Manufacturing Ethylene: Facts, Impacts, and Pathways

JUNE 2025

Ethylene is the highest volume commodity chemical in the U.S., with production resulting in about 44.4 MMT CO2/yr[1]—more than the annual emissions of the entire state of Nevada. It's used as a building block chemical to create plastics, packaging, construction materials, and many of the products encountered in daily life. From the onset, emissions from using fossil fuels are embedded in most ethylene production. Over 80% of the ethylene produced domestically uses ethane (Qian et al. 2023), a hydrocarbon gas derived from natural gas, as the feedstock (DOE 2022). Ethylene produced in other countries is more reliant on naphtha, a liquid petroleum product. Production pathways do exist to create ethylene from renewable hydrocarbon feedstocks, biomass, or captured and/or recycled carbon, but these make up a negligible amount of the current ethylene market (Lingle and Connolly 2023) as these routes are currently more expensive.

- Almost all ethylene manufactured in the U.S. uses steam cracking technology. Steam crackers are one of the most energy and carbon-intensive manufacturing processes (Galluci 2023).
- Ethylene, along with benzene, is the base for most of the world's plastics. For example, almost three quarters of the plastics consumed annually for packing and film (mostly single-use) are derivatives of ethylene (Bylsma et al. 2023).
- The U.S. produces 30-40 MMT of plastic waste annually, which translates to the highest per capita plastic waste production rate of any nation in the world. An estimated 1-2 MMT of waste is mismanaged and leaks into the environment in the U.S., polluting landscapes and waterways (Committee on the United States Contributions to Global Ocean Plastic Waste 2022).
- The U.S. has one of the lowest plastic packaging recycling rates in the world. Polyvinyl chloride (PVC) is an ethylene-based plastic that has a close to 0% recycling rate. Other ethylene-based plastics like polyethylene terephthalate (PET) bottles and HDPE milk bottles have much higher recycling rates, around 29%. Most plastics end up in landfills at the end of product life (Milbrandt et al. 2022).
- Some ethylene co-products are highly hazardous. For example, more than 90% of 1,3-butadiene is produced by ethylene crackers. Butadiene is a carcinogenic air pollutant that U.S. Environmental Protection Agency (EPA) recently concluded poses an unreasonable risk to human health from inhalation exposure to workers and fenceline communities.
- There is currently a serious oversupply of ethylene production capacity, placing one-third of the world's 330 ethylene crackers at serious risk of closure (Cui et al. 2024).

To reduce GHG emissions and minimize health and environmental impacts, innovative solutions need to be targeted across ethylene's feedstock, manufacturing process, and end-of-life phases. Sixty percent of

[1] Derived from data and models: Nicholson, Scott R., Nicholas A. Rorrer, Taylor Uekert, Greg Avery, Alberta C. Carpenter, and Gregg T. Beckham. 2023. "Manufacturing Energy and Greenhouse Gas Emissions Associated with United States Consumption of Organic Petrochemicals." *ACS Sustainable Chemistry & Engineering* 11 (6): 2198–2208. https://doi.org/10.1021/acssuschemeng.2c05417.; Meng, Fanran, Andreas Wagner, Alexandre B. Kremer, Daisuke Kanazawa, Jane J. Leung, Peter Goult, Min Guan, et al. 2023. "Planet-Compatible Pathways for Transitioning the Chemical Industry." *Proceedings of the National Academy of Sciences* 120 (8): e2218294120. https://doi.org/10.1073/pnas.2218294120.

ethylene's embodied emissions occur during the refining and manufacturing stage and 40% occur at the end of product life (Meng et al. 2023). When these products break down or are incinerated, fossil carbon is returned to the atmosphere. Release of carbon to the atmosphere at the end of product life is delayed when ethylene-based products are buried in landfills or remain in use as durable plastic goods (e.g., PVC in building applications), and enhancing the circularity of plastics can help to displace virgin fossil fuel feedstocks.

