2011-2021 Greenhouse Gas Reporting Program Industrial Profile: Petroleum Refineries Sector

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INTRODUCTION

All emissions presented here are as of 8/12/2022 and exclude biogenic carbon dioxide (CO_2). All greenhouse gas (GHG) emission data displayed in units of carbon dioxide equivalent (CO_2e) reflect the global warming potential (GWP) values from Table A-1 of 40 CFR 98, which is generally based on the Intergovernmental Panel on Climate Change's Fourth Assessment Report (IPCC AR4).

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 highest ranked sector in terms of GHG emissions per facility, with an average of 1.2 million metric tons of carbon dioxide equivalent (MMT CO_2e).
- The largest source of emissions in the Petroleum Refineries Sector is stationary fuel combustion, representing over two-thirds of GHG emissions in 2021.
- Emissions from this sector decreased by 7.5% from 2011 to 2021, with a low of 160.8 MMT CO_2e in 2020 and a high of 182.1 MMT CO_2e in 2018.
- In 2021, 62.0% of the emissions from the Petroleum Refineries Sector came from facilities in Texas, Louisiana, and California.

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 CO_2.

Who Reports?

As shown in Table 1, refineries began reporting to the Greenhouse Gas Reporting Program (GHGRP) in 2010. When the program began in 2010, all US refinery facilities reported to the GHGRP. Due to the programs' off-ramping provisions, some refineries qualified to discontinue reporting.[1] In 2021, as shown in Tables 2 and 3, 137 facilities in the Petroleum Refineries Sector reported GHG emissions of 164.9 MMT CO_2e. The Petroleum Refineries Sector reflects 1.8% of the facilities

[1] Refer to FAQ: When is a Facility Eligible to Stop Reporting? Available at: http://www.ccdsupport.com/confluence/pages/viewpage.action?pageId=243139271.

reporting direct emissions to the GHGRP. In 2021, the Petroleum Refineries Sector represented 2.8% of total U.S. GHG emissions.[2]

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–Number of Reporters (2011–2021)

Petroleum Refineries Sector	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Petroleum refineries	150	147	146	142	144	144	144	140	138	139	137

Reported Emissions

Table 3: Petroleum Refineries Sector– Emissions (MMT CO_2e) (2011–2021)

Sector	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Petroleum refineries	178.2	172.6	174.3	175.3	176.9	180.9	179.0	182.1	177.8	160.8	164.9

Reported Emission Sources

Figure 1 shows the Petroleum Refineries Sector emissions by source for 2021. 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 flares, catalytic cracking unit, fluid and delayed coking units, catalytic reforming units, sulfur recovery plants, coke calcining units, asphalt blowing operations, process vents, uncontrolled blowdown systems, equipment leaks, storage tanks and loading operations. Table 4 shows total reported emissions from process emissions, fuel combustion, and sorbent emissions.

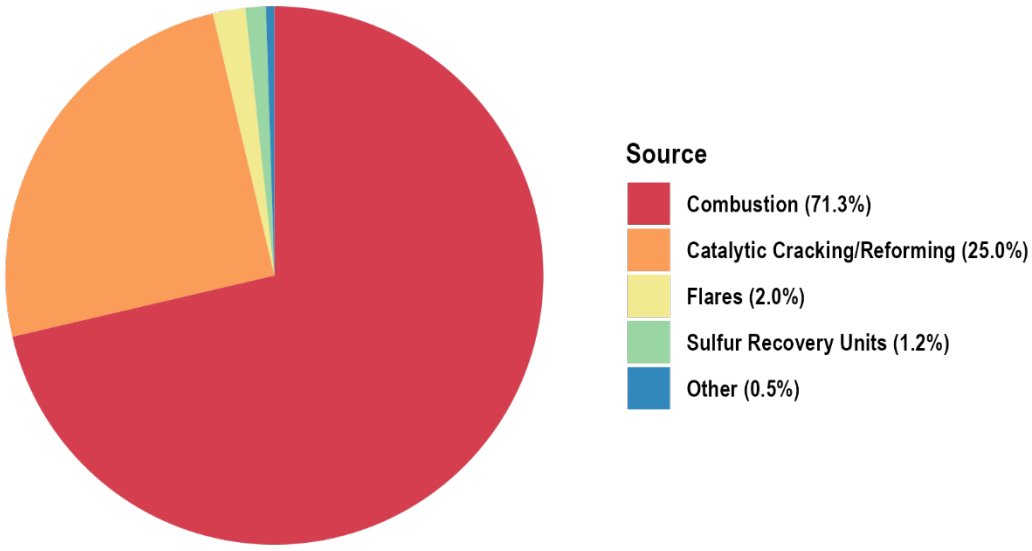
[2] Total U.S. GHG emissions for 2020 were 5,981 MMT CO_2e, as reported in the Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2020. U.S. Environmental Protection Agency. April 14, 2022. EPA 430-R-22-003. Available at: https://www.epa.gov/ghgemissions/inventory-us-greenhouse-gas-emissions-and-sinks.

