2011-2020 Greenhouse Gas Reporting Program Sector Profile: Petroleum Refineries Sector

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INTRODUCTION

All emissions presented here are as of 8/8/2021 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 1.15 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 2020.
- Emissions from this sector decreased by 9.7% from 2011 to 2020, with a low of 160.9 MMT CO_2e in 2020 and a high of 182.5 MMT CO_2e in 2018.
- In 2020, 62.5% 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 program's off-ramping provisions, some refineries qualified to discontinue reporting.[1] In 2020,

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

as shown in Tables 2 and 3, 140 facilities in the Petroleum Refineries Sector reported GHG emissions of 160.9 MMT CO_2e. The Petroleum Refineries Sector reflects 1.8% of the facilities reporting direct emissions to the GHGRP. In 2020, the Petroleum Refineries Sector represented 2.5% 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 (2011–2020)

Petroleum Refineries Sector	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Petroleum refineries	150	147	146	142	144	144	144	141	139	140

Reported Emissions

Table 3: Petroleum Refineries Sector– Emissions (MMT) (2011–2020)

Sector	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Petroleum refineries	178.2	172.6	174.3	175.3	176.9	180.9	179.2	182.5	178.1	160.9

Reported Emission Sources

Figure 1 shows the Petroleum Refineries Sector emissions by source for 2020. 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 and fuel combustion.

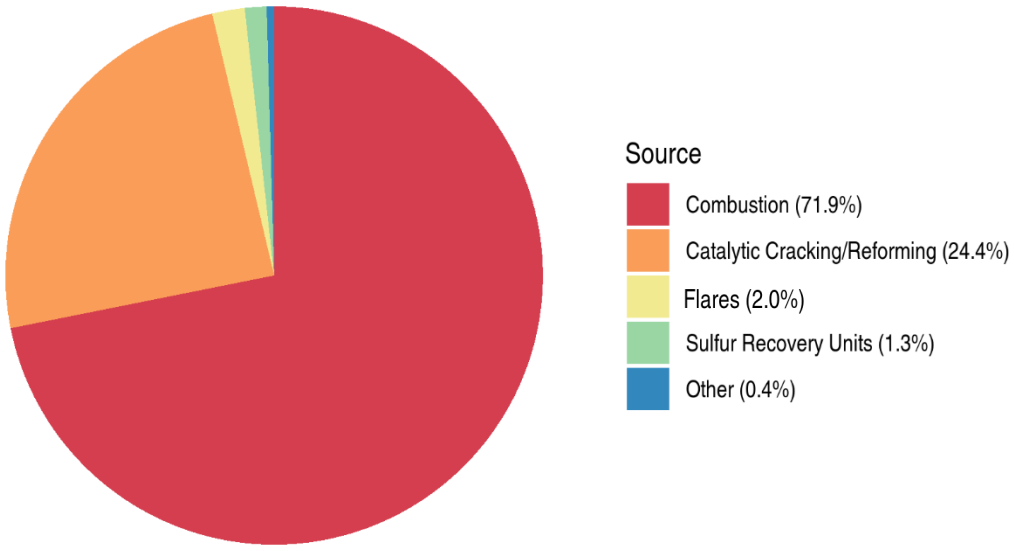
[2] Total U.S. GHG emissions for 2019 were 6,558 MMT CO_2e, as reported in the Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2019. U.S. Environmental Protection Agency. April 14, 2021. EPA 430-R-21-005. Available at: https://www.epa.gov/ghgemissions/inventory-us-greenhouse-gas-emissions-and-sinks.

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
Fuel Combustion	121.3	117.3	120.3	120.9	122.6	124.4	124.0	127.4	124.8	115.5
Process	56.9	55.3	53.9	54.3	54.3	56.5	55.2	55.1	53.3	45.4
Sorbent[c]	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05

[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).