Geography of Ethylene Production

Ethylene is produced at around 30 facilities today in the U.S. (Shaykevich et al. 2024). These facilities are concentrated in the Gulf Coast region of Texas and Louisiana, with additional production capacity in the Ohio River Valley region and upper Midwest along the Mississippi River (Figure 1). Facility siting is heavily influenced by access to abundant and low-cost natural gas, as well as proximity to additional chemical production that utilizes ethylene as a feedstock.

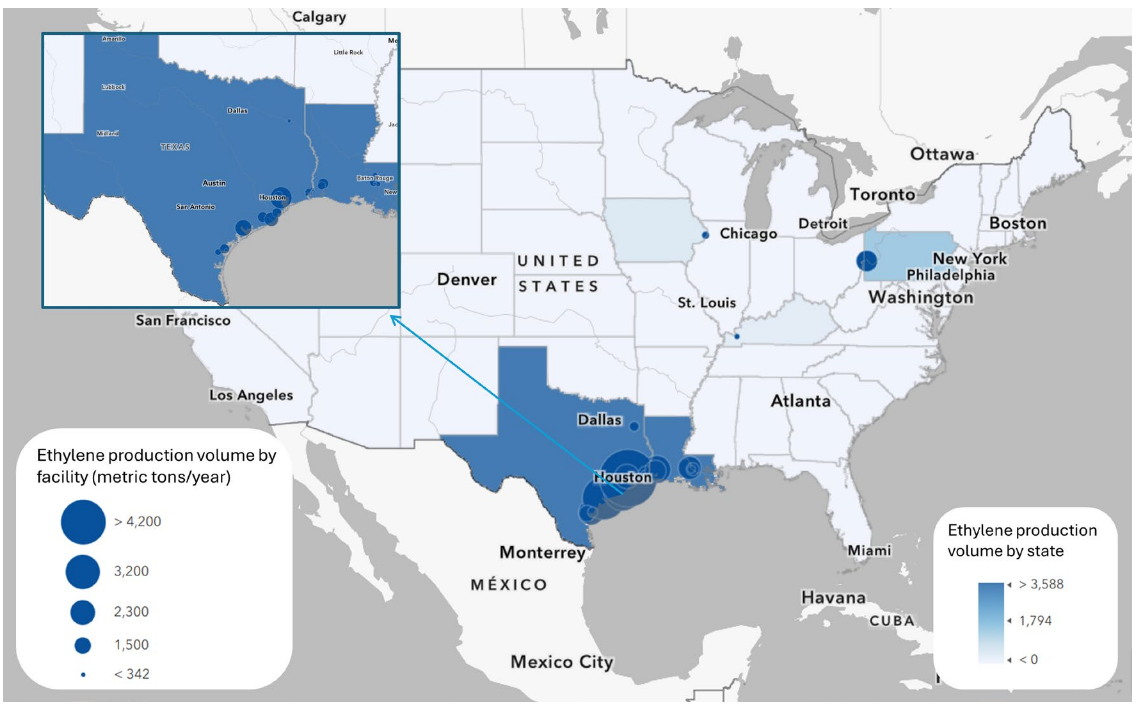

Figure 1. Map of U.S. ethylene production by state and facility, in metric tons/year. Data from Shaykevich et al. 2024.

Ethylene Market Structure

Bulk ethylene is the precursor to a vast number of chemical products—mostly plastics—consumed by a wide range of markets. Five main intermediate chemicals, however, account for about 80% of the bulk ethylene that is produced globally as illustrated in figure 2 (a simplified estimate of the general structure of how ethylene flows to derived intermediate products and primary end use markets). Three variations of polyethylene (linear low-density (LLDPE), low-density (LDPE), and high-density (HDPE)) are plastics used primarily for packaging, although HDPE is also prevalent in buildings (e.g. for pipes, plastic outdoor decks, or furniture). Ethylene dichloride is a precursor to PVC products. Ethylene oxide is used to make

PET polyester plastic for packaging and textiles, as well as to manufacture engine antifreezes and coolants.

