

Greenhouse Gas Reporting Program
Industrial Profile: Petroleum Refineries Sector

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PETROLEUM REFINERIES SECTOR

Highlights

- The Petroleum Refineries Sector is the fourth-largest greenhouse gas (GHG) emitting industrial sector among stationary sources behind Power Plants, Petroleum and Natural Gas Systems, and Chemicals, respectively.
- The Petroleum Refineries Sector is the second-highest ranked sector in terms of GHG emissions per facility, with an average of 1.23 million metric tons of carbon dioxide equivalent (MMT CO_{2e}), behind only Power Plants.
- The largest source of emissions in the Petroleum Refineries Sector is stationary fuel combustion, representing about two-thirds of GHG emissions in 2017.
- Emissions from this sector have remained fairly consistent over the past six years, decreasing by 0.4% from 2011 to 2017, with a low of 172.6 MMT CO_{2e} in 2012 to a high of 179.3 MMT CO_{2e} in 2016.
- In 2017, 62% of the emissions from the Petroleum Refineries Sector came from facilities in Texas, Louisiana, and California.

All emissions presented here are as of 8/19/2018 and exclude biogenic carbon dioxide (CO₂). All GHG emission data displayed in units of CO_{2e} reflect the global warming potential (GWP) values from the Intergovernmental Panel on Climate Change's Fourth Assessment Report ([IPCC AR4](#)).

About this Sector

The Petroleum Refineries Sector consists of facilities that produce gasoline, gasoline blending stocks, naphtha, kerosene, distillate fuel oils, residual fuel oils, lubricants, or asphalt (bitumen) by the distillation of petroleum or the re-distillation, cracking, or reforming of unfinished petroleum derivatives. Petroleum refineries emit GHGs from various processes, including but not limited to, venting, flares, and fugitive leaks from equipment (e.g., valves, flanges, pumps).

In addition to emissions from petroleum refining processes, this sector includes combustion emissions from stationary combustion units, except for electricity generating units (Subpart D), the emissions of which are included in the Power Plant Sector. Emissions from hydrogen production plants located at refineries are included in the Non-Fluorinated Chemicals Sector. Emissions from industrial waste landfills and industrial wastewater treatment at these facilities are included in the Waste Sector. Most petroleum refineries also report as suppliers of petroleum products and a few petroleum refineries also report as suppliers of CO₂.

Who Reports?

As shown in Table 1, refineries began reporting to the Greenhouse Gas Reporting Program (GHGRP) in 2010. The refineries required to report to the GHGRP include all of the refineries in the US and all of the GHG emissions from the sector (see Table 2). In 2017, as shown in Tables 3 and 4, 144 facilities in the Petroleum Refineries Sector reported GHG emissions of 177.4 MMT CO_{2e}. The Petroleum Refineries Sector reflects 1.9% of the facilities reporting direct emissions to the GHGRP. In 2017, the Petroleum Refineries Sector represented 2.7% of total U.S. GHG emissions.¹

¹ The total U.S. GHG emissions are 6,456.72 MMT CO_{2e}, as reported in the *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2017*. EPA 430-R-19001. U.S. Environmental Protection Agency. Available: <https://www.epa.gov/ghgemissions/inventory-us-greenhouse-gas-emissions-and-sinks-1990-2017>.

Table 1: Petroleum Refineries Sector – Reporting Schedule by Subpart

Subpart	Source Category	Applicability	First Reporting Year
Y	Petroleum refineries	All facilities	2010

Table 2: Petroleum Refineries Sector – GHGRP Coverage (as of Reporting Year 2017)

Source Category	GHGRP Coverage of Industry	Estimated Percent of Industry Facilities Covered by GHGRP	Estimated Percent of Industry GHG Emissions Covered by GHGRP
Petroleum refineries	All facilities	100%	100%

Table 3: Petroleum Refineries Sector– Number of Reporters (2015–2017)

Petroleum Refineries Sector	Number of Reporters		
	2015	2016	2017
Petroleum refineries	144	144	144

Reported Emissions

Table 4: Petroleum Refineries Sector– Emissions (2015–2017)

Sector	Emissions (MMT CO _{2e})		
	2015	2016	2017
Petroleum refineries	175.3	179.3	177.4

Reported Process Emission Sources

Figure 1 shows the Petroleum Refineries Sector emissions by source for 2017. The largest sources of GHG emissions at petroleum refineries are stationary fuel combustion units (e.g., steam boilers, process furnaces, process heaters). The Petroleum Refineries Sector also reports process emissions from catalytic cracking and reforming units, fluid and delayed coking units, coke calcining units, asphalt blowing operations, blowdown systems, storage tanks, equipment leaks, loading operations, flares, sulfur recovery plants, and process vents. Table 5 shows total reported emissions from process emissions and fuel combustion.