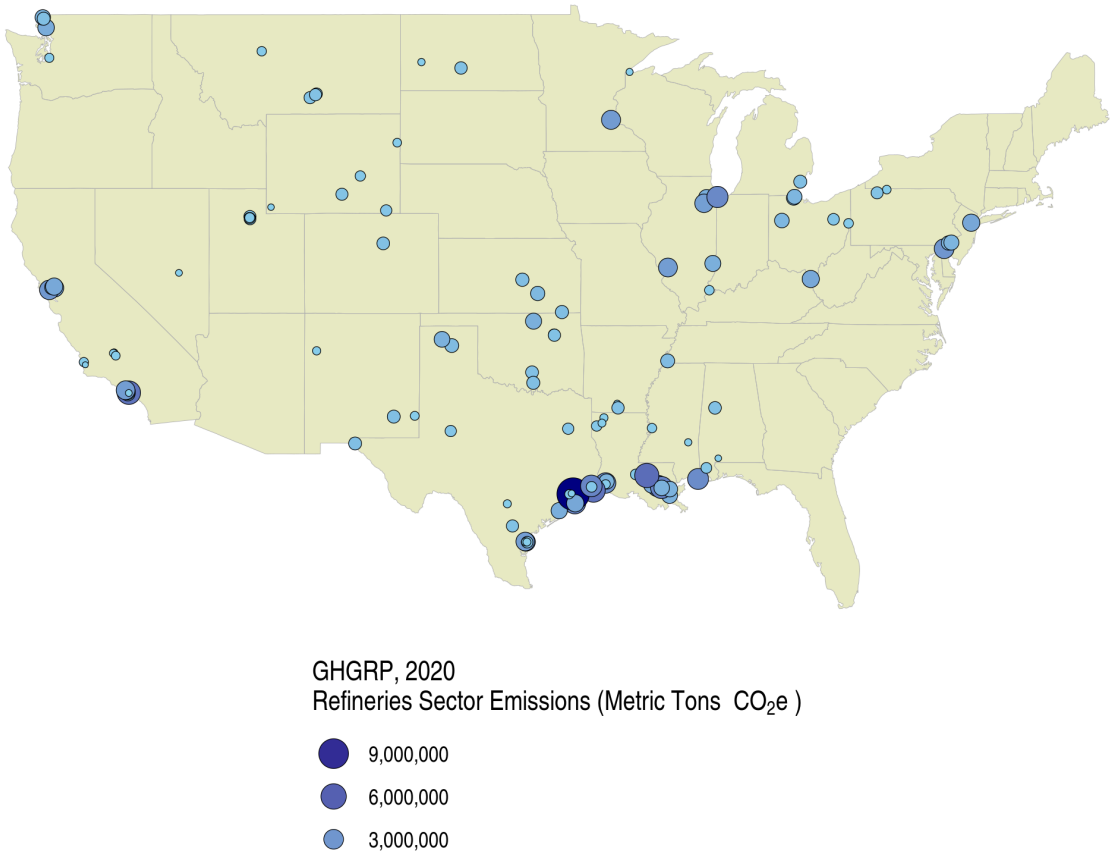
Figure 1: 2020 Petroleum Refineries Sector: Emissions by Source [a, b, c]



[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.
[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.