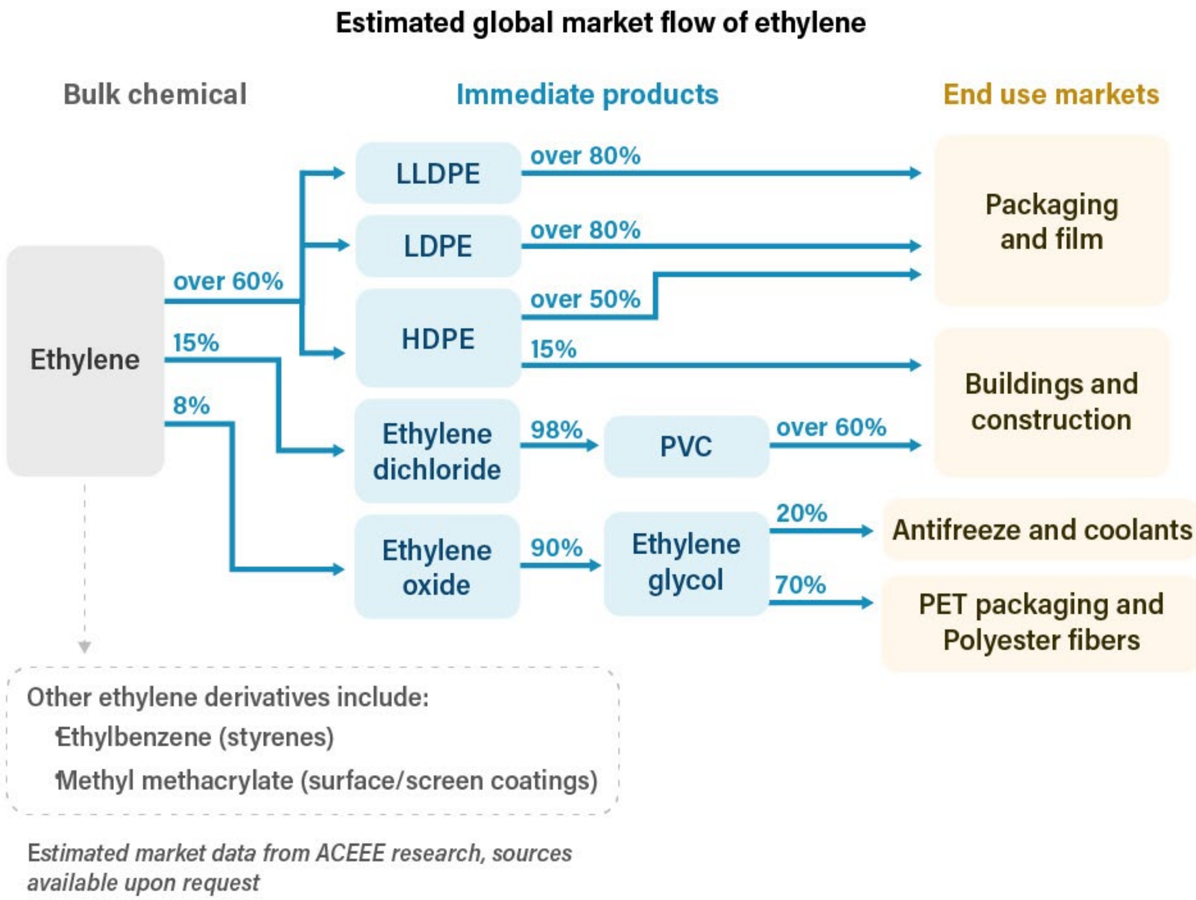

Figure 2. The estimated global market flow of ethylene which shows the five main intermediate chemical products derived from ethylene. Data sources available upon request.

Health and Environmental Safety Impacts of Ethylene Production

Ethylene production has released toxic pollutants, including known carcinogens such as benzene or 1,3-butadiene, into fenceline communities for decades[2]. Manufacturing facilities are permitted to release a set amount of air toxics, although standards for installed pollution control technology can be periodically made more stringent. This regulatory strategy makes it difficult to directly or proactively limit emissions from industrial facilities, even if there are known violations of facility air quality permits (Song 2024).

