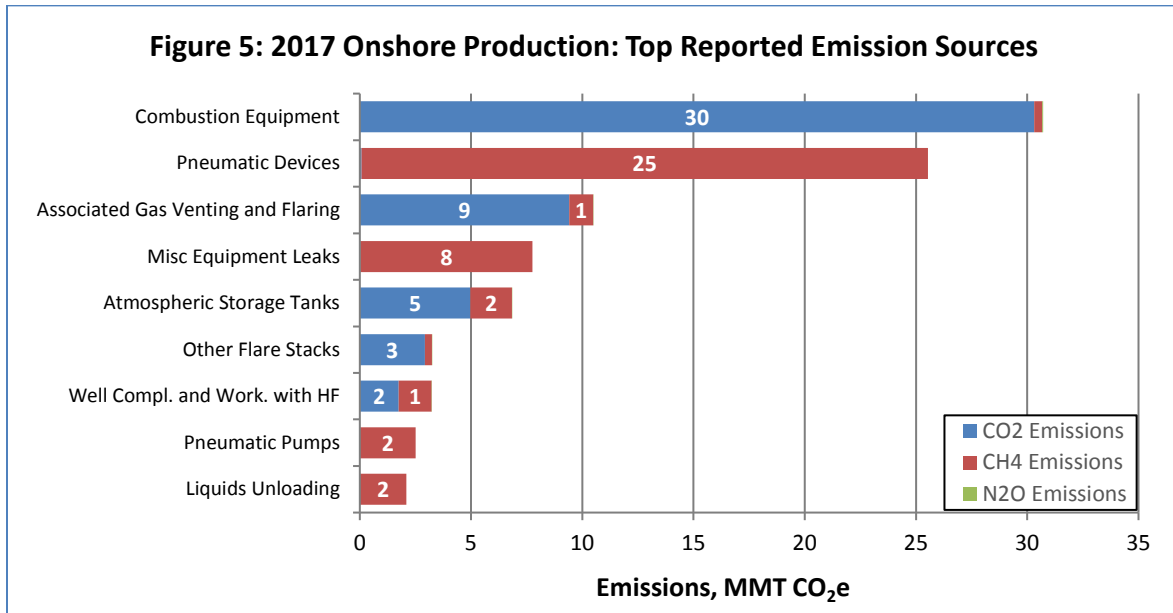
Note: Segment totals may not equal sum of individual GHGs due to independent rounding.

Reported GHG Emissions by Industry Segment and Source

The following section provides information on reported GHG emissions organized by industry segment. For each segment, the top reported emission sources are presented.