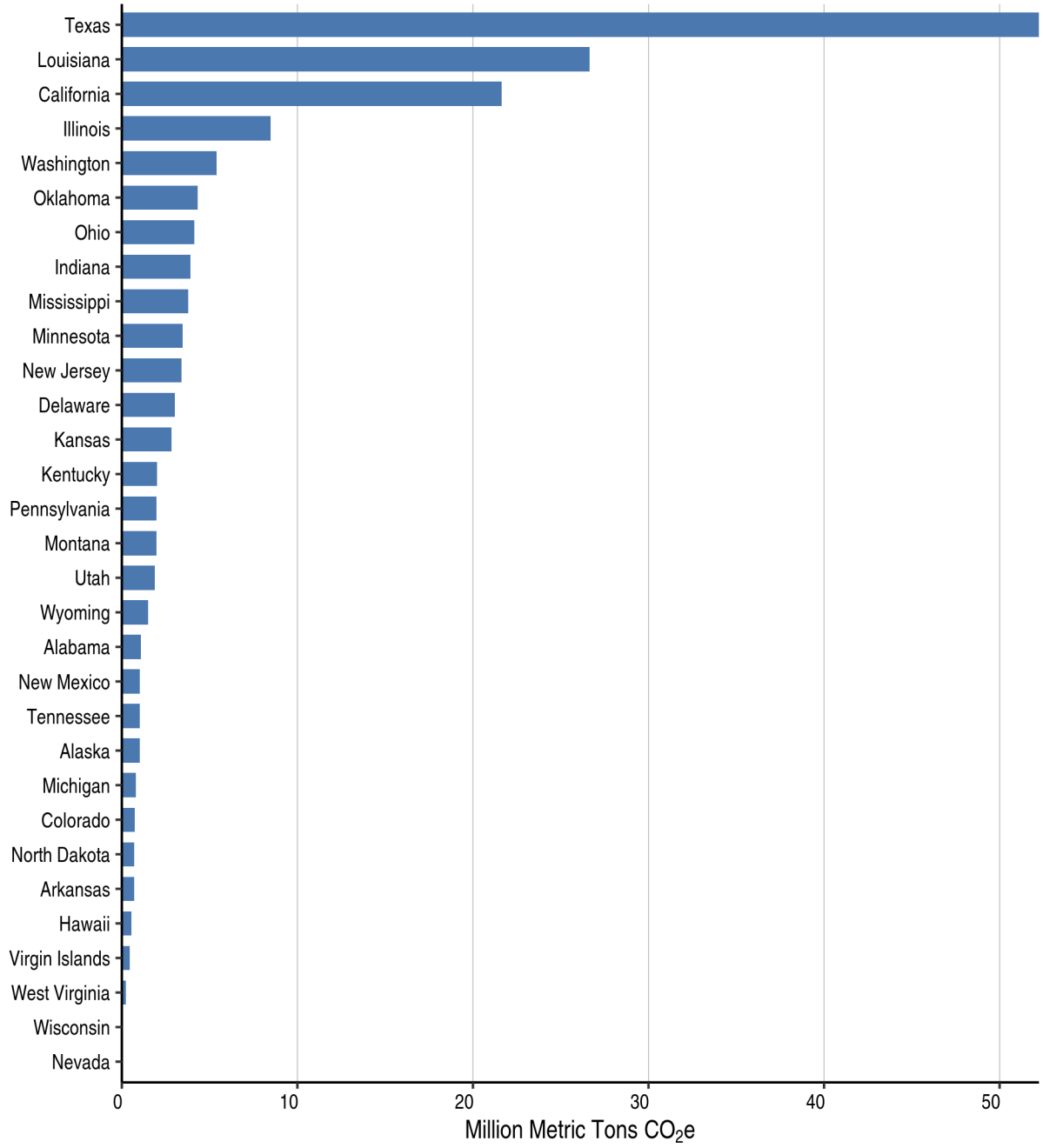
Figure 2: Petroleum Refineries Sector: Emissions by Range and Location (2020)



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 2020. In 2020, 62.5% of the emissions from the Petroleum Refineries Sector came from facilities in Texas, Louisiana, and California

Figure 3: Petroleum Refineries Sector: Emissions by State (2020) [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 2020. Click here to view the most current information using FLIGHT.

Petroleum Refineries Sector: Emission Trends 2019 - 2020

Emissions in the Petroleum Refineries Sector decreased by approximately 9.7% from 2019 to 2020, with the number of reporters increasing 0.7% over those two years.

Petroleum Refineries Sector: Longer-Term Emission Trends

Reported emissions in the refineries sector remained relatively consistent from 2011 to 2019, followed by a drop in reported emissions in 2020. Prior to 2020, refinery emissions ranged from a minimum of 172.6 million metric tons (MMT) CO_2e in 2012 to a maximum of 182.5 MMT CO_2e in 2018. A slight decrease in emissions of 0.1% was observed in the 2011 (178.2 MMT CO_2e) through 2019 (178.1 MMT CO_2e) time series. Reported emissions decreased to 160.9 MMT CO_2e in 2020, a decrease of 9.7% from 2019.

Historically, refinery emissions trends depend on the number of operating refineries, the operable capacity, and the production slate. With respect to these three factors, we note the number of reporting facilities decreased from 150 in 2011 to 140 in 2020 because some facilities closed and a few very small facilities were no longer required to report.[3] The COVID-19 pandemic created challenging market conditions for refinery operators and resulted in the closure of a handful of facilities.[4] The number of reporting facilities is expected to continue to decrease in 2021.

With respect to operable capacity, we found that overall operable capacity (measured in thousand barrels per calendar day[5]) increased by 5.2% from 2011 to 2020. This data demonstrates that the expanded production capacity at existing refineries more than offset production declines from refineries that closed.