- Every facility in the U.S. that produces ethylene also emits chemicals which are linked to reproductive harms, cancer, and respiratory diseases (EDF 2024) and 11 of the 27 facilities had

[2] Facility-specific data on toxic releases and violations can be found at fencelinedata.org, which combines data from the EPA's Toxics Release Inventory, Greenhouse Gas Reporting Program (GHGRP) and Enforcement and Compliance History Online (ECHO) programs.

high priority violations of their clean air permits between 2020 and 2023 (Shaykevich et al., 2024).

- Twenty-three of 27 (85%) of ethylene facilities are located within three miles of disadvantaged communities (ibid.)
- Downstream ethylene derivative chemicals can also be toxic, especially to chemical workers and fenceline communities. This is especially true for ethylene dichloride, used to make vinyl chloride, a component of PVC plastics (Tabuchi 2024) and even more so for ethylene oxide, also a major ethylene derivative that is classified as a hazardous air pollutant (EPA 2018), primarily contributing to PET polyester value chains.
- There are also toxicity concerns for consumers from the use of ethylene-based plastics. Ethylene products break down into “microplastics,” which are already ubiquitous and easily ingested. There is growing research into the negative impacts of microplastics on human health (Rahman et al. 2021).

Technological Pathways: Challenges and Opportunities

Challenge: International chemical facilities could outcompete the U.S. in a new growing market for low-emissions chemical products.

The chemical industry in the U.S. grew rapidly because of the availability of low-cost ethane feedstocks, and because it was able to build on well-established infrastructure, especially along the Gulf Coast. The economic benefits of the chemical sector in the U.S., however, are declining. In Louisiana, the petrochemical sector only accounts for 4.5% of the state’s revenues compared to 40% in the 1990s (Sanzillo et al. 2024). A new ethylene plant in Pennsylvania, operational as of 2022 and given over $1.5 billion in state tax incentives, has yet to deliver measurable economic benefits to the county where it is located (de Place and Stone 2023). The U.S. chemical industry needs to invest in cutting edge research and develop the infrastructure to support markets for more sustainable chemical products, to improve resiliency and competitiveness of the industry, and to ensure that economic benefits accrue to the states and communities where facilities are located.

- **Additional RD&D funding** can help companies commercialize cutting edge technologies that produce chemical products with fewer emissions, while reducing demand for fossil fuel feedstocks. Promising efforts include developing alternative feedstocks at scale and commercializing more efficient processing technologies that avoid toxic emissions.
    - If biofeedstocks are to play a key role in sustainable product portfolios, there will be a need to scale bio-refining and processing technologies, to improve process efficiency, and to develop new supply chains from regions rich in waste biomass (e.g., corn stover from the Midwest or forestry residue from the north and southeast).
    - The majority of carbon capture funding to date has been for sequestration and storage; there is a need for expanded support for carbon utilization strategies that reuse waste carbon from other industrial sectors (e.g., cement, steel) to produce durable carbon-based materials. For example, one of the Industrial Demonstration Program awards announced in 2024 provides $200 million federal cost share for a pilot facility along the Gulf Coast planning to utilize captured waste carbon to produce ethylene (OCED 2024).

    - There are potentially transformative new production pathways that could reduce energy waste, cut pollution emissions, and enhance the circularity of the chemical industry. Additional state and federal support can help to incentivize new facilities in the U.S. to scale promising new chemical production methods, within value chains such as PET plastic (IN EDC 2024).

- **Market and tax policy tools** can address the price disparity between conventional and lower-emission, innovative production methods for ethylene, encouraging companies to invest in cutting-edge technologies and production strategies.
    - Clean contracts for differences (CCfDs) are a new market tool in the context of U.S. state and federal policy that could be more economically efficient than tax credits for driving demand for cleaner products, especially for more durable ethylene-based products (i.e., outside of packaging) (Gangotra et al. 2023).
    - Production tax credits or investment tax credits, implemented at either the federal or state level, could help to overcome price barriers between ethylene produced from alternative feedstocks or in decarbonized facilities and conventionally produced ethylene.
    - Carbon border adjustment policies can help cleaner U.S. products maintain trade advantages over chemical products produced abroad that are more emissions-intensive.