Table 4: Petroleum Refineries - Emissions (MMT CO_2e) from Fuel Combustion and Other Processes [a, b]

Emissions Source Type	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Fuel Combustion	121.3	117.3	120.3	120.9	122.6	124.4	124.0	127.2	124.6	115.5	117.5
Process	56.9	55.3	53.9	54.3	54.3	56.5	55.0	54.9	53.2	45.3	47.3
Sorbent [c]	<0.05	0.0	0.0	0.0	< 0.05	< 0.05	< 0.05	< 0.05	0.0	0.0	0.0

[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).

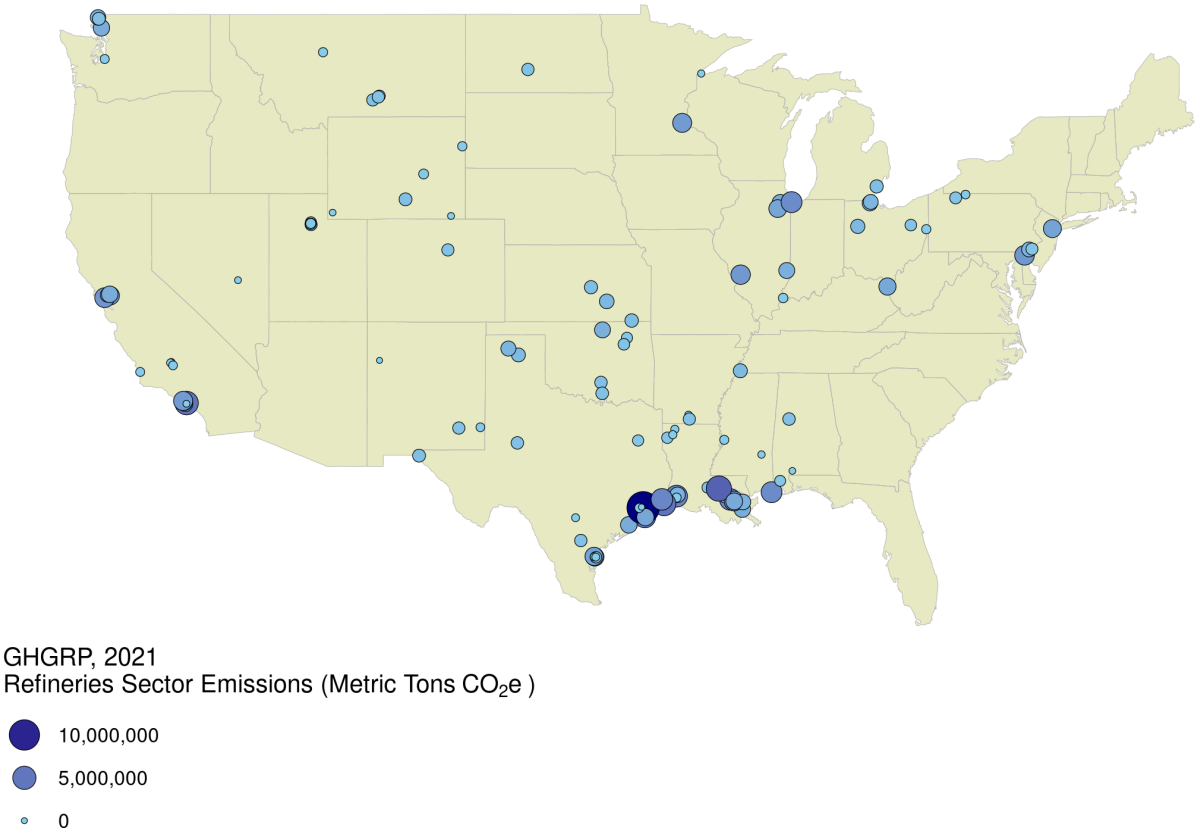
Figure 1: 2021 Petroleum Refineries Sector: Emissions by Source [a, b, c]



[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 (not including sorbent emissions monitored by a CEMS).
[c] 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.

