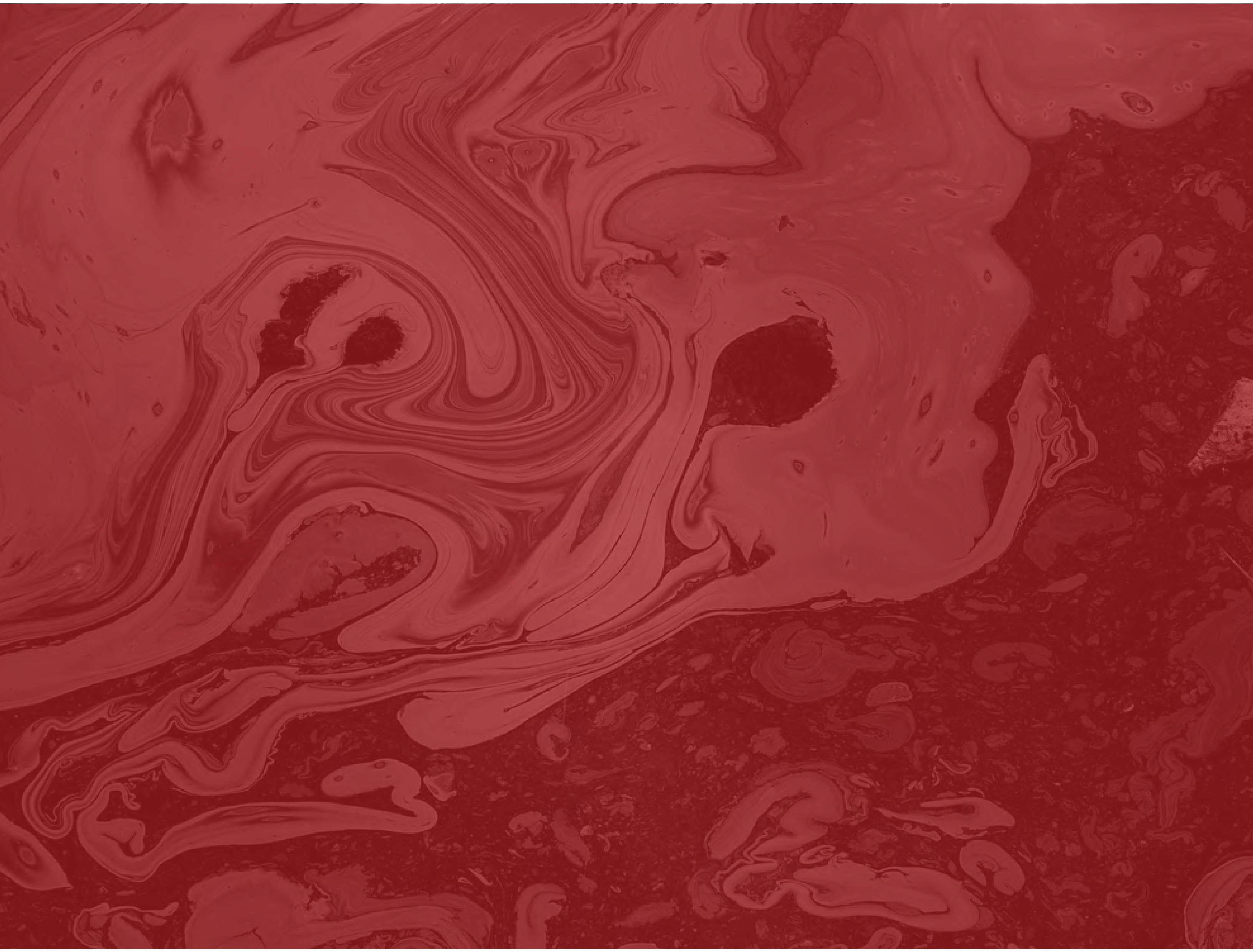