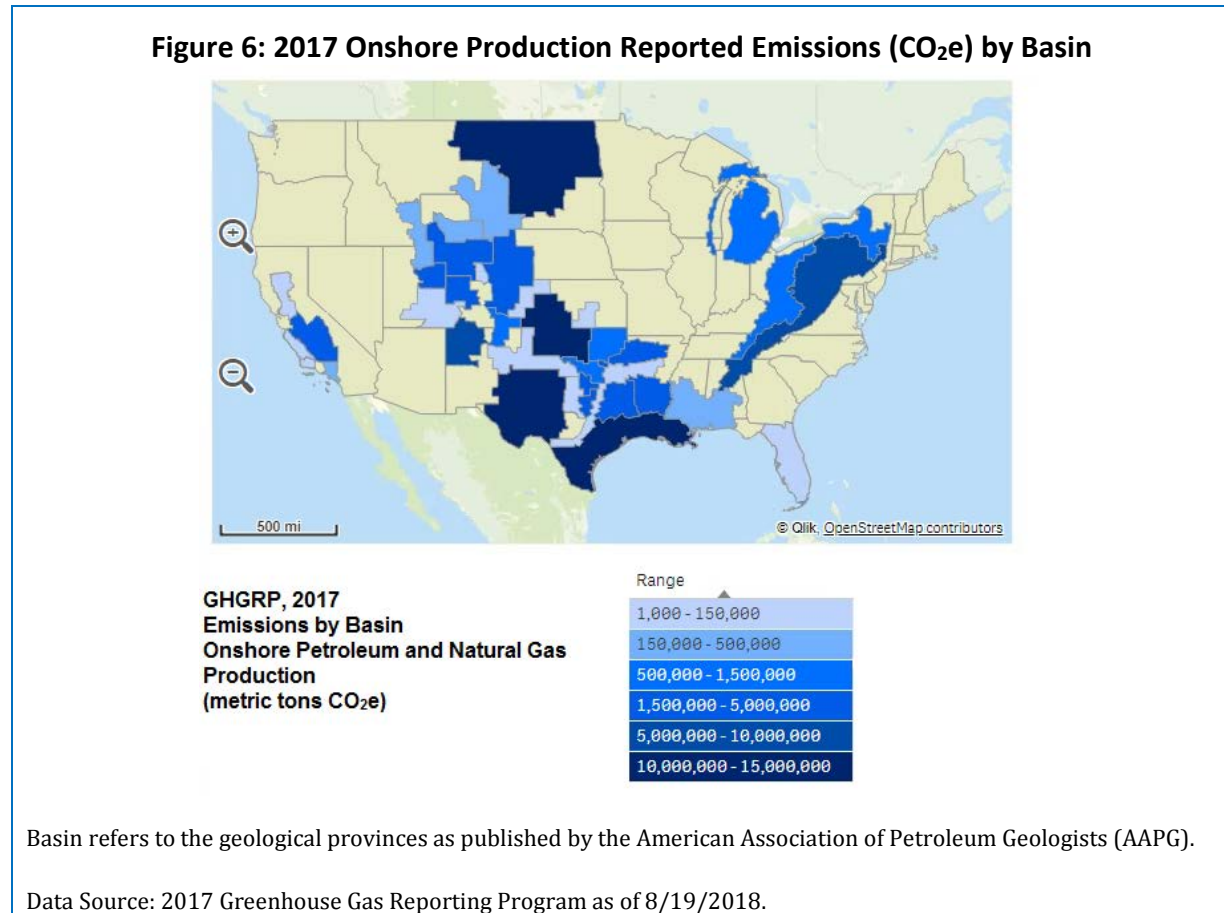
Onshore Production

The EPA received annual reports from 497 facilities in the onshore production segment and reported emissions totaled 93.8 MMT CO₂e. Methane emissions totaled 44.0 MMT CO₂e and carbon dioxide emissions totaled 49.8 MMT CO₂e. Combustion equipment (30.7 MMT CO₂e) and pneumatic devices (25.5 MMT CO₂e) were the top reported emission sources, followed by associated gas venting and flaring (10.5 MMT CO₂e), miscellaneous equipment leaks (7.8 MMT CO₂e), atmospheric tanks (6.8 MMT CO₂e), and other flare stacks (3.2 MMT CO₂e). Onshore production emissions by greenhouse gas from the top reported emission sources are presented in Figure 5 for 2017.



Note: Segment totals may not equal sum of individual GHGs due to independent rounding.

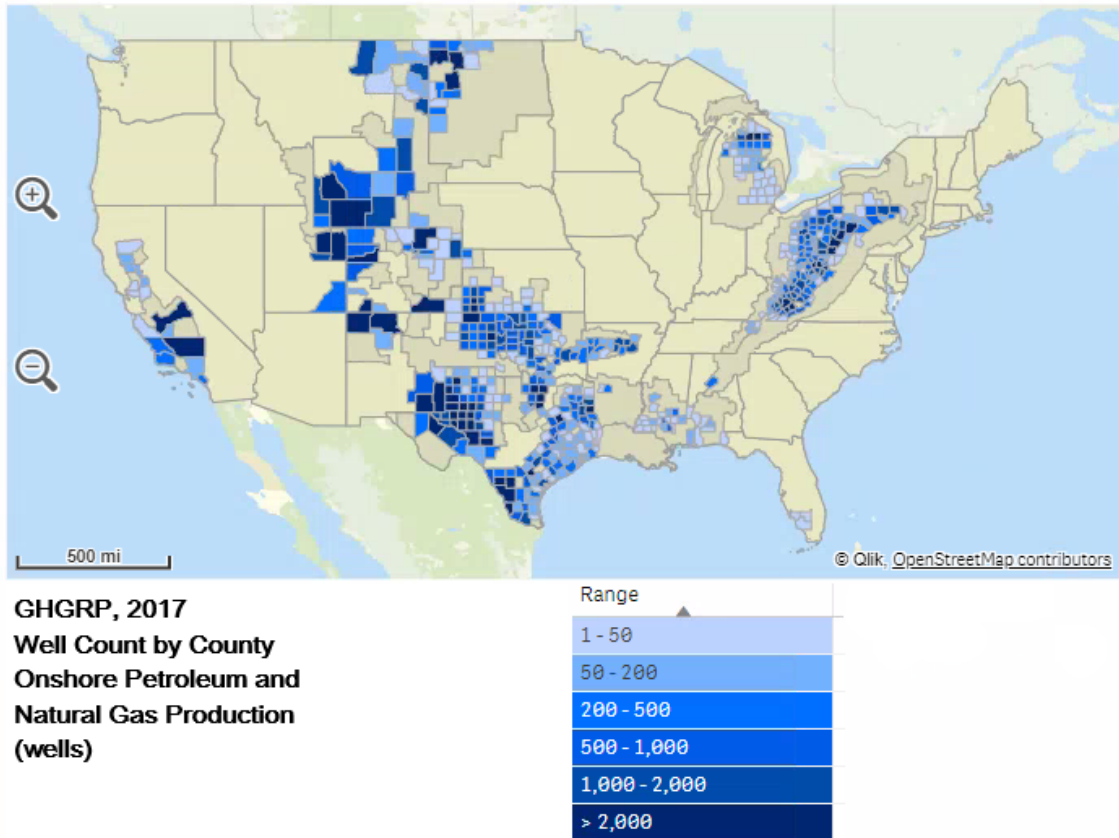
Figure 6 shows 2017 onshore production reported emissions by basin.



Starting with data reported for 2016, onshore production facilities reported well identification numbers and certain emission source types associated with wells. A well identification number is either the US Well Number (formerly referred to as the API Well Number, or API Number), or the unique well number assigned by its permitting authority if the well does not have a US Well Number.⁵ Figure 7 shows 2017 well count by county for onshore production facilities.

⁵ Professional Petroleum Data Management Association. [The US Well Number Standard: An Identifier for Petroleum Industry Wells in the USA](#). Version 2013 rev 1, published June 19, 2014.