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

Figure 2: Location and Relative Emissions for Facilities Reporting in the Petroleum Refineries Sector (2021)

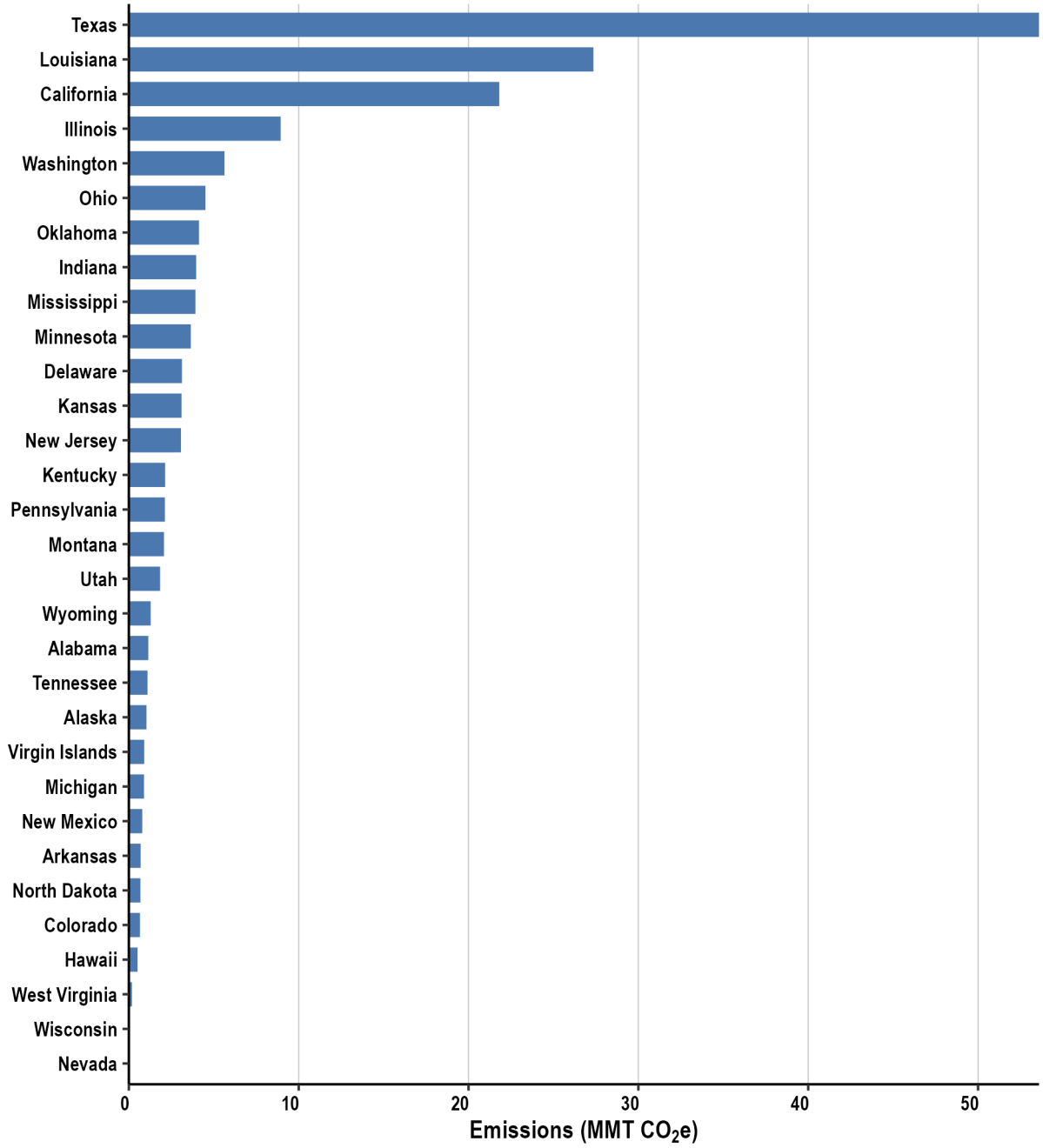


Note: Each circle on the map corresponds to a facility reporting in the petroleum refineries sector. Both the size and color of each circle are continuous gradients corresponding to a facility's emissions.