Finally, finished motor gasoline, distillate fuel oil, and jet fuel are the predominant fuels produced by refineries. During 2020, there were observed changes to refinery production slates due to the COVID-19 pandemic. Notably, the demand for transportation fuels, specifically finished motor gasoline and jet fuel, significantly decreased in 2020. These reductions in demand resulted in a 13.4% decrease in refinery throughput (measured as gross input to refineries in thousand barrels per day[6]) as compared to 2019. To adjust for lower demand, refineries shifted the production mix at domestic refineries[7] and likely had operational changes such as idling units and units running below capacity. These changes in refinery operations appear to have decreased the efficiency of refinery processes, resulting in an increase in normalized emissions per gross input (metric tons CO_2e per gross input to refineries in thousand barrels per day[8]) for 2020. In 2020, normalized emissions per gross input increased 4.3% as compared to 2019. The 2020 normalized emissions per gross input are inconsistent with the historical time series trend. Historically a reduction in

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

[4] U.S. Energy Information Administration, Refinery closures decreased U.S. refinery capacity during 2020 (accessed September 20, 2021) at: https://www.eia.gov/todayinenergy/detail.php?id=48636

[5] U.S. Energy Information Administration, Refinery Utilization and Capacity (accessed September 16, 2021) at: http://www.eia.gov/dnav/pet/pet_pnp_unc_dcu_nus_a.htm.

[6] U.S. Energy Information Administration, Refinery Utilization and Capacity (accessed September 16, 2021) at: http://www.eia.gov/dnav/pet/pet_pnp_unc_dcu_nus_a.htm.

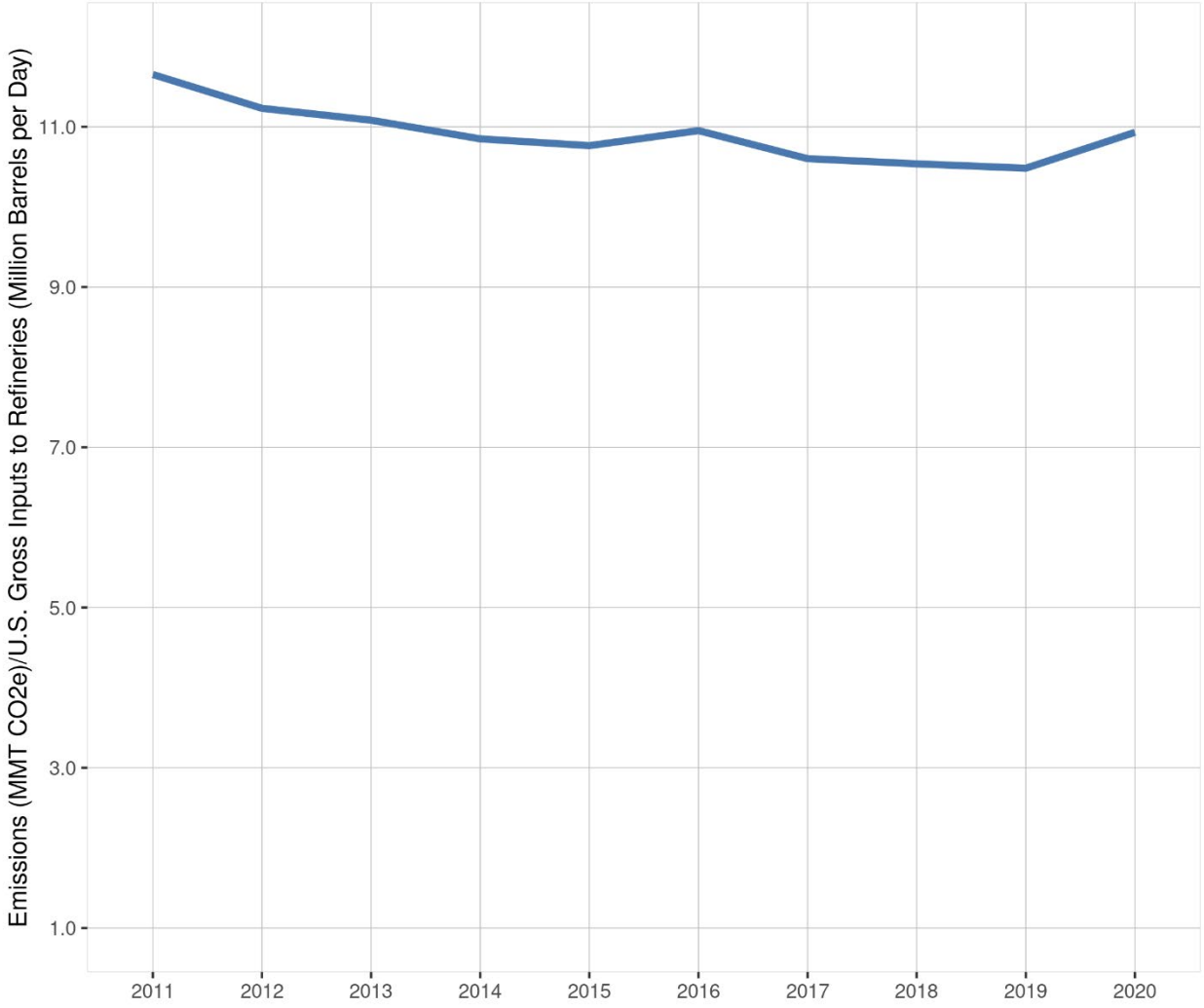
[7] U.S. Energy Information Administration, Changing demand for petroleum products has led to operational changes at U.S. refineries (accessed September 20, 2021) at: https://www.eia.gov/todayinenergy/detail.php?id=44936