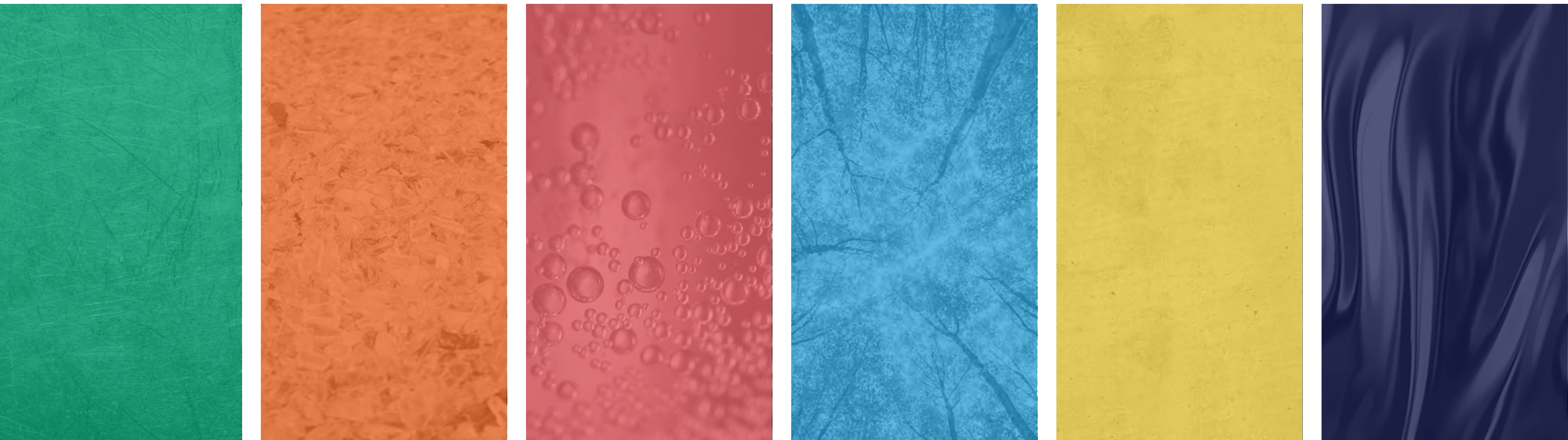
Refining