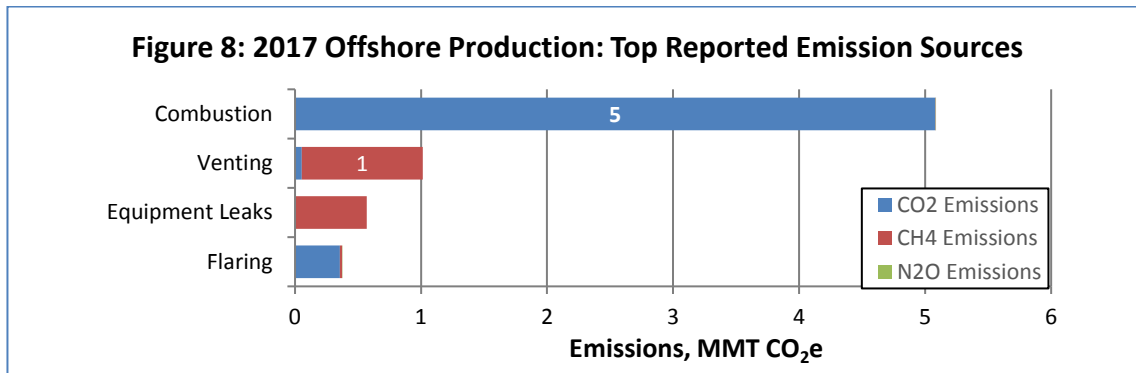
Figure 7: 2017 Onshore Production Well Count by County



Data Source: 2017 Greenhouse Gas Reporting Program as of 8/19/2018; image updated Sept. 2019.

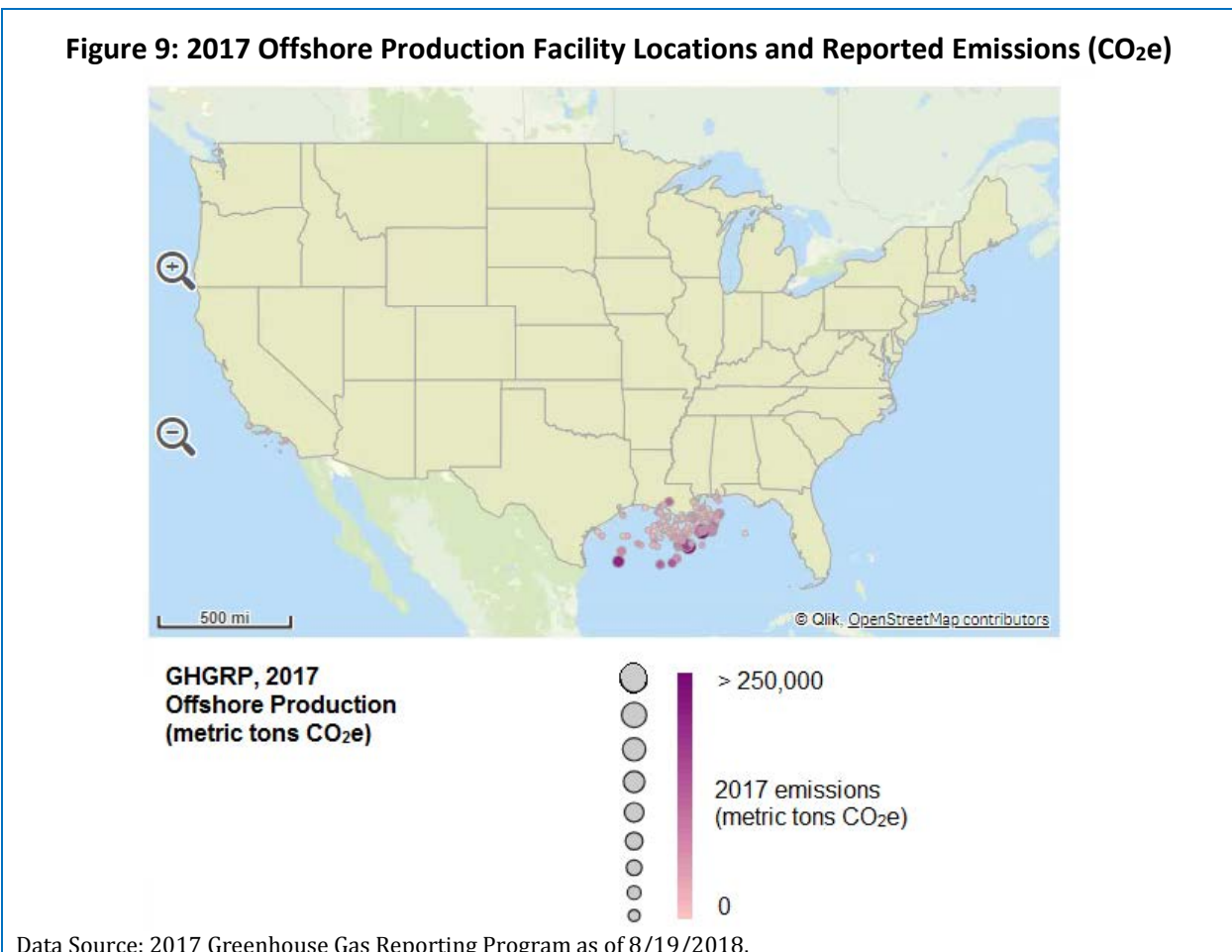
Offshore Production

The EPA received annual reports from 141 facilities in the offshore production segment that totaled 7.0 MMT CO₂e. For offshore production, facilities calculate process emissions using requirements that were established by the Bureau of Ocean Energy Management (BOEM). In addition, the GHGRP collects data on combustion emissions. While the full list of process emission sources is extensive, it can generally be categorized into vented emissions, flaring, and equipment leaks. The top reported source of emissions for offshore production was from combustion (5 MMT CO₂e), followed by venting (1 MMT CO₂e). See Figure 8 below for offshore emissions by emission source category.



Note: Segment totals may not equal sum of individual GHGs due to independent rounding.