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 2021. In 2021, 62.0% of the emissions from the Petroleum Refineries Sector came from facilities in Texas, Louisiana, and California.

Figure 3: Petroleum Refineries Sector: Emissions by State (2021) [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 2021. Access the most recent data using FLIGHT.

Petroleum Refineries Sector: Emission Trends 2020 – 2021

Emissions in the Petroleum Refineries Sector increased by approximately 2.5% from 2020 to 2021, with the number of reporters decreasing 1.4% over the same timeframe.

Petroleum Refineries Sector: Longer-Term Emission Trends

GHGRP emissions reported by the refineries sector remained relatively consistent from 2011 to 2019, followed by a significant drop of nearly 10% in reported emissions in 2020 due to reduced demand during COVID-19 pandemic shutdowns. A rebound in production and associated emissions began in 2021, with emissions increasing by nearly 3% to 164.9 MMT CO_2e from the record low emissions reported to the GHGRP in 2020.

Historically, refinery emissions trends depend on three factors: the number of operating refineries, the operable capacity, and the production slate. With respect to the number of reporting facilities, the count has decreased from 150 to 137 over the last decade because some refineries closed and a few very small refineries are no longer required to report.[3] Notably, in 2021, a large refinery in Belle Chase, Louisiana operated by Phillips 66 closed due to weather related effects of Hurricane Ida while two new smaller refineries in Texas and California came online.[4] The number of refineries reporting to the GHGRP is expected to continue to decrease in the next few years.[5]

With respect to operable capacity, we found that overall operable capacity (measured in thousand barrels per calendar day) has increased by 2% over the last decade.[6] Over the last two years, however, there has been a decrease in operable capacity of nearly 4%. So, while the decades-long trend demonstrates that the expanded production capacity at existing and new refineries more than offsets production declines from refinery closures, the trend may be turning toward a sustained nationwide decline in operating capacity as a result of the expected shift toward electric vehicles and use of renewable fuels.

Finally, finished motor gasoline, distillate fuel oil, and jet fuel are the predominant fuels produced by refineries. During 2020, changes to refinery production slates were observed that are likely due to the COVID-19 pandemic. Notably, the demand for transportation fuels, specifically finished motor gasoline and jet fuel, significantly decreased in 2020. As a consequence of the decreased production of finished motor gasoline and jet fuel, we observed an increase in normalized emissions (i.e., metric tons CO_2e per gross input to refineries in thousand barrels per day) in 2020 demonstrating production inefficiencies.[7] In 2021, the production of finished motor gasoline (including motor gasoline blend components) and kerosene jet fuel increased by 7% and 28%,

[3] 40 CFR §98.2(i)(1) and (2) describe provisions under which a facility may discontinue reporting.

[4] U.S. Energy Information Administration, *U.S. refinery capacity decreased during 2021 for second consecutive year* (accessed September 19, 2022) at: https://www.eia.gov/todayinenergy/detail.php?id=52939.

[5] U.S. Energy Information Administration, *U.S. refinery capacity decreased during 2021 for second consecutive year* (accessed September 19, 2022) at: https://www.eia.gov/todayinenergy/detail.php?id=52939.

[6] U.S. Energy Information Administration, *Refinery Utilization and Capacity* (accessed September 19, 2022) at: http://www.eia.gov/dnav/pet/pet_pnp_unc_dcu_nus_a.htm.

[7] U.S. Energy Information Administration, Refinery Utilization and Capacity (accessed September 19, 2022) at: http://www.eia.gov/dnav/pet/pet_pnp_unc_dcu_nus_a.htm.

respectively.[8,9] Distillate oil production remained flat compared to 2020, decreasing by 2%.[10] These overall changes in demand resulted in a net 6% increase in refinery throughput in 2021 (measured as gross input to refineries in thousand barrels per day) as compared to 2020.[11] The normalized emissions in 2021 are consistent with pre-pandemic values indicating adjustment and stabilization of production processes in response to market conditions.
Figure 4 shows the trend of normalized emissions per gross input from 2011 to 2021, and Table 5 shows the GHGRP emissions in the Petroleum Refineries Sector have remained in a relatively narrow range from 2011 to 2021.