Challenge: Direct electrification of chemical manufacturing processes is an efficient pathway to safer, cleaner manufacturing facilities but energy systems are not yet ready for large new demands for electricity.

Most manufacturing process emissions for ethylene occur during steam cracking, a high temperature heating process reliant on natural gas—which accounts for an estimated 90% of the 12.2 MMT of CO_2 energy-related emissions released when converting ethane to ethylene. Electrifying steam crackers could potentially eliminate emissions from this production step, if clean electricity can be sourced to power this equipment.

- The first industrial-scale demonstration of an electrified cracker, requiring six MW of renewable energy, came online at a BASF plant in Germany in April 2024 (BASF 2024). This demonstration electrified approximately 10% of the facility production capacity of ethylene.
- High capital expenditures, relatively low natural gas prices, and competition for access to clean, affordable electricity are major barriers to electrifying more steam crackers. Strategies to overcome these issues include state or federal clean heat or electrification tax credits, and state or federal grant or loan programs that defray the capital expenditure costs to be an early adopter of electrification technologies.
- Market and regulatory reforms will also be needed, to streamline the process of permitting and building additional new clean energy infrastructure in support of the policy goal of decarbonizing the grid while meeting growing demand (McCarthy 2024). Demand side solutions, including energy efficiency and customer demand flexibility, should also be deployed to avoid overbuilding the grid and increasing customer bills.

Challenge: Without a reduction in demand for primary plastic products, the chemical industry is unlikely to see its emissions decrease by 2050.

Demand for plastics is on track to at least double by 2050, under current policies; the associated carbon emissions could consume more than a quarter of the remaining global carbon budget that leads to a 50% chance of remaining below a 1.5-degrees Celsius warming threshold (Karali et al 2024). To meet global climate targets while also addressing a growing plastic pollution crisis, demand for carbon-intensive primary plastic production must decrease. While technology strategies can cut ~80% of chemical sector emissions by 2050, the remaining 20% requires demand reduction (DOE 2025).

- More than 70% of plastic waste in U.S. landfills consists of single-use plastic products (Milbrandt et al 2022), and almost 75% of single-use plastic products are derived from ethylene. At the local level, single-use plastic bans, mostly for plastic bags, are in place in many jurisdictions across the country (Kandasamy 2024).
- Mandated recycled content for plastics market subsectors can help to overcome the higher prices of recycled feedstocks and support the expansion and improvement of recycling infrastructure—in the U.S. only 5% of plastics are recycled. The European Union has set a goal of 30% recycled content in all plastic packaging by 2030 (EU 2024). California has passed a bill that requires all plastic beverage containers to contain at least 50% recycled material by 2030 (CalRecycle 2024).
- Improved data tracking infrastructure is needed to measure the relative carbon intensity of chemical products, including ethylene-based plastics, incentivizing companies to develop more carbon-efficient production strategies. Standardized and carefully regulated mass balance approaches (Beers et al. 2022) can lead to more transparent supply chains and improve the development of competitive markets for lower-carbon plastic products, including products produced from biobased or recycled feedstocks instead of virgin fossil fuels.

References

BASF. 2024. "BASF, SABIC, and Linde Celebrate the Start-up of the World's First Large-Scale Electrically Heated Steam Cracking Furnace." April 17, 2024. https://www.basf.com/basf/www/global/en/media/news-releases/2024/04/p-24-177.

Beers, Kathryn, Kelsea Schumacher, Kalman Migler, Kc Morris, and Joshua Kneifel. 2022. "An Assessment of Mass Balance Accounting Methods for Polymers Workshop Report." NIST SP 1500-206. Gaithersburg, MD: National Institute of Standards and Technology (U.S.). https://doi.org/10.6028/NIST.SP.1500-206.

Bylsma, Sasha, TJ Conway, and Joseph Fallurin. 2023. "We Can Cut Petrochemical Use Today: Framing the Challenge and Opportunity." RMI. https://rmi.org/insight/we-can-cut-petrochemicals-use-today/.