3.2 Refining

The petroleum refining sector in the United States produced over 18 million barrels of oil per day in 2021.[323] Refineries take raw materials, typically crude oils and semi-processed hydrocarbon mixtures, and refine them into various petroleum products including chemical feedstocks, transport fuels, industrial fuels, and others. These products are integrated into many large and diverse sectors of the economy, especially transportation and chemical manufacturing. The United States consumed over 20.5 million barrels per day of refined oil in 2019.[324] The transportation sector consumed approximately 70 percent, while manufacturing processes consumed an additional 24 percent as feedstock and fuels.[325] In 2019, the U.S. petroleum refining sector generated $551 billion in product[326] and employed over 69,000 workers.[327]

Given refined petroleum's key role across the U.S. economy, decarbonizing the refining sector is essential. However, it will also be difficult given that most refining processes in the United States are highly optimized and integrated by connected process flows. Integrated solutions that would reduce emissions are beyond the control of the refining sector alone. Petroleum refining is also very carbon intensive given its process unit complexity and heavy reliance on fossil fuel feedstocks and fuel carbon content (***Figure 13***).[328]

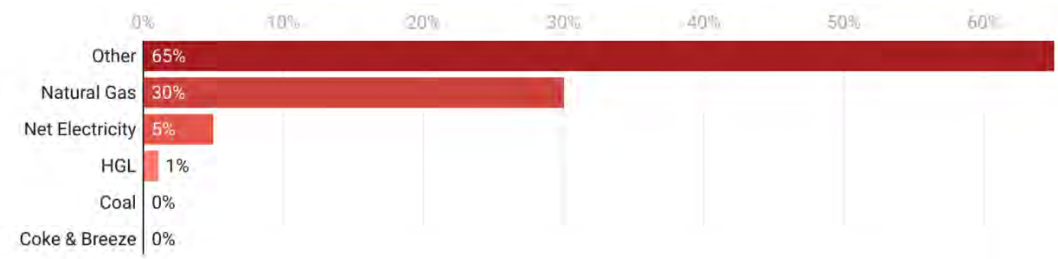
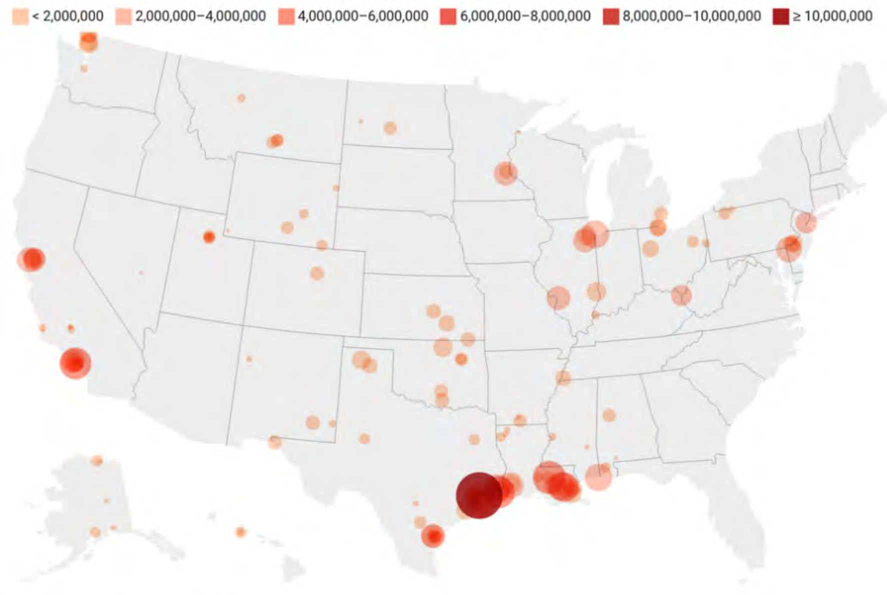


Figure 13: Refining sector fuel and non-fuel uses of energy in 2018 (as a percentage of total trillion Btu). Source: U.S. EIA, MECS 2018, Table 1.2.

The refining sector emits around 244 MMT CO_2e/year (including emissions from offsite generation), with process heating, combined heat and power (CHP), and boilers accounting for the most direct emissions (***Figure 14***).[329]

Figure 14: Refining sector sources of GHG emissions in 2018, by major end use. Source: U.S. DOE, Manufacturing Energy and Carbon Footprint: Petroleum Refining Sector.

Figure 15 depicts regional petroleum refining facilities' locations and GHG emissions, which concentrate mostly in coastal states near ports and industrial clusters.[330]



State	Total GHG Emissions	Facilities
TX	52,242,917	32
LA	26,654,659	18
CA	21,636,619	20
IL	8,459,555	4
WA	5,407,375	5
OK	4,323,052	6
OH	4,136,493	4
IN	3,907,928	2
MS	3,767,979	3
MN	3,478,918	2

Source: EPA Flight 2020 • Created with Datawrapper

Figure 15: Location and total reported emissions (metric tons CO_2e) of petroleum refining plants in the United States (left). Top 10 states by total GHG emissions from refining facilities (right table). Size and darkness of bubbles scale with level of emissions. Source: U.S. EPA, FLIGHT.

Options to reduce direct emissions at the refinery level include energy efficiency, material efficiency, alternative feedstocks (e.g., biomass), and carbon dioxide capture and reuse. For reuse, carbon dioxide can be combined with hydrogen to form synthesis gas, which can be used to make many chemicals.

Several corporate commitments have a reliance on offsets, so there is an opportunity to steer GHG reduction strategies to direct reductions of onsite emissions.