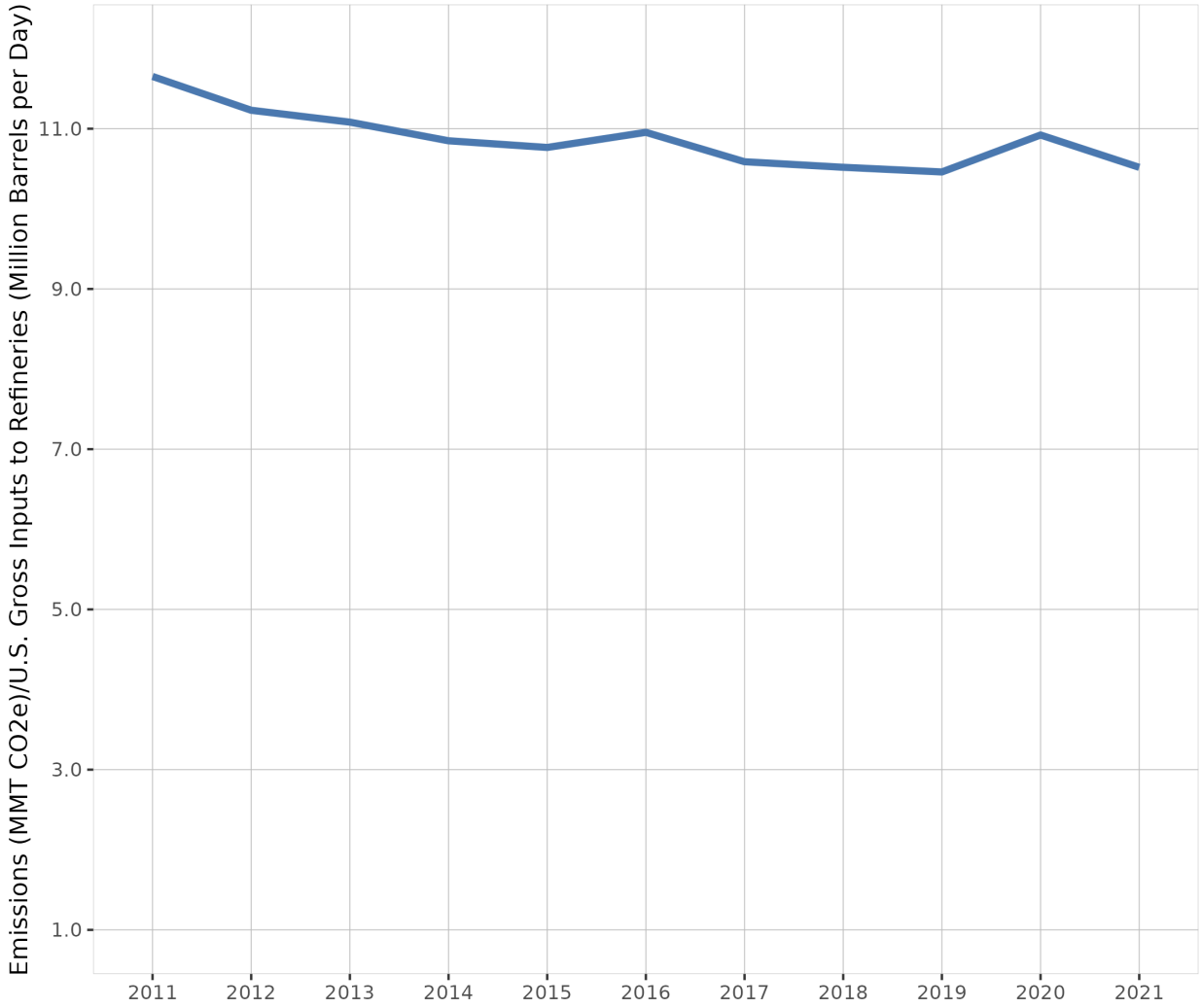
[8] U.S. Energy Information Administration, *U.S. Refinery Net Production* (accessed September 19, 2022) at: https://www.eia.gov/dnav/pet/pet_pnp_refp2_dc_nus_mbbl_a.htm .