CalRecycle. 2024. "Plastic Minimum Content Standards and Reporting (AB 793)." CalRecycle Home Page. 2024. https://calrecycle.ca.gov/bevcontainer/bevdistman/plasticcontent/.

Committee on the United States Contributions to Global Ocean Plastic Waste, Ocean Studies Board, Division on Earth and Life Studies, and National Academies of Sciences, Engineering, and Medicine. 2022. *Reckoning with the U.S. Role in Global Ocean Plastic Waste*. Washington, D.C.: National Academies Press. https://doi.org/10.17226/26132.

Cui, Kelly, Kai Sen Chong, Shruthi Vangipuram, and Alan Gelder. 2024. "Which Global Steam Crackers Are at Most Risk of Closure?" Wood Mackenzie. https://www.woodmac.com/news/opinion/which-global-steam-crackers-are-at-most-risk-of-closure/.

de Place, Eric, and Julia Stone. 2023. "A Cautionary Tale of Petrochemicals from Pennsylvania." Ohio River Valley Institute. https://ohiorivervalleyinstitute.org/wp-content/uploads/2023/06/Updated-A-Cautionary-Tale-of-Petrochemicals-from-Pennsylvania-3.pdf.

Environmental Defense Fund (EDF). 2024. Chemical Exposure Action Map. https://experience.arcgis.com/experience/8373cf21e36744dc87b07950566a3bf4/page/Main/?draft=true&org=edfmaps.

European Parliament (EU). 2024. "How to Reduce Plastic Waste: EU Measures Explained." European Parliament. May 15, 2024. https://www.europarl.europa.eu/topics/en/article/20180830STO11347/how-to-reduce-plastic-waste-eu-measures-explained.

Gallucci, Maria. October 2023. Canary Media. This key chemical is super dirty to make. Can an electric furnace help? https://www.canarymedia.com/articles/clean-industry/this-key-chemical-is-super-dirty-to-make-can-an-electric-furnace-help.

Indiana Economic Development Corporation (IN EDC). 2024. "Sustainea Plans $400M Investment in Indiana, Advancing Agbiosciences & Circular Economy." October 10, 2024. https://iedc.in.gov/events/news/details/2024/10/10/sustainea-plans-400m-investment-in-indiana-advancing-agbiosciences-circular-economy.

Jones, Jim. 2024. "FDA, Industry Actions End Sales of PFAS Used in US Food Packaging." U.S. Food & Drug Administration. FDA. February 28, 2024. https://www.fda.gov/news-events/press-announcements/fda-industry-actions-end-sales-pfas-used-us-food-packaging.

Karali, Nihan, Nina Khanna, and Nihar Shah. 2024. "Climate Impact of Primary Plastic Production," April. https://escholarship.org/uc/item/12s624vf.

Kandasamy, Ambika. 2024. "Mapping the Nation's Mixed Bag on Plastic Bans." National Wildlife Federation. June 27, 2024. https://www.nwf.org/Home/Magazines/National-Wildlife/2024/Summer/Conservation/Plastic-Bag-Bans-Map.

Lingle, Rick, and Kate Bertrand Connolly. 2023. "Dow Sources Bio-Based Feedstock for US Plastics Production." Plastics Today. June 1, 2023. https://www.plasticstoday.com/biopolymers/dow-sources-bio-based-feedstock-for-us-plastics-production.

McCarthy, Dan. 2024. "Chart: Texas Plans to Build the Most Clean Energy of Any State." Canary Media. September 13, 2024. https://www.canarymedia.com/articles/clean-energy/chart-texas-plans-to-build-far-more-clean-energy-than-any-other-state.

Meng, Fanran, Andreas Wagner, Alexandre B. Kremer, Daisuke Kanazawa, Jane J. Leung, Peter Goult, Min Guan, et al. 2023. "Planet-Compatible Pathways for Transitioning the Chemical Industry." *Proceedings of the National Academy of Sciences* 120 (8): e2218294120. https://doi.org/10.1073/pnas.2218294120.