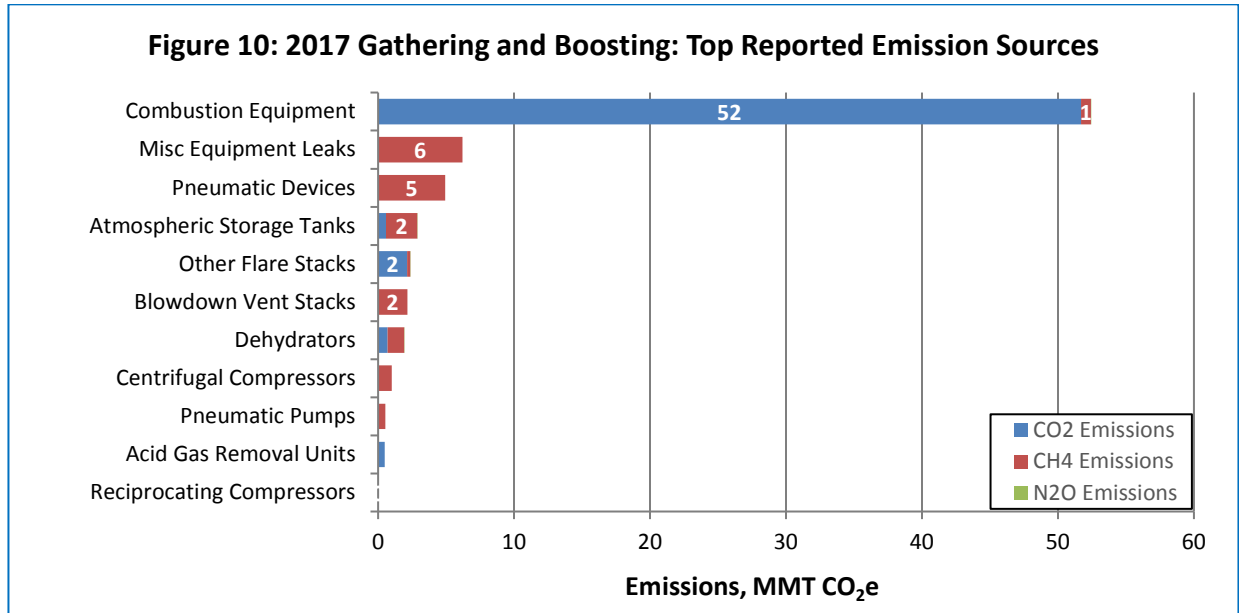
Figure 9 shows 2017 facility locations and reported emissions (CO₂e) for offshore production facilities.



Gathering and Boosting

The gathering and boosting segment was first reported in 2016. In 2017, the EPA received annual reports from 321 facilities in the gathering and boosting segment and reported emissions totaled

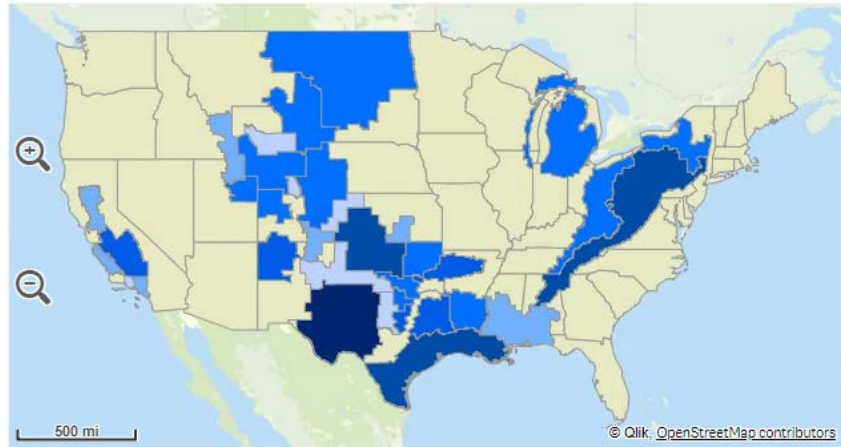
75.0 MMT CO₂e. Methane emissions totaled 19.3 MMT CO₂e and carbon dioxide emissions totaled 55.7 MMT CO₂e. Combustion equipment (52.5 MMT CO₂e) was the top reported emission source, followed by miscellaneous equipment leaks (6.2 MMT CO₂e), pneumatic devices (4.9 MMT CO₂e), and atmospheric tanks (2.9 MMT CO₂e). See Figure 10 below for gathering and boosting emissions by greenhouse gas for the top reported emission sources in 2017.



Note: Segment totals may not equal sum of individual GHGs due to independent rounding.

Figure 11 shows 2017 gathering and boosting reported emissions by basin.