[9] U.S. Energy Information Administration, *U.S. Refinery Net Inputs* (accessed September 28, 2022) at: https://www.eia.gov/dnav/pet/pet_pnp_inpt2_dc_nus_mbbl_a.htm.

[10] U.S. Energy Information Administration, *U.S. Refinery Net Production* (accessed September 19, 2022) at: https://www.eia.gov/dnav/pet/pet_pnp_refp2_dc_nus_mbbl_a.htm.

[11] U.S. Energy Information Administration, *Refinery Utilization and Capacity* (accessed September 19, 2022) at: http://www.eia.gov/dnav/pet/pet_pnp_unc_dcu_nus_a.htm.

Figure 4: Normalized Emissions Per Gross Input to Petroleum Refineries (2011 - 2021)[a]



[a] *EIA data source: https://www.eia.gov/dnav/pet/hist/LeafHandler.ashx?n=pet&s=mgirius2&f=a.*

Table 5: Petroleum Refineries Sector - Emissions by GHG (MMT CO_2e)

Petroleum Refineries Sector	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Carbon Dioxide	176.8	171.3	173.0	174.0	175.6	179.6	177.6	180.8	176.3	159.6	163.6
Methane	0.9	0.8	0.8	0.8	0.8	0.8	0.8	0.9	0.9	0.8	0.8
Nitrous Oxide	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.4	0.5

Average and Range of Emissions per Reporter

Figure 5 shows the average emissions per reporter for the Petroleum Refineries Sector compared with the average emissions per reporter for all GHGRP direct emitters. The Petroleum Refineries Sector is the highest ranked sector in terms of GHG emissions per facility, with an average of 1.2 MMT CO_2e, just overtaking the Power Plants Sector in 2021. Figure 6 and Table 6 display the percentage and numbers of facilities reporting at different emission ranges, respectively. Figure 6 additionally shows a comparison to the GHGRP overall. Figure 6 shows 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 (2021)