Milbrandt, Anelia, Kamyria Coney, Alex Badgett, and Gregg T. Beckham. 2022. "Quantification and Evaluation of Plastic Waste in the United States." Resources, Conservation and Recycling 183 (August):106363. https://doi.org/10.1016/j.resconrec.2022.106363.

Minnesota Pollution Control Agency (MN PCA). 2024. "Groundbreaking Study Shows Unaffordable Costs of PFAS Cleanup from Wastewater." November 22, 2024. https://www.pca.state.mn.us/news-and-stories/groundbreaking-study-shows-unaffordable-costs-of-pfas-cleanup-from-wastewater.

Office of Clean Energy Demonstrations (OCED). 2024. Industrial Demonstration Program Selections for Award Negotiations: Chemicals and Refining. https://www.energy.gov/oced/industrial-demonstrations-program-selections-award-negotiations-chemicals-and-refining.

Qian, Huimin, Yueru Zhao, Fen Qin, and Guobao Song. 2023. "Life-Cycle Environmental Burdens of Ethylene Production in the Context of China's Chemical Feedstock Transition from Naphtha to Coal and Shale Gas by-Product of Ethane." Environmental Impact Assessment Review 101 (July):107152. https://doi.org/10.1016/j.eiar.2023.107152.

Rahman, Arifur, Atanu Sarkar, Om Prakash Yadav, Gopal Achari, and Jaroslav Slobodnik. 2021. "Potential Human Health Risks Due to Environmental Exposure to Nano- and Microplastics and Knowledge Gaps: A Scoping Review." Science of The Total Environment 757 (February):143872. https://doi.org/10.1016/j.scitotenv.2020.143872.

Sanzillo, Tom, Suzanne Mattei, and Abhishek Sinha. 2024. "The Declining Significance of the Petrochemical Industry in Louisiana." Institute for Energy Economics and Financial Analysis. https://ieefa.org/sites/default/files/2024-10/Louisiana%20Petchem%20Report_October%202024%20%282%29.pdf.

Shaykevich, Alexandra, Lottie Mitchell, Paul MacGillis-Falcon, Brendan Gibbons, Tom Pelton, Sarah Kula, and Courtney Bernhardt. 2024. "Feeding the Plastics Industrial Complex: Taking Public Subsidies, Breaking Pollution Laws." Environmental Integrity Project. https://environmentalintegrity.org/wp-content/uploads/2024/03/Feeding-the-Plastics-Industrial-Complex-3.14.24.pdf.

Song, Lisa. 2024. "The EPA Has Done Nearly Everything It Can to Clean Up This Town. It Hasn't Worked." ProPublica. April 15, 2024. https://www.propublica.org/article/calvert-city-kentucky-epa-pollution-westlake-sacrifice-zones.

Tabuchi, Hiroko. 2024. "The E.P.A. Moves Toward Regulating a Widely Used, Dangerous Chemical." The New York Times, July 24, 2024, sec. Climate. https://www.nytimes.com/2024/07/24/climate/epa-vinyl-chloride-regulation.html.

U.S. Department of the Interior (Interior). 2024. "Reducing Single-Use Plastic Pollution". https://www.doi.gov/reducing-single-use-plastic-pollution.

U.S. Department of Energy. 2022. "U.S. Ethane: Market Issues and Opportunities." Washington, D.C.: U.S. Department of Energy. https://www.energy.gov/sites/default/files/2023-06/U.S.Ethane-Market-Issues-and-Opportunities.pdf.

U.S. Department of Energy. 2025. "Transformative Pathways for U.S. Industry: Unlocking American Innovation." DOE/EE-2963. U.S. Department of Energy. https://doi.org/10.2172/2478652.

U.S. Environmental Protection Agency (EPA), OAR. 2018. "Hazardous Air Pollutants: Ethylene Oxide (EtO)." Collections and Lists. August 13, 2018. https://www.epa.gov/hazardous-air-pollutants-ethylene-oxide.