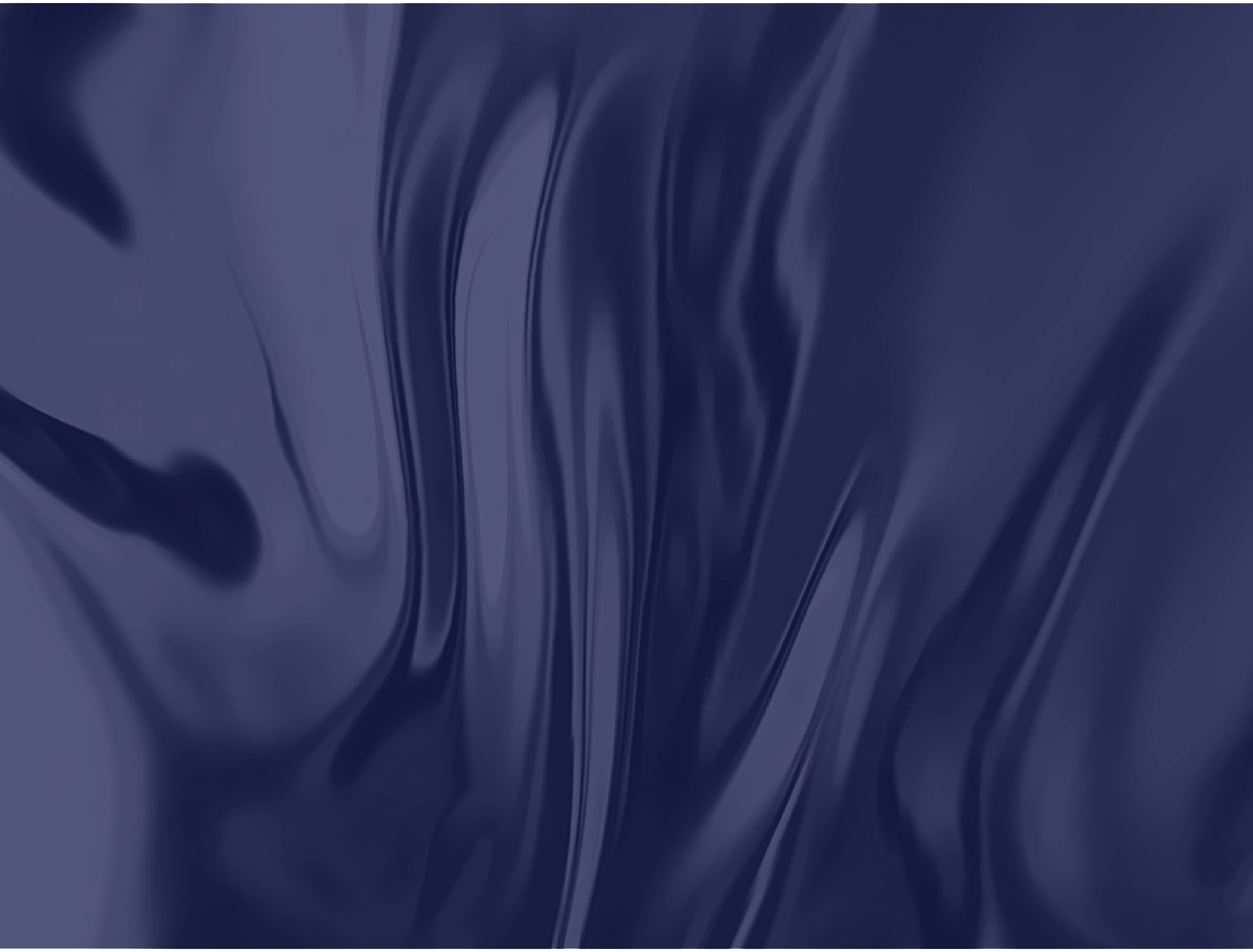
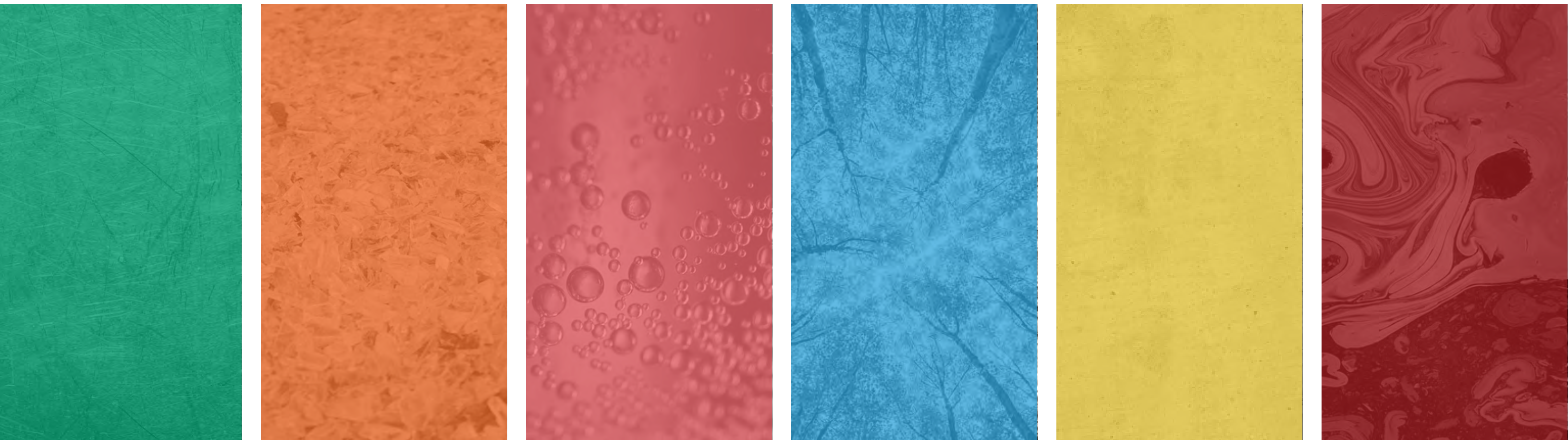
Chemicals