Figure 11: 2017 Gathering and Boosting Reported Emissions (CO₂e) by Basin



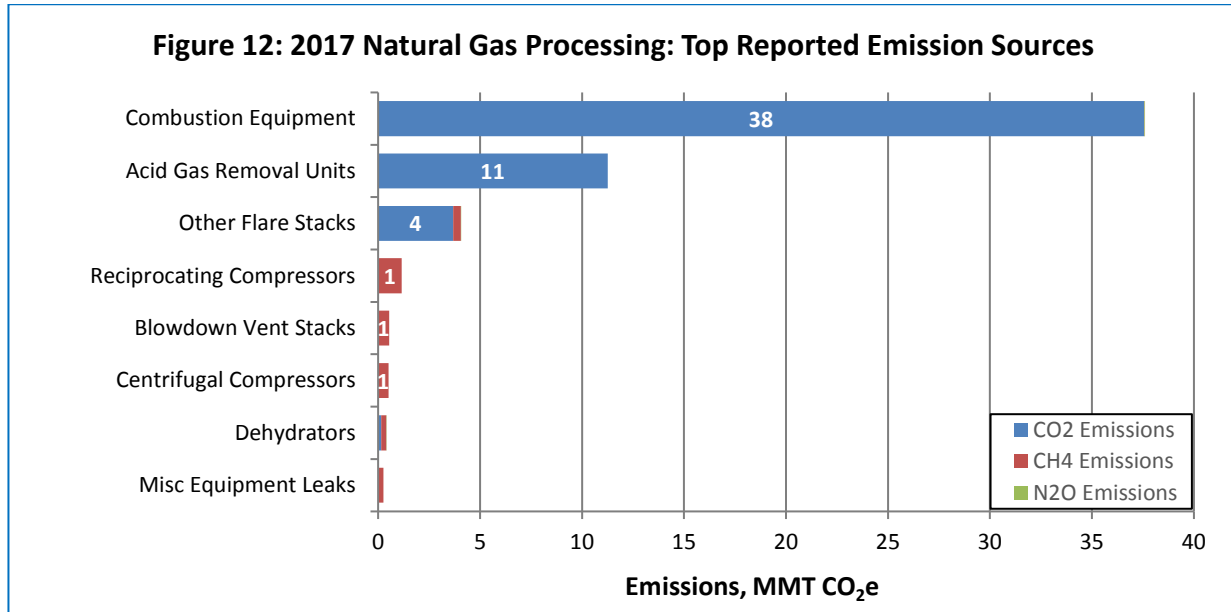
**GHGRP, 2017
Emissions by Basin
Onshore Petroleum and Natural
Gas
Gathering & Boosting
(metric tons (CO₂e))**

Range
1,000 - 150,000
150,000 - 500,000
500,000 - 1,500,000
1,500,000 - 5,000,000
5,000,000 - 10,000,000
10,000,000 - 15,000,000

Data Source: 2017 Greenhouse Gas Reporting Program as of 8/19/2018.

Natural Gas Processing

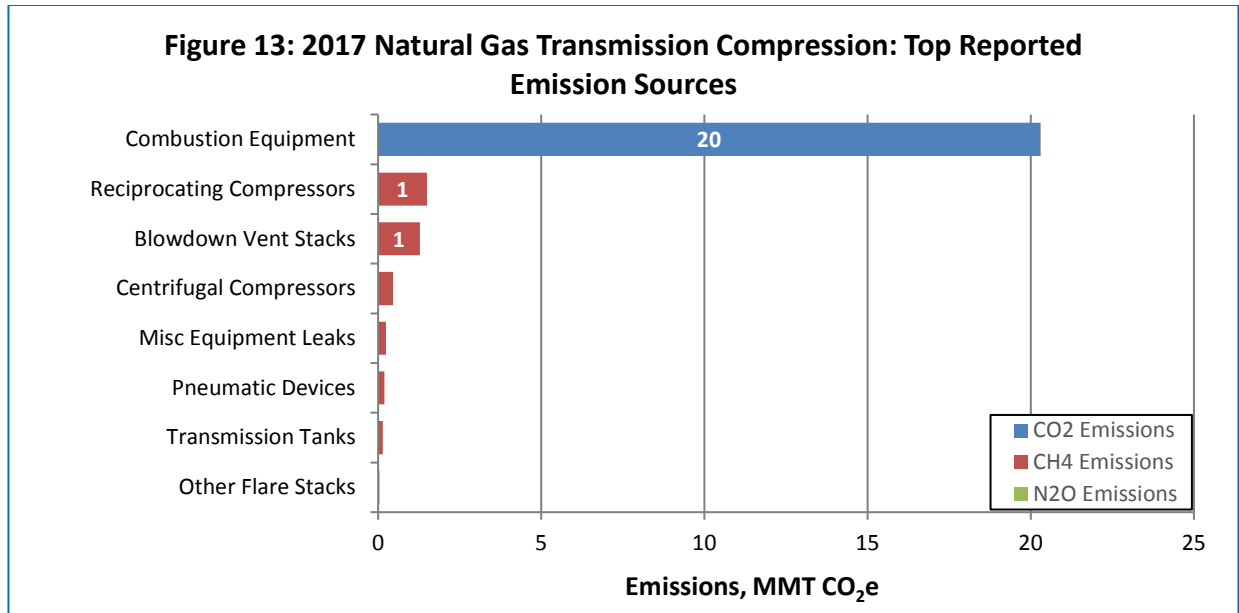
The EPA received annual reports from 449 facilities in the natural gas processing segment, and reported emissions totaled 55.8 MMT CO₂e. Methane emissions totaled 3.1 MMT CO₂e, and carbon dioxide emissions totaled 52.7 MMT CO₂e. As presented in Figure 12, the top reported emission sources were combustion equipment (37.6 MMT CO₂e), acid gas removal units (11.3 MMT CO₂e), and other flare stacks (4.1 MMT CO₂e).



Note: Segment totals may not equal sum of individual GHGs due to independent rounding.

Natural Gas Transmission Compression

The EPA received annual reports from 529 facilities in the natural gas transmission compression segment, and reported emissions totaled 24.2 MMT CO₂e. Methane emissions totaled 3.8 MMT CO₂e and carbon dioxide emissions totaled 20.3 MMT CO₂e. Combustion emissions (20.3 MMT CO₂e) were larger than process emissions. Following combustion equipment, the top reported emission sources were reciprocating compressors (1.5 MMT CO₂e) and blowdown vent stacks (1.3 MMT CO₂e). See Figure 13 for natural gas transmission emissions by greenhouse gas for the top reported emission sources in 2017.