Table 5: Petroleum Refineries – Emissions from Fuel Combustion and Other Processes^{a, b}

Fuel Type	Total Reported Emissions (MMT CO _{2e})		
	2015	2016	2017
Fuel combustion	120.9	122.8	122.0
Process emissions	54.4	56.5	55.1
Sorbent ^c	**	**	**

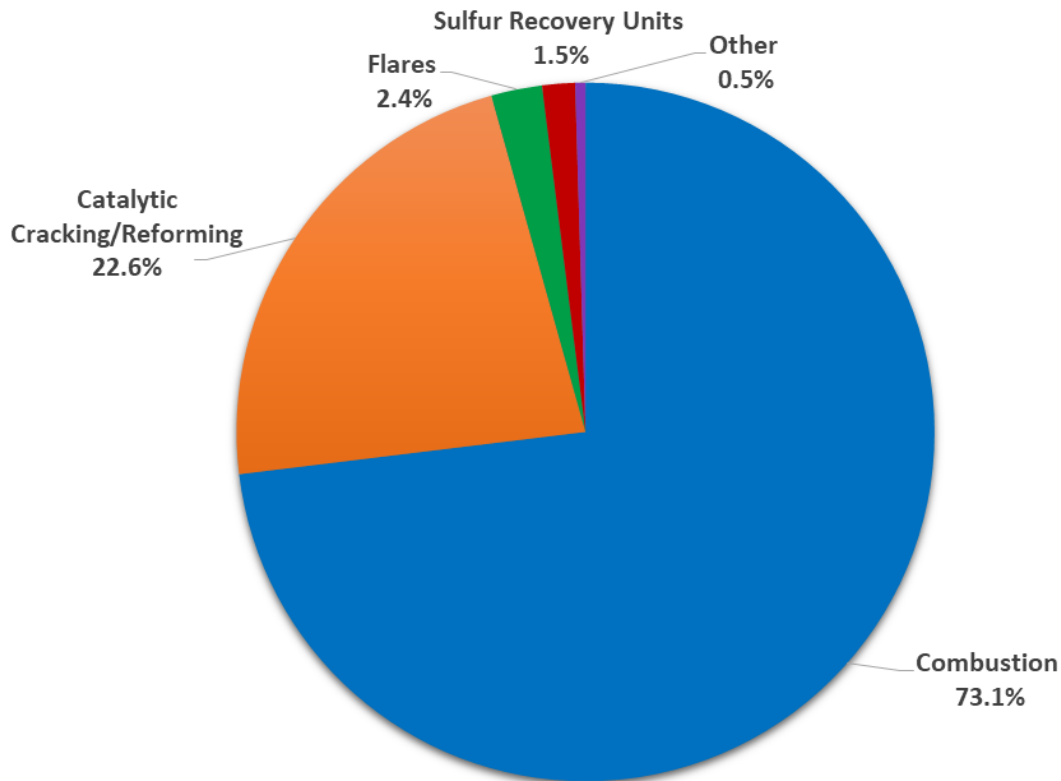
^a Emissions from fuel combustion are defined here as emissions reported under Subpart C. Emissions from other processes are reported under Subpart Y.

^b Emission values presented may differ slightly from other publicly available GHGRP data due to minor differences in the calculation methodology. Sums of individual rows might not match totals sector emissions due to individual rounding.

^c Does not include sorbent emissions monitored by a continuous emission monitoring system (CEMS).

** Total reported emissions are less than 0.05 MMT CO_{2e}.

 **FIGURE 1: 2017 PETROLEUM REFINERIES SECTOR: EMISSIONS BY SOURCE^{a, b}**



^a Emissions from fuel combustion are defined here as emissions reported under Subpart C, and emissions from other processes are reported under Subpart Y.

^b “Other Sources” include coke calcining units, process vents, uncontrolled blowdown systems, asphalt blowing operations, equipment leaks, delayed coking units, storage tanks, loading operations, and emissions from sorbent use.

Table 6 shows the total reported combustion emissions in the Petroleum Refineries Sector by fuel type. The predominant fuel used by refineries, fuel gas, is a byproduct off-gas from refining processes that is captured and used as a fuel.

Table 6: Petroleum Refineries Sector – Combustion Emissions by Fuel Type^a

Fuel Type	Total Reported Emissions (MMT CO ₂ e) ^b		
	2015	2016	2017
Coal	**	**	**
Natural gas	21.9	22.1	21.9
Petroleum products	0.8	0.8	0.7
Other fuels ^c	98.2	99.9	99.3
Total Combustion	120.9	122.8	122.0

^a In cases where CO₂ emissions were reported at the unit level (i.e., CEMS-monitored sources), fuel-level CO₂ emissions were calculated by the U.S. Environmental Protection Agency (EPA) based on other data directly reported by facilities, as well as default emission factors.