3.1 Chemicals

The chemicals industry is a $768 billion enterprise that generates around 25 percent of U.S. gross domestic product (GDP), producing more than 70,000 products that reach over 750,000 end users.[301] The 11,000 manufacturers, employment of over 529,000 skilled workers, and supply chain networks touch more than 96 percent of manufactured goods.[302] Because the chemical sector's products help enable energy and GHG emissions reductions in other sectors, decarbonizing the chemical industry and expanding production of low-embodied-carbon products can have impacts across multiple sectors.

The chemicals industry is the largest energy consumer in the U.S. industrial sector when both fuel use and feedstocks are included.[303] The majority of energy consumed comes from natural gas and related products (hydrocarbon gas liquids [HGLs]). Fuel oil and heavy liquids, coal, and coke account for about 10 percent of the total combined energy consumption (Figure 9).[304]

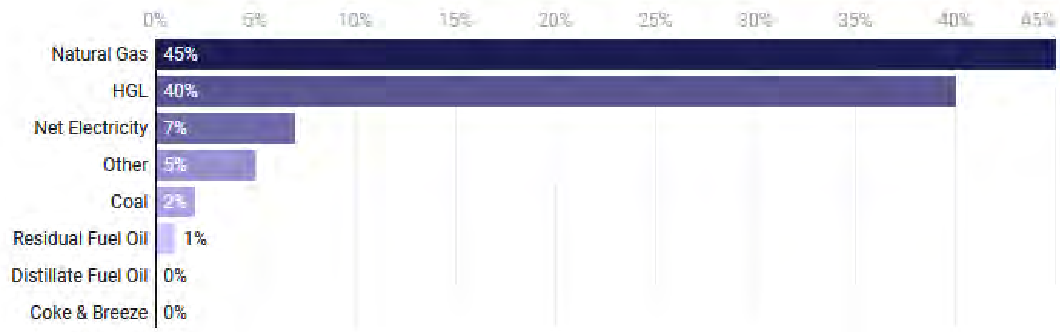


Figure 9: Chemicals sector fuel and non-fuel uses of energy in 2018 (as a percentage of total trillion Btu). Source: U.S. EIA, MECS 2018, Table 1.2.