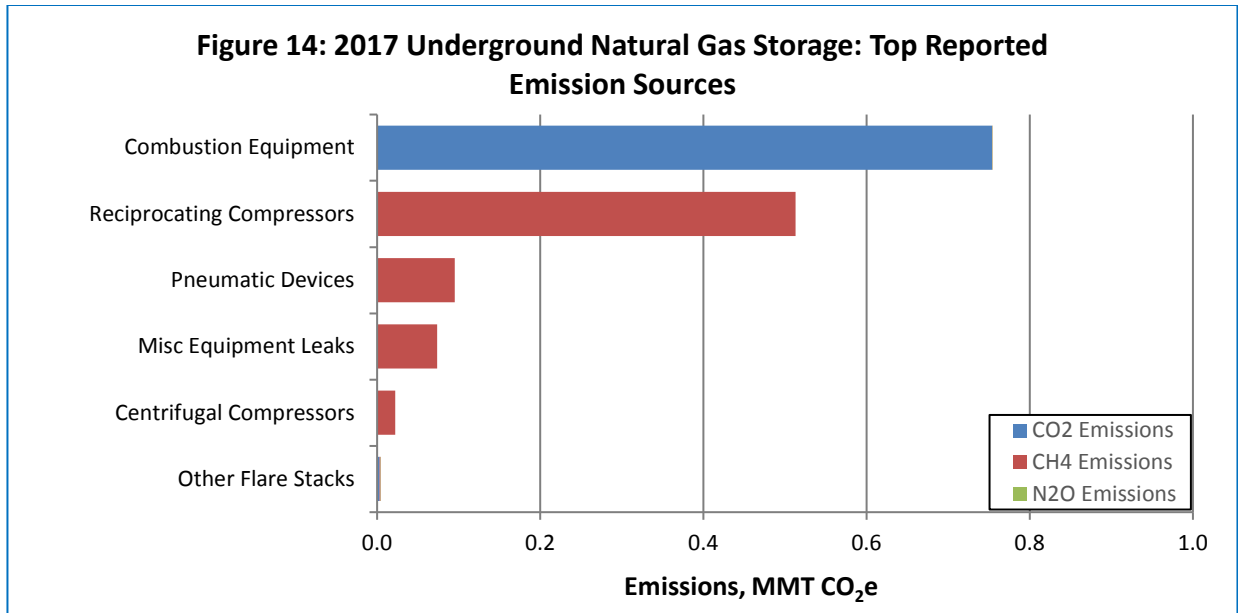
Note: Segment totals may not equal sum of individual GHGs due to independent rounding.

Natural Gas Transmission Pipeline

GHG emissions from the natural gas transmission pipeline segment were first reported in 2016. The segment contains one reported emission source, blowdown vent stacks. In 2017, the EPA received annual reports from 33 facilities in the natural gas transmission pipeline segment and reported emissions totaled 2.6 MMT CO₂e. Methane emissions totaled 2.6 MMT CO₂e and carbon dioxide emissions totaled less than 0.01 MMT CO₂e.

Underground Natural Gas Storage

The EPA received annual reports from 48 facilities in the underground natural gas storage segment and reported emissions totaled 1.5 MMT CO₂e. Methane emissions totaled 0.7 MMT CO₂e and carbon dioxide emissions totaled 0.8 MMT CO₂e. As presented in Figure 14, combustion equipment (0.8 MMT CO₂e) was the top reported source of emissions for underground natural gas storage, followed by reciprocating compressors (0.5 MMT CO₂e).



Note: Segment totals may not equal sum of individual GHGs due to independent rounding.

LNG Import/Export

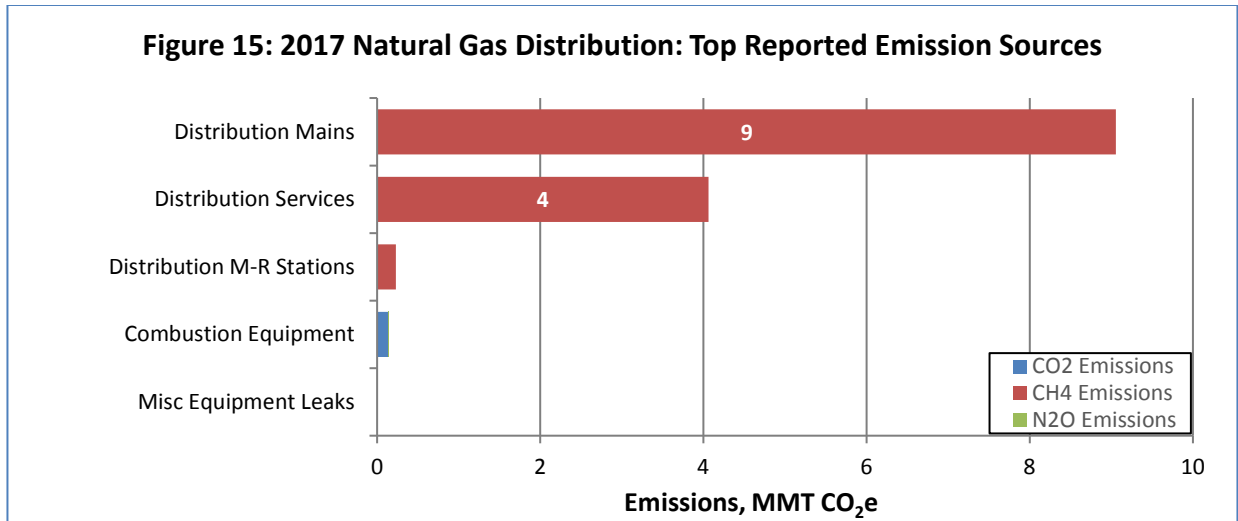
The EPA received emission reports from six LNG import/export terminals and reported emissions totaled 3.8 MMT CO₂e. Methane emissions totaled 0.04 MMT CO₂e and carbon dioxide emissions totaled 3.7 MMT CO₂e. The top reported source of emissions was combustion equipment (3.4 MMT CO₂e).