^b Sums of individual fuels might not match totals due to individual rounding.

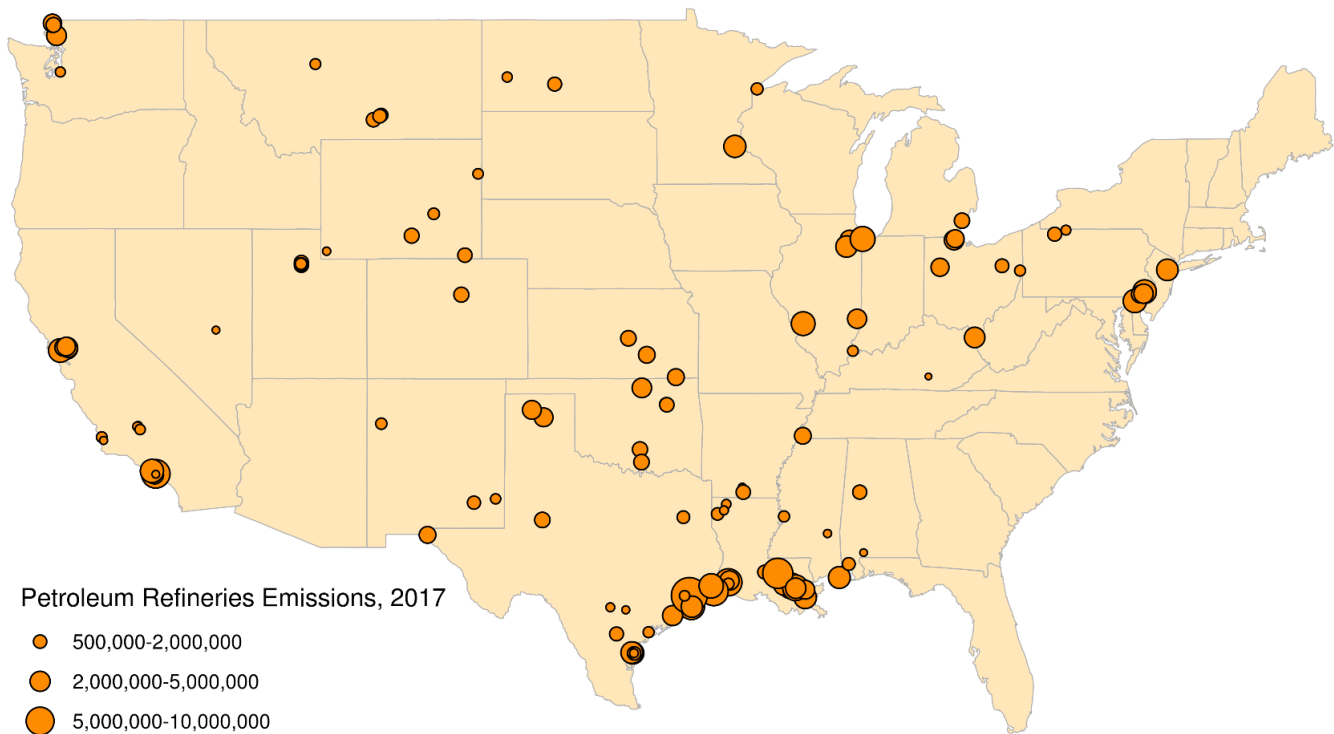
^c Excludes biogenic CO₂. The primary fuel contributing to emissions from the Other Fuels category for the Petroleum Refineries Sector is fuel gas. Fuel gas is categorized under the “Other fuels-gaseous” category within Table C-1 to Subpart C of Part 98.

** Total reported emissions are less than 0.05 MMT CO₂e.

Figure 2 shows the locations of direct-emitting facilities in the contiguous United States.



FIGURE 2: REFINERIES SECTOR: EMISSIONS BY RANGE AND LOCATION (2017)