Large companies—including Motiva, Marathon, and ExxonMobil—have focused their corporate GHG reductions primarily on waste reduction, ISO 14001 and ISO 9001 certifications, logistics improvements, and emissions monitoring. Opportunities for further emissions reductions exist in efficiency improvements in both processes and onsite power and steam generation, reducing the carbon intensity of refiners' feedstocks and energy sources by introducing renewables and lower-carbon fossil fuel-based energy, and the capture of carbon dioxide emitted by refiners for storage or utilization. [331, 332]

Marathon Oil is one of the largest petroleum companies in the United States, with 16 refineries in 13 states and producing over three million barrels per day. Marathon has a goal of reducing GHG emissions intensity by a minimum of 50 percent by 2025 vs. a 2019 baseline. Currently, emissions intensity in Marathon Oil refining is approximately 20.4 metric tons of CO_2e/MBOE (million-barrel oil equivalent). The company plans to meet its targets through soil carbon sequestration and by purchasing of renewable energy credits to fully offset scope 2 emissions. However, it is important to note that these strategies include a mixture of onsite and offsite (e.g., offset) approaches, which do not all address direct emissions from the source. [333]

Valero Energy is another of the largest petroleum refining companies in the United States with 13 refineries in five states and over two million barrels refined per day. Valero plans to reduce and offset 100 percent of its global refining scope 1 and 2 GHG emissions by 2035. The company is approaching these targets through several strategies, including embracing low-carbon renewable fuels and increasing efficiency through energy and material management, which has recycling, risk assessment, and energy auditing components.[334] Reaching these goals will require both additional private action and supportive public policy.

Decarbonization of the refining sector will require enabling policies, programs, capital investments, and R&D to overcome barriers that include significant amounts of high-grade waste heat, capital constraints, the interconnectedness of refinery processes, and regulatory issues such as permitting. It will also require the proactive pursuit of low-carbon fuels and feedstocks routes that are available to industry today (e.g., biomass and RNG, see sections below) as well as actively engaging in the planning and development of longer-range solutions (e.g., hydrogen, CCUS). Refining emissions will also likely decrease as demand for its products decline. For example, the transportation sector is rapidly moving towards low-carbon alternatives (e.g., electric and hydrogen light-, medium-, and heavy-duty vehicles, sustainable aviation fuels). However, there will still be near-term need to decarbonize the refining sector given that this transition will likely last several decades and there will still be some demand for petroleum feedstocks and fuels consumed by other manufacturing processes. Additional policies will complement the modest progress made by private companies in their primarily offsite commitments to emissions mitigation. The barriers and policy connections are summarized in ***Table 9***.

Table 9: Decarbonization barriers and policy opportunities for the refining sector.

Challenge / Barrier	State Opportunities	Policy Connections
Supportive R&D needs to increase penetration of innovative decarbonization technology options	• Low-carbon electrolysis of hydrogen, low-carbon feedstocks, increased use of biomass for fuel, biogenic feedstocks, and CCUS are key routes to reduce emissions	• State funds leveraged with federal funds in R&D can help bridge the gap between innovative options and commercial viability
Emerging efficiency improving technologies need to be implemented	• New heat exchangers and motors, electrified boilers, and technical reconfiguration of refineries' processing can save energy and emissions now • Energy management systems and strategic planning to reduce emissions can enable more efficiency measures	• Incentives and rebates for replacing old technology with new controls, process optimizing technology • Mandates for energy management, statewide energy management programs, energy audits, can enable more industrial efficiency
Refining produces significant amounts of waste heat	• Enhanced recovery of low-grade heat for reuse and interunit heat integration; large refineries typically have enhanced capability to capture useful waste heat	• Incentives for industrial clusters and other shared industrial infrastructure can aid waste heat reuse

Roadmaps for Refining Industry

- Japan Decarbonization Roadmap and Transition Finance for Oil and Gas Refining (2022)
- UK Roadmap for Refining Sector (2015)
- UK Roadmap for Refining Sector (Appendices) (2015)
- WRI: Technological Pathways for Decarbonizing Petroleum Refining (2021)

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