LNG Storage

The EPA received emission reports from six LNG storage facilities. Total reported emissions from LNG storage were less than 0.01 MMT CO₂e.

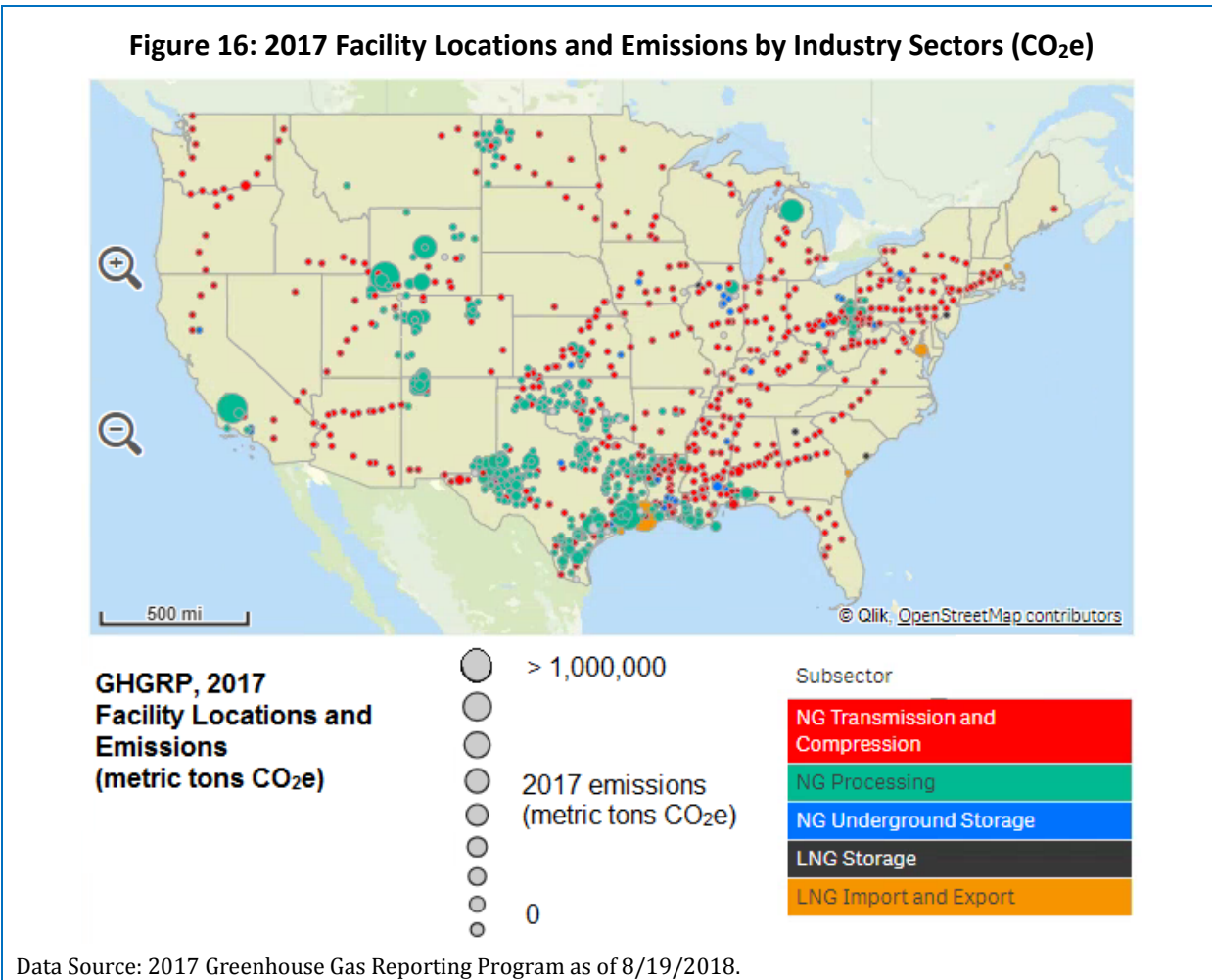
Natural Gas Distribution

The EPA received annual reports from 169 facilities in the natural gas distribution segment, and reported emissions totaled 13.5 MMT CO₂e. Methane emissions totaled 13.3 MMT CO₂e and carbon dioxide emissions totaled 0.2 MMT CO₂e. Figure 15 presents natural gas distribution emissions by source.



Note: Segment totals may not equal sum of individual GHGs due to independent rounding.

Figure 16 shows reported emissions (CO₂e) and facility locations for natural gas processing, natural gas transmission and compression, underground natural gas storage, LNG storage, and LNG import/export facilities.



Changes from 2011 to 2017

The following section describes the reported data for the 2011 through 2017 calendar years for Petroleum and Natural Gas Systems.⁶

Changes in Number of Facilities

Annual reported facility counts from 2011 to 2017 are shown in Table 2. The change in number of facilities is primarily a result of facilities reporting under two new industry segments in 2016: gathering and boosting and natural gas transmission pipeline.⁷ It should also be noted that emissions can be variable in the Petroleum and Natural Gas Systems sector and it is not unexpected that emissions for a facility may go above 25,000 metric tons CO₂e in a given year. Once the reporting threshold is triggered, facilities must report to the GHGRP until emissions are below the threshold for a period of time specified in the regulations, or until all emission sources at a facility cease operation. As a result, the number of facilities reporting to the GHGRP may vary from year-to-year.