The chemical sector emits around 332 MMT CO_2e/year (including emissions from offsite generation), with process emissions, process heating, and combined heat and power (CHP) accounting for the most direct emissions (***Figure 10***). [305]

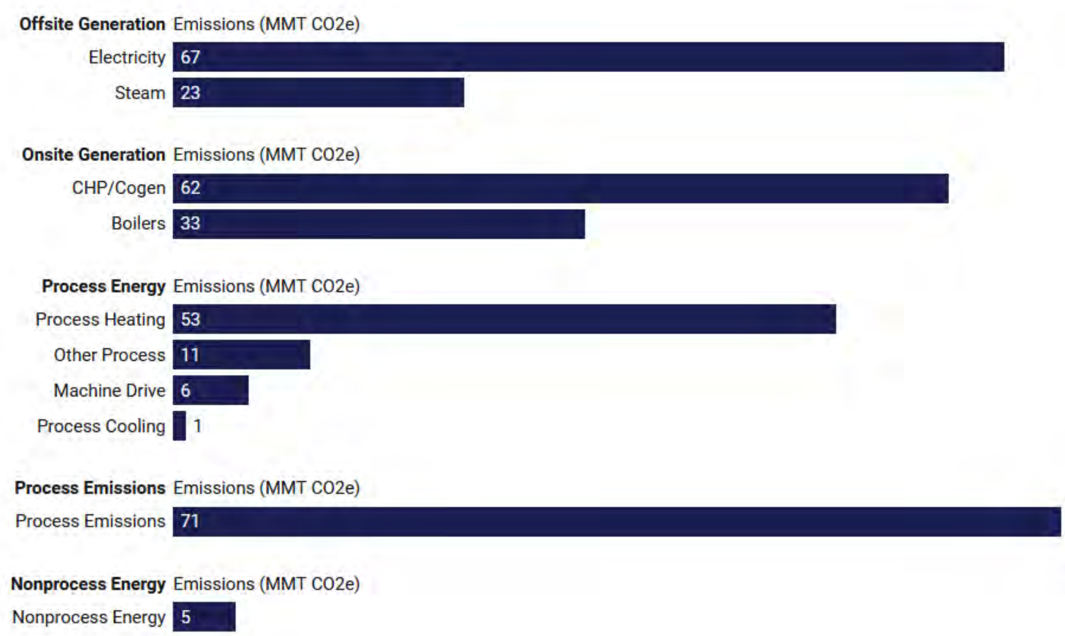


Figure 10: Chemical sector sources of GHG emissions in 2018, by major end use. Source: U.S. DOE, Manufacturing Energy and Carbon Footprint: Chemical Sector.

The chemicals sector comprises a diverse subset of manufactured goods. Petrochemical production—a class of chemicals derived from petroleum or natural gas—accounts for most (32 percent) of the overall chemical sector's direct GHG emissions. Ethylene (a plastics precursor), methanol (a precursor to formaldehyde and other chemicals), and carbon black (a rubber additive) production account for most petrochemical emissions. Another large portion (22 percent) of GHG emissions is associated with hydrogen production—a foundational building block for ammonia and methanol—two large-volume commodity chemicals. Ammonia and nitric acid are both primarily used in fertilizer production. Nitric acid is also a feedstock for producing adipic acid, a major constituent of nylon (***Figure 11***). [306]