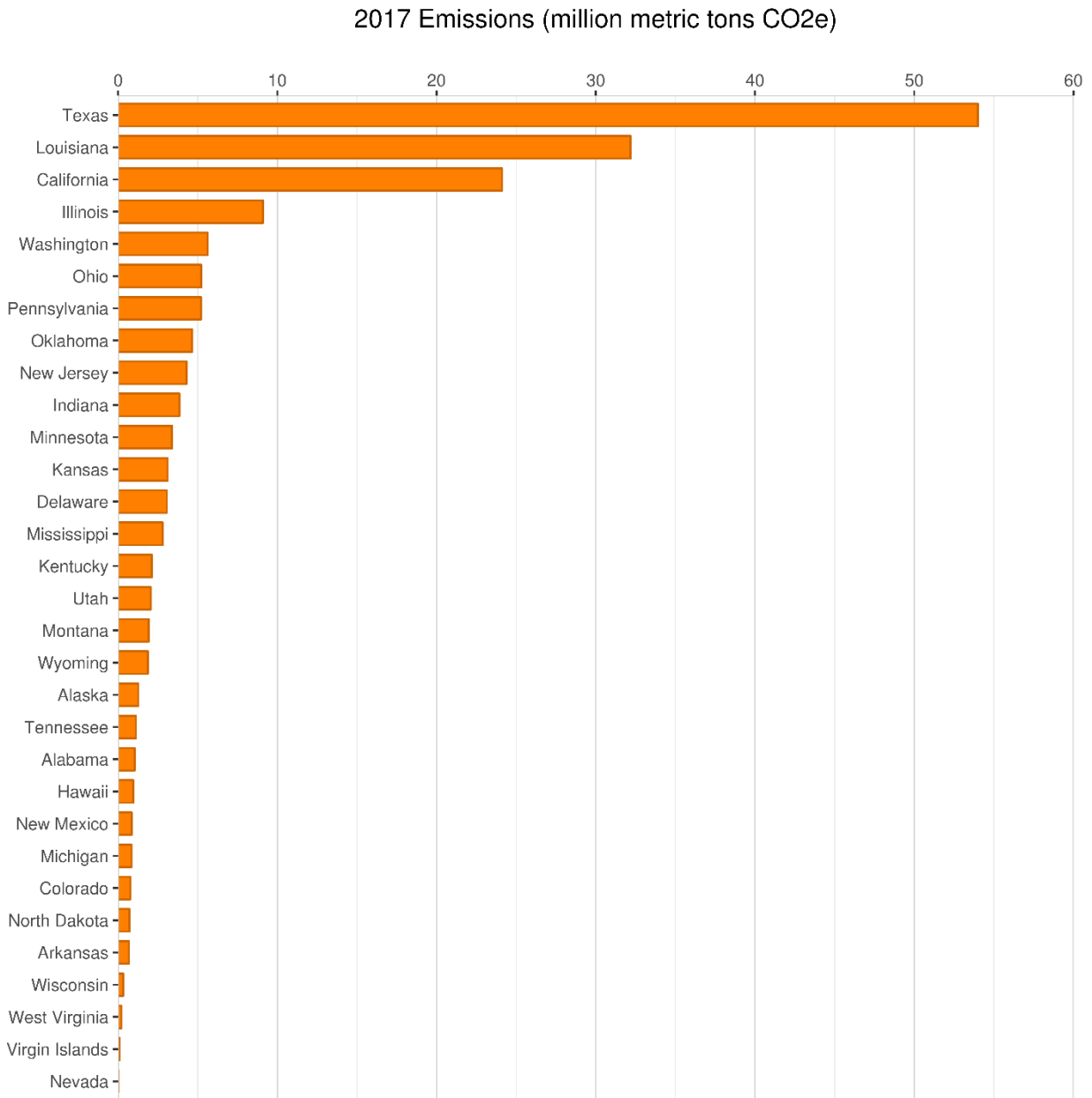
Data Source: 2017 Greenhouse Gas Reporting Program

Circle sizes in Figure 2 correspond to the quantity of emissions reported by that facility. Petroleum refineries are also located in Alaska, Hawaii, and, the U.S. Virgin Islands (<https://www.epa.gov/ghgreporting/ghgrp-refineries>).

Readers can identify the largest-emitting facilities by visiting the Facility Level Information on the Greenhouse Gases Tool (FLIGHT) website (<https://ghgdata.epa.gov/ghgp/main.do>).

Figure 3 shows the GHGRP emissions from the Petroleum Refineries Sector by state for 2017. In 2017, 62% of the emissions from the Petroleum Refineries Sector came from facilities in Texas, Louisiana, and California.

 **FIGURE 3: REFINERIES SECTOR: EMISSIONS BY STATE (2017)^a**



^a Represents total emissions reported to the GHGRP from this sector. States not shown had no petroleum refining sector emissions reported to the GHGRP in 2017.