Changes in Reported Emissions

Annual reported emissions values from 2011 to 2017 by industry segment are shown in Table 3. The largest change in total reported emissions from year to year occurred from 2015 to 2016 and is generally attributable to the addition of the two new industry segments in 2016. Other changes in emissions are the result of a number of factors, such as changes in the number of facilities, operational changes (e.g., increased flaring), calculation changes (e.g., reduced BMM use), and changes in the reporting landscape, including the addition of new industry segments and new emission sources within existing industry segments (e.g., oil well completions and workovers with hydraulic fracturing). Total reported emissions increased 1.5 percent between 2016 and 2017 while the number of facilities decreased 0.1 percent.

⁶ The EPA received resubmissions of 2011 through 2017 data from certain facilities and this section describes the 2011-2017 time series updated to include the resubmitted data.

⁷ The decrease in the number of facilities from 2015 to 2016 is mostly due to the addition of the gathering and boosting segment. For gathering and boosting, a “facility” means all gathering pipelines and other equipment located along those pipelines that are under common ownership or common control by a gathering and boosting system owner or operator and that are located in a single hydrocarbon basin. Gathering and boosting includes certain stationary and portable fuel combustion equipment emissions that may have been published for Reporting Years 2011-2015 as Other Petroleum and Natural Gas Systems and reported using a facility definition referring to all co-located emission sources that are commonly owned or operated.

Table 2: Number of Facilities by Industry Segment: 2011 to 2017

Industry Segment ¹	2011 Number of Facilities	2012 Number of Facilities	2013 Number of Facilities	2014 Number of Facilities	2015 Number of Facilities	2016 Number of Facilities	2017 Number of Facilities
Onshore Production ²	459	507	509	570	535	514	497
Offshore Production	101	108	109	129	133	137	141
Gathering and Boosting ³	N/A	N/A	N/A	N/A	N/A	301	321
Natural Gas Processing	374	403	438	479	466	447	449
Natural Gas Transmission Compression	421	458	487	522	520	526	529
Natural Gas Transmission Pipeline ³	N/A	N/A	N/A	N/A	N/A	27	33
Underground Natural Gas Storage	49	52	51	54	53	53	48
LNG Import/Export	8	8	8	8	7	6	6
LNG Storage	6	5	5	5	7	6	6
Natural Gas Distribution	183	183	176	181	177	170	169
Other Oil and Gas Combustion ⁴	338	388	419	490	544	91	79
Total	1,921	2,096	2,187	2,419	2,419	2,256	2,253

Notes:

1. Total number of facilities is smaller than the sum of facilities from each segment because some facilities reported under multiple segments. A facility is included in the count of number of facilities if it reported emissions (even if the reported emissions were zero) under a given segment.
2. Beginning in Reporting Year 2016, Onshore Production facilities began reporting emissions from oil well completions and workovers with hydraulic fracturing. These emissions were not reported for prior reporting years.
3. This industry segment began reporting data for the first time in Reporting Year 2016.
4. Beginning in Reporting Year 2016, facilities that met the definition of Gathering and Boosting reported emissions for applicable sources. This includes certain stationary and portable fuel combustion equipment emissions that may have been published for Reporting Years 2011-2015 as Other Petroleum and Natural Gas Systems.

Table 3: Reported Emissions by Industry Segment: 2011 to 2017

Industry Segment	2011 Reported Emissions (MMT CO ₂ e)	2012 Reported Emissions (MMT CO ₂ e)	2013 Reported Emissions (MMT CO ₂ e)	2014 Reported Emissions (MMT CO ₂ e)	2015 Reported Emissions (MMT CO ₂ e)	2016 Reported Emissions (MMT CO ₂ e)	2017 Reported Emissions (MMT CO ₂ e)
Onshore Production ¹	92	93	98	102	101	85	94
Offshore Production	6	7	6	7	7	7	7
Gathering and Boosting ²	N/A	N/A	N/A	N/A	N/A	82	75
Natural Gas Processing	59	60	59	60	59	55	56
Natural Gas Transmission Compression	24	24	23	22	23	22	24
Natural Gas Transmission Pipeline ²	N/A	N/A	N/A	N/A	N/A	3	3
Underground Natural Gas Storage	2	2	2	2	2	1	1
LNG Import/Export	1	1	<1	1	1	2	4
LNG Storage	<1	<1	<1	<1	<1	<1	<1
Natural Gas Distribution	16	15	15	15	14	14	13
Other Oil and Gas Combustion ³	23	25	24	28	29	7	7
Total	222	226	228	235	235	280	284

Notes:

1. Beginning in Reporting Year 2016, Onshore Production facilities began reporting emissions from oil well completions and workovers with hydraulic fracturing. These emissions were not reported for prior reporting years.
2. This industry segment began reporting data for the first time in Reporting Year 2016.
3. Beginning in Reporting Year 2016, facilities that met the definition of Gathering and Boosting reported emissions for applicable sources. This includes certain stationary and portable fuel combustion equipment emissions that may have been published for Reporting Years 2011-2015 as Other Petroleum and Natural Gas Systems.

Additional Information

[Access GHGRP data.](#)

[Access additional information about Petroleum and Natural Gas Systems in the GHGRP, including reporting requirements and calculation methods.](#)

[Access the GHGRP Petroleum and Natural Gas Systems Data Highlights Page.](#)

[Access Facility Level Information on Greenhouse Gases Tool \(FLIGHT\).](#)

Glossary

IPCC AR4 refers to the Fourth Assessment Report by the Intergovernmental Panel on Climate Change. *Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, Pachauri, R.K. and Reisinger, A. (eds)]. IPCC, Geneva, Switzerland, 2007.* The AR4 values also can be found in the current version of Table A-1 in subpart A of 40 CFR part 98.

IPCC AR5 refers to the Fifth Assessment Report by the Intergovernmental Panel on Climate Change. *Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Stocker, T.F., D. Qin, G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley (eds)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.*