[8] U.S. Energy Information Administration, Refinery Utilization and Capacity (accessed September 16, 2021) at: http://www.eia.gov/dnav/pet/pet_pnp_unc_dcu_nus_a.htm.

normalized emissions per gross input was observed, reflecting efficiency projects undertaken by refineries including the use of flare gas recovery.

Figure 4 shows the trend of normalized emissions per gross input from 2011 to 2020, and Table 5 shows that GHGRP emissions in the Petroleum Refineries Sector have remained in a relatively narrow range from 2011 to 2020.

Figure 4: Normalized Emissions Per Gross Input to Petroleum Refineries (2011 - 2020)[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) [a]

Petroleum Refineries Sector	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Carbon Dioxide	176.8	171.3	173.0	174.0	175.5	179.5	177.9	181.1	176.7	159.7
Methane	0.9	0.8	0.8	0.8	0.8	0.8	0.8	0.9	0.9	0.8
Nitrous Oxide	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5

[a] *Totals 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 GHGRP direct emitters. The Petroleum Refineries Sector is the second-highest ranked sector in terms of GHG emissions per facility, with an average of 1.15 MMT CO_2e, behind only the Power Plants Sector. 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 (2020)

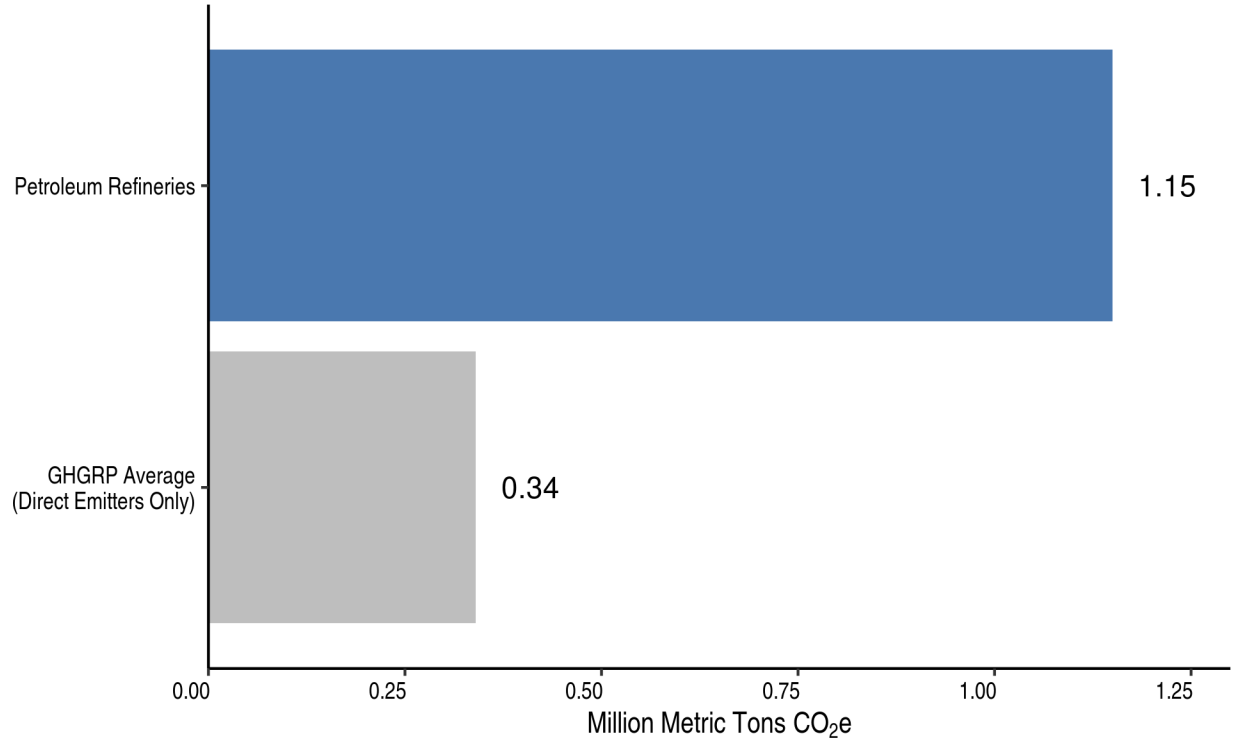


Figure 6: Percentage of Facilities in the Petroleum Refineries Sector by Emission Ranges (2020)

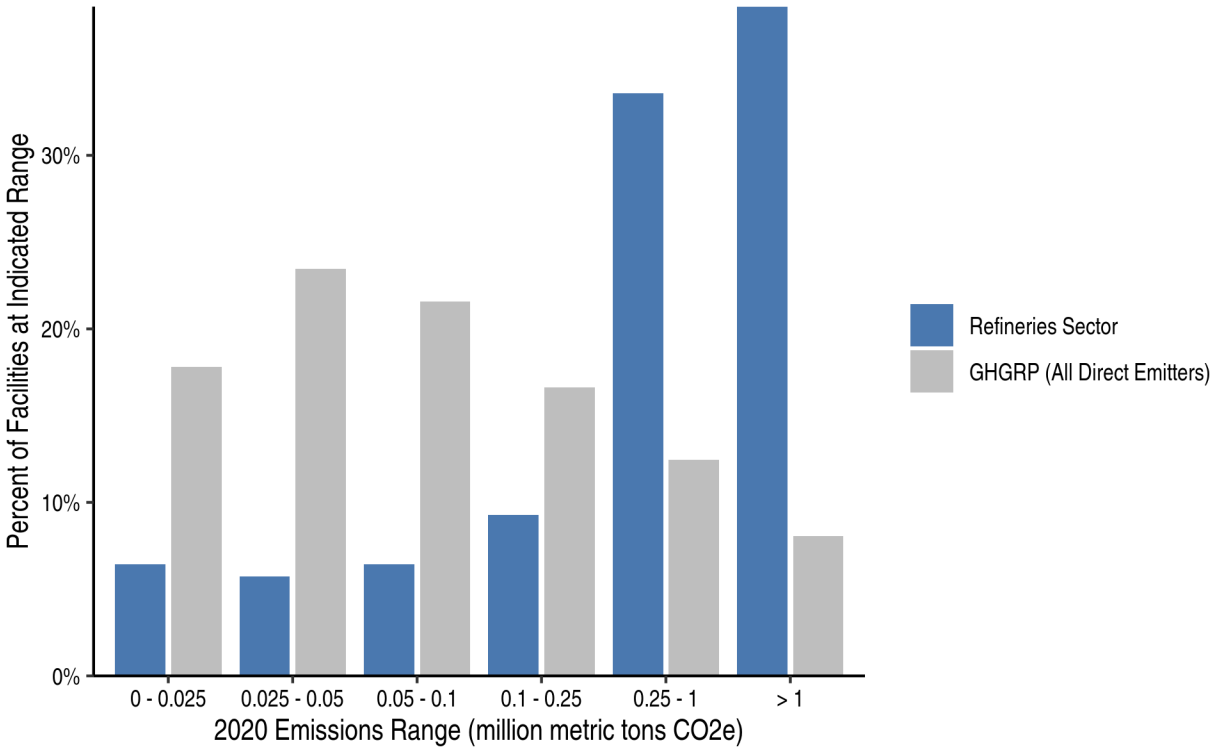


Table 6: Petroleum Refineries Sector - Number of Reporters by Emission Ranges (MMT) (2020)

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	9	8	9	13	47	54

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.