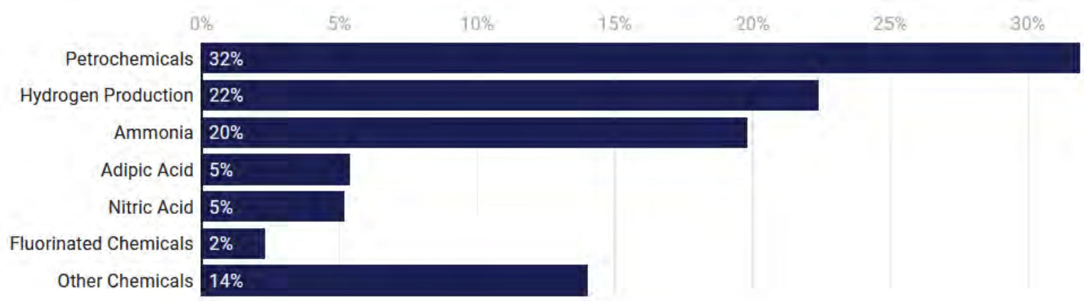
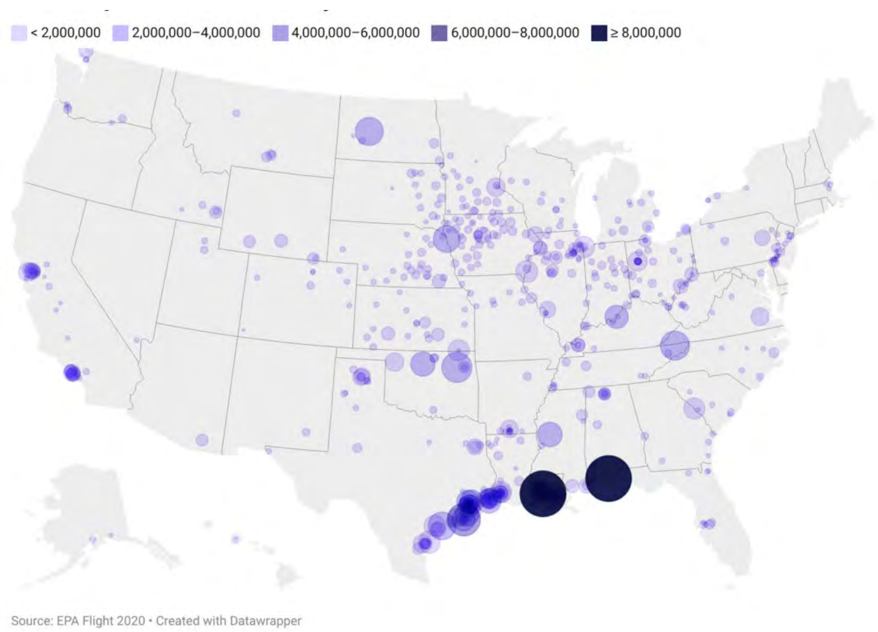


Figure 11: Relative contribution of direct GHG emissions in the chemical sector (as a percentage of MMT CO_2e). Source: U.S. EPA, Greenhouse Gas Reporting Program.

These GHG emissions data suggest early ways to engage the decarbonization pillars mentioned earlier, including:

- Replacing fuel oil / heavy liquids and coal / coke with low-carbon feedstocks such as biofuels or renewable natural gas where feasible;
- Transitioning natural gas usage to biofuels and low-carbon electricity;
- Transitioning hydrogen production from steam methane reformers to electrolysis (e.g., using electricity generated from wind, solar);
- Electrifying process heat where multiple electric technologies are commercial, given that the generation and use of process heat accounts for 55 percent of the energy spend, [307] with 60 percent of that heat being at or under 150^{o} C; [308]
- Utilizing low-carbon hydrogen for higher temperature process heat applications;
- Scaling up use of biomass and renewable natural gas (RNG) to use for process heat applications and other fuels and feedstocks uses; [309]
- Increasing energy and materials efficiency; and
- Utilizing carbon capture from major point (typically dilute) and relatively pure sources.



State	Total GHG Emissions	Facilities
TX	57,824,880	117
LA	41,280,991	81
IA	10,963,159	44
FL	9,974,360	13
CA	9,781,735	32
OK	8,349,657	9
IL	6,185,997	38
MS	4,540,634	10
TN	4,428,031	12
OH	4,413,403	30

Figure 12: Location and total reported emissions (metric tons CO_2e) of chemical manufacturing plants in the United States (left). Top 10 states by total GHG emissions from chemical facilities (right table). Size and darkness of bubbles scale with level of emissions. Source: U.S. EPA, FLIGHT.

As exemplified in ***Figure 12***,[310] the chemical industry is typically clustered for historical, feedstock and energy availability, market proximity, and transportation reasons.[n] This geographic concentration has implications for decarbonization pathways. For example, the concentration of chemical production in several areas may align well with proposed hydrogen or carbon dioxide pipelines, particularly where there is relatively high-purity carbon dioxide that can be captured (e.g., from the production of bioethanol in the upper Midwest). This is important when considering the decarbonization pathways in roadmaps that address general industry decarbonization routes[311, 312, 313] or are more specific to the chemical industry (many chemical industry roadmaps are largely from outside the United States).[314, 315, 316]

[n] Many chemical facilities are collocated with refineries, especially along the Gulf and Pacific Coasts, but this figure disaggregates chemical from refining facilities. See ***Section 3.2: Refining*** for more information on refineries.