[Click here to view the most current information using FLIGHT.](#)


Petroleum Refineries Sector: Emission Trends 2016–2017

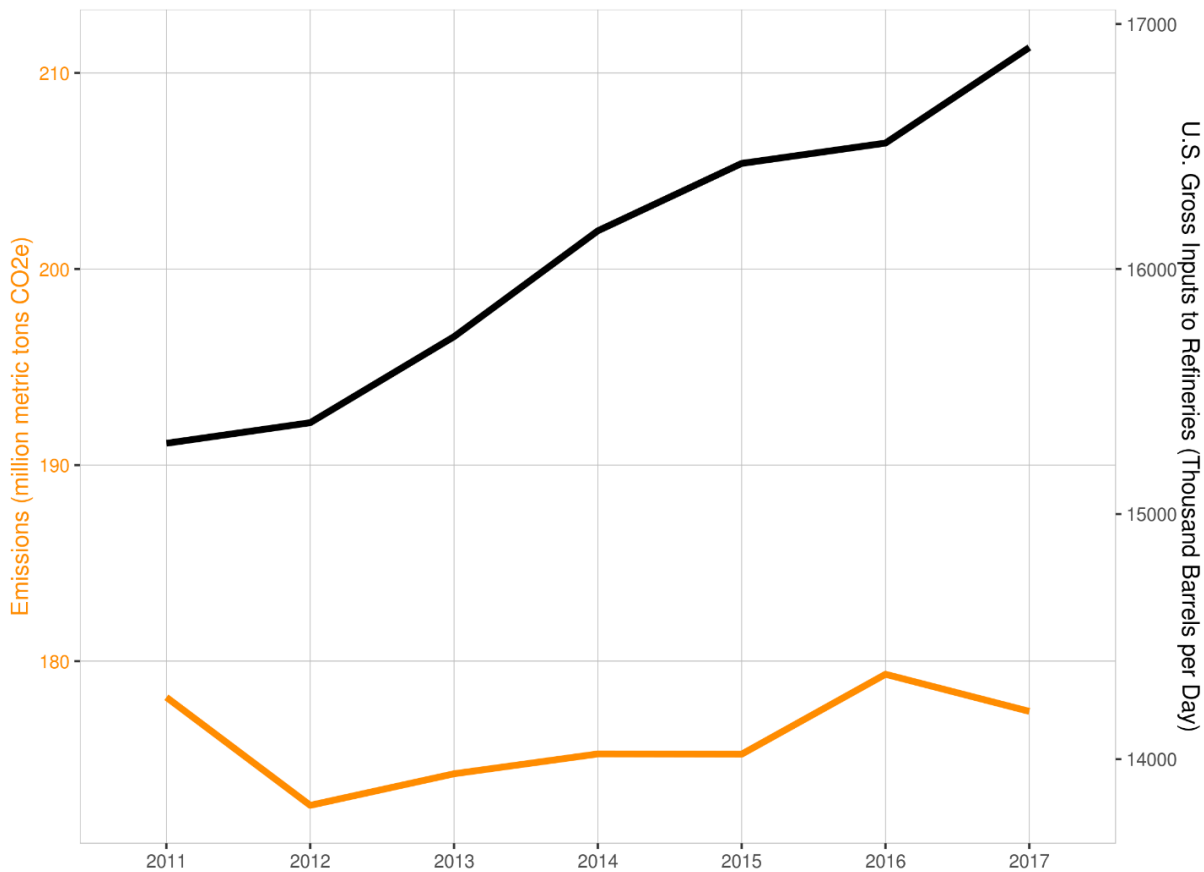
Emissions in the Petroleum Refineries Sector decreased by approximately 1.1% from 2016 to 2017, with the number of reporters over those two years remaining the same.

Petroleum Refineries Sector: Longer-Term Emission Trends

Figure 4 and Table 7 show that GHGRP emissions in the Petroleum Refineries Sector have remained in a relatively narrow range from 2011 to 2017. Emissions have ranged from a low of 172.6 MMT CO₂e in 2012 to a high of 179.3 MMT CO₂e in 2016. The number of facilities reporting under this sector has slightly declined, ranging from 150 in 2011 to 144 in 2017, with a low of 142 in 2014.

The U.S. Gross Inputs to Refineries data from the U.S. Department of Energy’s Energy Information Administration (EIA) observed a 10.6% increase in the daily average atmospheric crude input from 2011 to 2017, and a 2.9% increase from 2015 to 2017. As a result, the declining number of facilities points to a steadily increasing average refinery capacity, as the result of expansions at existing refineries over time.

 **FIGURE 4: ANNUAL REPORTED DIRECT EMISSIONS FROM THE REFINERIES SECTOR AND EIA U.S. GROSS INPUTS TO REFINERIES (2011–2017)**



^a EIA data source: <https://www.eia.gov/dnav/pet/hist/LeafHandler.ashx?n=pet&s=mgirius2&f=a>.