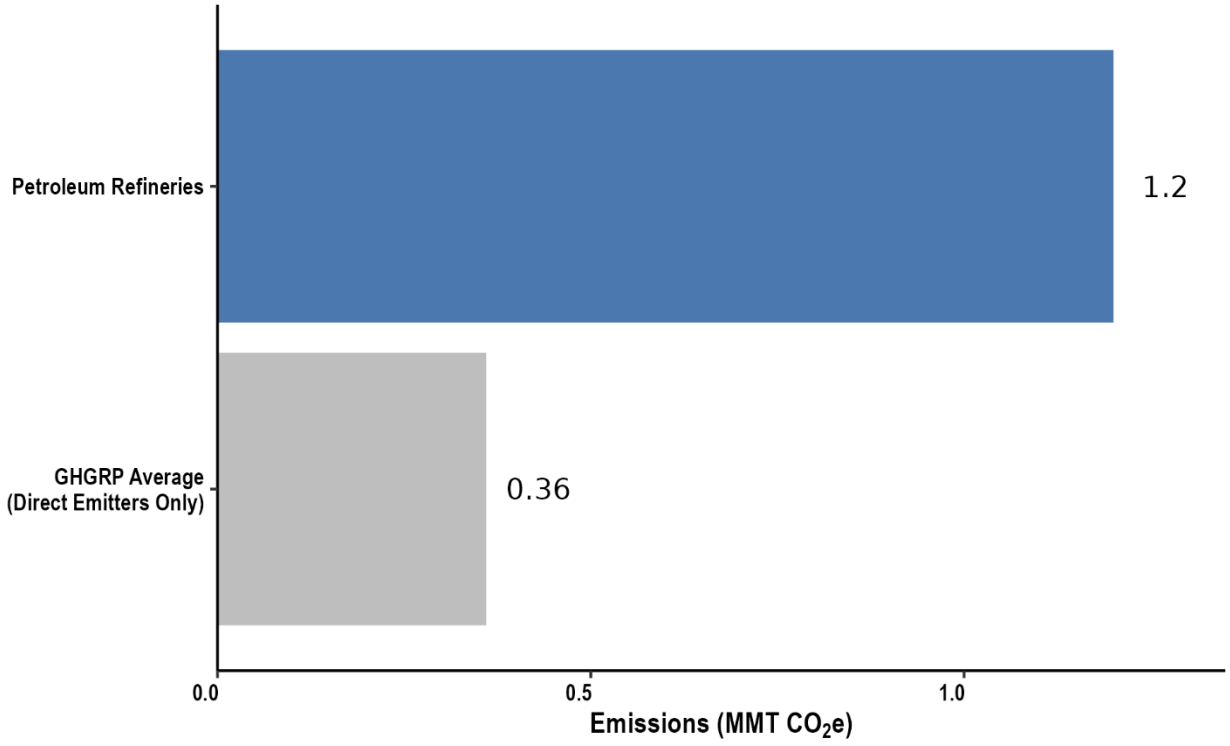


Figure 6: Percentage of Facilities in the Petroleum Refineries Sector by Emission Ranges (2021)

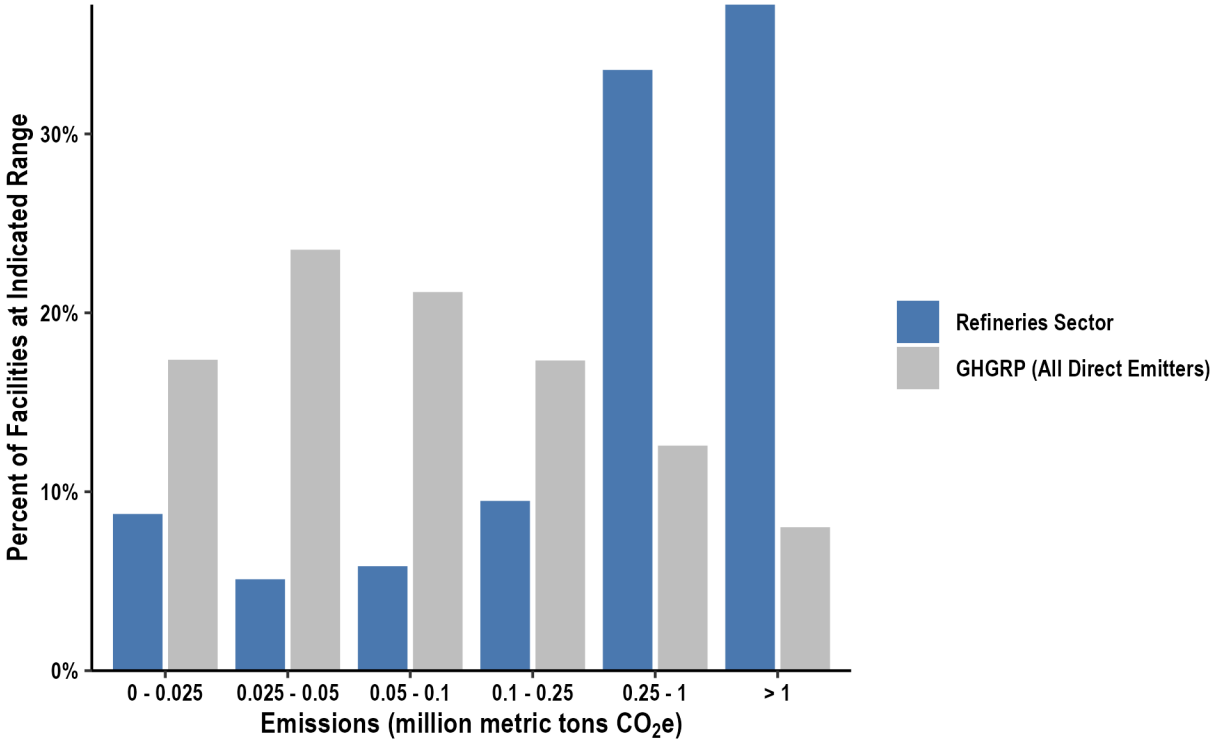


Table 6: Petroleum Refineries Sector - Number of Reporters by Emission Ranges (MMT) (2021)

Petroleum Refineries Sector	0 - 0.025	0.025 - 0.05	0.05 - 0.1	0.1 - 0.25	0.25 - 1	> 1
Total refineries sector	12	7	8	13	46	51

Calculation Methods Used

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 CO_2, 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.

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 CO_2 emissions:

- **CEMS** - Operate a CEMS in the final exhaust stack.

- **Monitoring** – Large catalytic cracking units and fluid coking units must monitor exhaust gas oxygen, CO_2, 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.

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 CO_2 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.