Several chemical companies have established GHG reduction goals, with some (mostly smaller) setting science-based targets.[317] The goals range from ambitious to modest, with a few targeting carbon neutrality.[318] Companies are pursuing decarbonization pillars in near- and longer-term initiatives aligned with their goals. For example, BASF (the largest global chemical producer) is exploring industrial heat pumps (near-term) and electric cracker technology (longer-term).[319] In another example, Dow Chemical is pursuing a zero-emissions ethylene complex,[320] as well as partnering on an electric cracker.[321]

Transforming the chemical industry to achieve net-zero GHG emissions will be exceptionally challenging given the manufacturing complexity, high degree of capital investment, and long lifetime of equipment. Additional considerations for the chemicals industry include the $208 billion that has been invested across 351 projects in the last decade: due to the shale gas boom, chemical producers invested heavily in state-of-the-art ethylene crackers and downstream facilities, so this long-term investment into natural gas will be difficult to override.[322] Near-term options for these major point sources include fuel-switching to renewable natural gas, capture and reuse of hydrogen from the cracking process, and carbon dioxide capture. There are opportunities for states to lower the barriers and help companies accelerate the adoption of multiple decarbonization pillars, described in ***Table 8***.

Table 8: Decarbonization barriers and policy opportunities for the chemical industry.

Challenge / Barrier	State Opportunities	Policy Connections
Low price of fossil energy / feedstocks means substantial cost increase for low-carbon alternatives	• RD&D, energy and materials efficiency for emerging / transformative technologies can help • Early on, incentives, carbon pricing, or performance standards be needed to counteract cost disadvantage	• Support energy managers for small/medium manufacturers and encourage efficiency networks, waste reduction/reuse • Design incentives, provisions to defray cost increases for low-carbon technologies
High capital costs, large portion of new capital (shale gas)	• Start with low-capital replacement strategies (energy, material efficiency)	• Design incentives for low-carbon technologies so when capital replacement opportunities arise (e.g., boilers) the low-carbon choices are favored
Electrification has a low penetration rate that is increasing slowly	• Spark electric technology adoption in parallel with greening of the grid • Encourage direct use of low-carbon electricity at clusters to advance integrated solutions	• Incentivize electric technology adoption • Support infrastructure to bring low-carbon electricity to industry, integrate storage and control systems • Devise incentives to address electric / natural gas price disparity
Ability to quantify embodied carbon and follow in supply chains nascent	• Advance understanding of embodied carbon in materials for state sponsored projects	• Engage on initiatives to improve knowledge infrastructure, in parallel with efforts to increase market pull for low-carbon products

Challenge / Barrier	State Opportunities	Policy Connections
Capture of GHGs very expensive Few carbon dioxide reuse cases within facility fence lines Multitude of smaller sources	• Understand major carbon dioxide sources, encourage plans to address them • Pilot / demo capture and reuse at chemical facilities • Support mini-CCS capture pilots	• Support infrastructure and interconnections for mitigation • Stipulate a reduction plan for facilities in future air permits • Engage in pilots
Workforce largely untrained in decarbonization solutions	• Develop training • Support curricula development	• Initiate training programs, on-site internships, re-skilling, etc. for decarbonization in partnership with industry
Value return for material recycling highly uncertain	• Support programs that find additional value return options	• Mandate base levels for recycled content • Mandate only recyclable materials • Increase costs for disposal

Roadmaps for the Chemicals Industry

- France Chemical Industry Decarbonization Roadmap (2021) [English summary]
- Germany, Working towards a GHG Neutral Chemical Industry in Germany, VCI, (2019)
- Japan Decarbonization and Transition Finance Roadmap for the Chemicals Sector (2021)
- Netherlands, Chemistry for Climate: Roadmap for the Dutch Chemical Industry Towards 2050, VNCI, (2018)
- UK Roadmap for Chemicals (2015)
- UK Roadmap for Chemicals (Appendices) (2015)
- Planet Positive Chemicals: Pathways for the chemical industry to enable a sustainable global economy, SystemIQ (2022)

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