Table 7: Petroleum Refineries Sector – Emissions by GHG (MMT CO₂e)^a

Petroleum Refineries Sector	Reporting Year						
	2011	2012	2013	2014	2015	2016	2017
Number of facilities	150	147	146	142	144	144	144
Total emissions (MMT CO ₂ e)	178.2	172.6	174.3	175.3	175.3	179.3	177.4
Emissions by GHG							
CO ₂	176.8	171.3	173.0	174.0	173.9	178.0	176.1
Methane	0.85	0.82	0.80	0.78	0.82	0.81	0.81
Nitrous oxide	0.47	0.49	0.50	0.50	0.51	0.52	0.51

^aTotals may not sum due to independent rounding.

Figure 5 shows the average emissions per reporter for the Petroleum Refineries Sector compared with the average emissions per reporter for all direct emitters. The Petroleum Refineries Sector is the second-highest ranked sector in terms of GHG emissions per facility, with an average of 1.23 MMT CO₂e, behind only the Power Plants Sector. Figure 6 and Table 8 display the percentage of facilities reporting at different emission ranges for the Petroleum Refineries Sector and all GHG direct emitters, which show a larger percentage of refineries reporting emissions in higher emission ranges than those reported by all GHGRP direct emitters.

 **FIGURE 5: AVERAGE EMISSIONS PER REPORTER FROM THE PETROLEUM REFINERIES SECTOR (2017)**

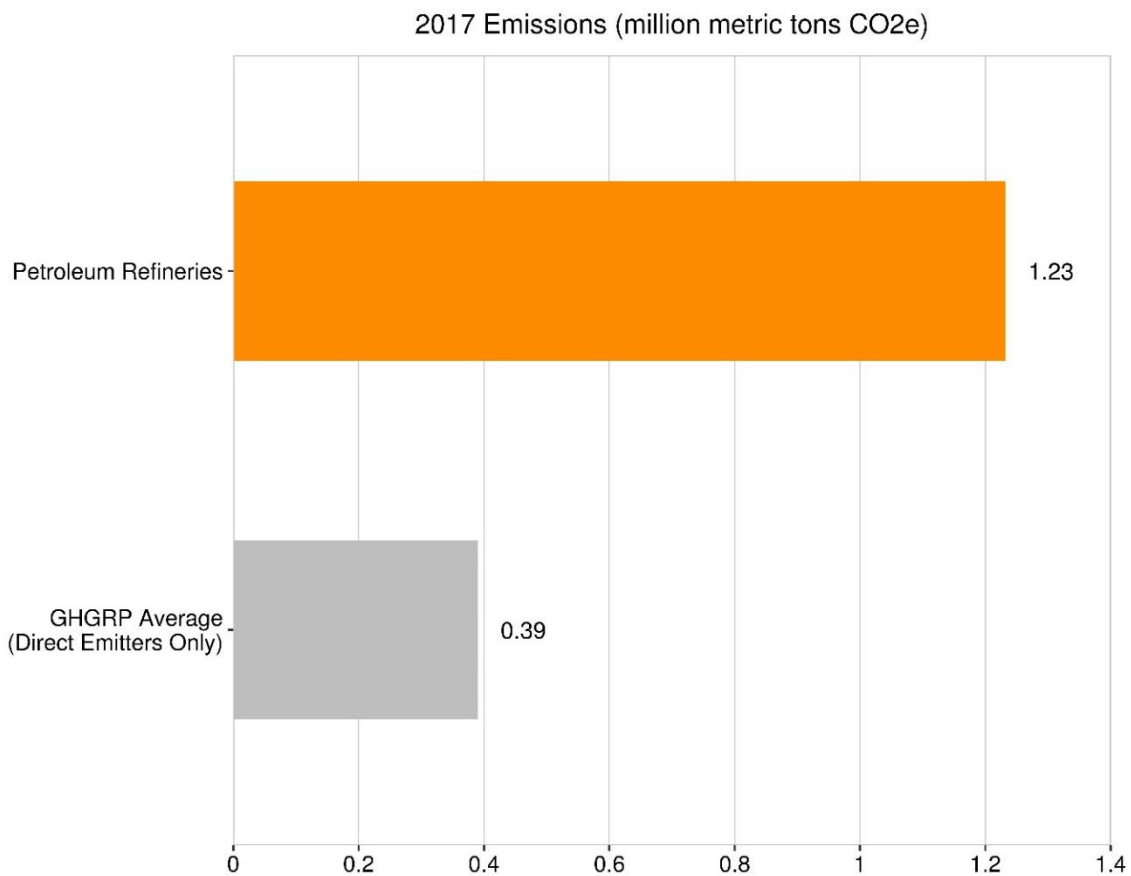




FIGURE 6: PERCENTAGE OF FACILITIES IN THE REFINERIES SECTOR AT VARIOUS EMISSION RANGES (2017)

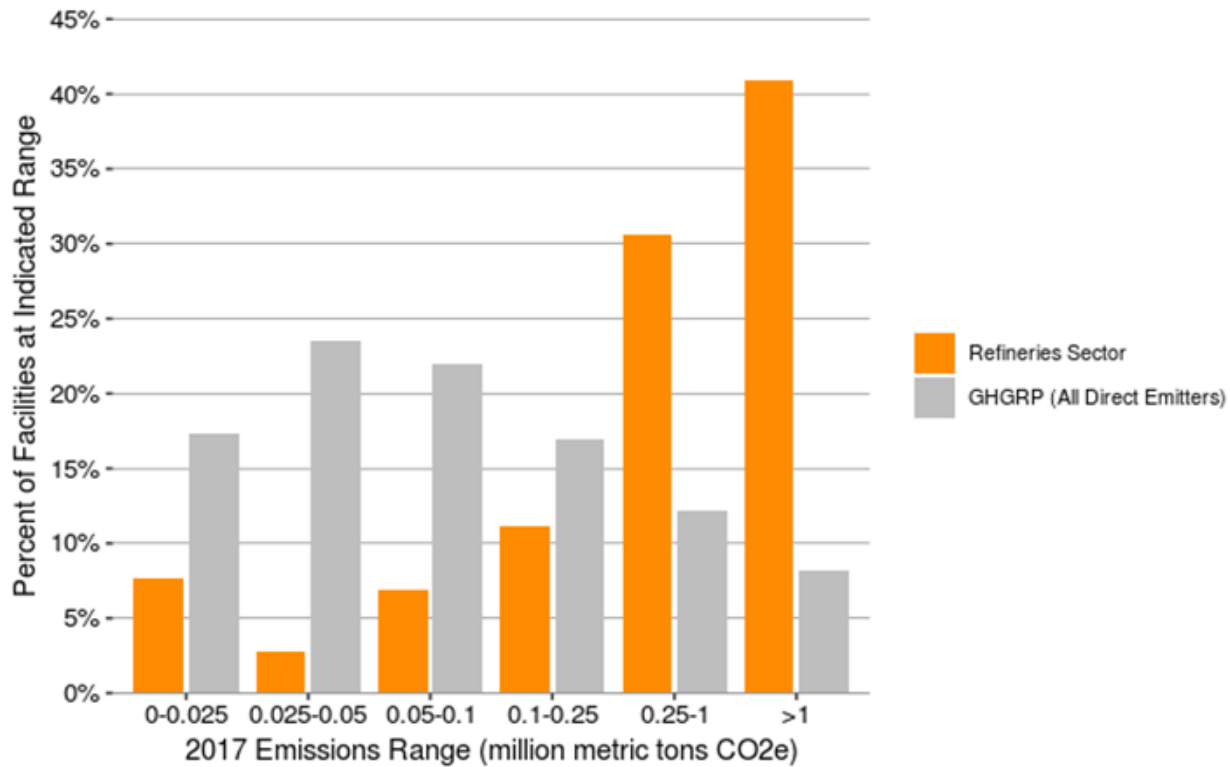


Table 8: Petroleum Refineries Sector – Number of Reporters by Emission Range (2017)

Petroleum Refineries Sector	Emission Range (MMT CO ₂ e)					
	0-0.025	0.025-0.05	0.05-0.1	0.1-0.25	0.25-1	> 1
Total refineries sector	11	4	10	16	44	59

Calculation Methods Used

Table 9 summarizes the calculation methods used by facilities in the Petroleum Refineries Sector.

Emission Calculation Methodology from Stationary Fuel Combustion Units

For fuel combustion emissions, facilities must generally follow the applicable tier methodology prescribed in Subpart C (general stationary fuel combustion sources) to calculate CO₂, methane, and nitrous oxide emissions. However, the Petroleum Refineries Sector has more stringent requirements for fuel gas, and thus the vast majority of fuel gas combustion emissions have to be calculated using Subpart C’s Tier 3 calculation methodology. The calculation methodologies for Subpart C are explained [here](#).

Table 9: Petroleum Refineries Sector Emission Calculation Methodologies

Type of Emissions	Methodology	Percent of Emissions Monitored by Method (by type)		
		2015	2016	2017
Process Emissions	CEMS	18.0%	18.4%	18.5%
	Measurement data	68.4%	68.5%	67.9%
	Engineering estimates or emission factors	13.6%	13.1%	13.6%
Combustion Emissions	CEMS (Tier 4) ^a	0.3%	0.2%	0.2%
	Measured carbon content, and, if applicable, molecular weight (Tier 3)	84.5%	85.4%	86.4%
	Measured high-heating values (HHVs) and default emission factors (Tier 2)	11.9%	11.2%	10.6%
	Default HHVs and emission factors (Tier 1)	3.3%	3.1%	2.7%

^a CEMS emissions include CO₂ from fossil fuel combustion and, if applicable, CO₂ from sorbent.

Emission Calculation Methodologies for Process Emission Sources

Process vents. The major source of process vent emissions at petroleum refineries – catalytic cracking, fluid coking, and catalytic reforming units – have the following options for calculating CO₂ emissions:

- **CEMS** – Operate a CEMS in the final exhaust stack.
- **Monitoring** – Large catalytic cracking units and fluid coking units must monitor exhaust gas oxygen, CO₂, and, if necessary, CO concentrations continuously, or no less frequently than hourly, prior to the combustion of other fossil fuels. Catalytic reforming and smaller (i.e., less than 10,000 barrels per stream day) catalytic cracking and fluid coking units have the option to measure these parameters at least daily or use an emission factor (see below).
- **Emission factor** – Catalytic cracking units and fluid coking units with rated capacities less than 10,000 barrels per stream day can calculate emissions using a coke burn-off factor and the carbon content of the coke (either the measured or default value). Catalytic reforming units, regardless of size, can also use a coke burn-off factor.

Other process emission sources. The calculation methodologies include direct measurements, engineering calculations, process knowledge, and emission factors.

Data Verification and Analysis

As a part of the reporting and verification process, EPA evaluates annual GHG reports with electronic checks. EPA contacts facilities regarding potential reporting issues and facilities resubmit reports as errors are identified. Additional information on EPA's verification process is available [here](#).

As discussed above, EPA also used an outside dataset from the Department of Energy's EIA to evaluate emissions reported to the GHGRP. This dataset may be accessed [here](#). Specifically, the

U.S. Gross Inputs to Refineries data observed a 10.6% increase in the daily average atmospheric crude input from 2011 to 2017, and a 2.9% increase from 2015 to 2017.

Glossary

CEMS means continuous emissions monitoring system.

CO_{2e} means carbon dioxide equivalent, which is a metric used to compare the emissions from various GHGs based upon their GWP. The CO₂ for a gas is calculated by multiplying the tons of the gas by the associated GWP.

Direct emitters are facilities that combust fuels or otherwise put GHGs into the atmosphere directly from their facility. Alternatively, **suppliers** are entities that supply certain fossil fuels or fluorinated gases into the economy that – when combusted, released, or oxidized – emit GHGs into the atmosphere.

Distillate fuel oil means a classification for one of the petroleum fractions produced in conventional distillation operations and from crackers and hydrotreating process units. The generic term “distillate fuel oil” includes kerosene, kerosene-type jet fuel, diesel fuels (No. 1, No. 2, and No. 4), and fuel oils (No. 1, No. 2, and No. 4).

FLIGHT refers to EPA’s GHG data publication tool, named the Facility Level Information on Greenhouse Gases Tool (<http://ghgdata.epa.gov>).

Fuel gas means gas that is generated as a byproduct at a petroleum refinery or petrochemical plant and that is combusted separately or in combination with any type of gas.

GHGRP means EPA’s Greenhouse Gas Reporting Program (40 CFR Part 98).

GHGRP vs. GHG Inventory: EPA’s Greenhouse Gas Reporting Program (GHGRP) collects and disseminates annual GHG data from individual facilities and suppliers across the U.S. economy. EPA also develops the annual Inventory of U.S. Greenhouse Gas Emissions and Sinks (GHG Inventory) to track total national emissions of GHGs to meet U.S. government commitments to the United Nations Framework Convention on Climate Change. The GHGRP and Inventory datasets are complementary; however, there are also important differences in the data and approach. For more information, please see <https://www.epa.gov/ghgreporting/greenhouse-gas-reporting-program-and-us-inventory-greenhouse-gas-emissions-and-sinks>.

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 A. Reisinger (eds.)]. IPCC, Geneva, Switzerland, 2007. The IPCC AR4 values also can be found in the current version of Table A-1 in Subpart A of 40 CFR Part 98.

MMT means million metric tons.

Naphtha is a generic term applied to a petroleum fraction of crude oil that is the raw material for gasoline.

Petroleum products mean all refined and semi-refined products that are produced at a refinery by processing crude oil and other petroleum-based feedstocks, including petroleum products derived

from co-processing biomass and petroleum feedstock together, but not including plastics or plastic products. Petroleum products may be combusted for energy use, or they may be used either for non-energy processes or as non-energy products. Fuel gas is included in the petroleum product fuel category for all sectors other than petrochemical production. For petrochemical production, fuel gas is classified separately.

Residual fuel oil refers to fuel oils No. 5 and No. 6.