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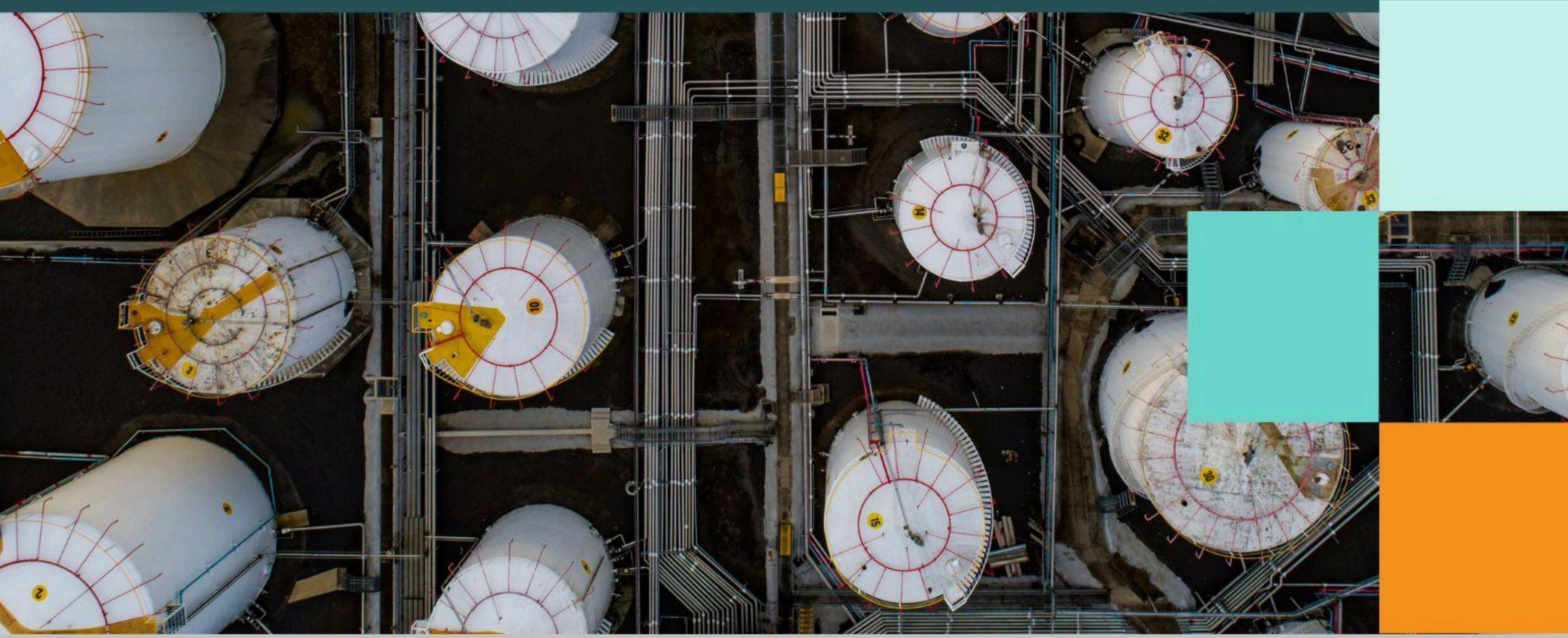
Emissions Assessment of Petrochemical Facilities in the Ohio River Valley and Gulf Coast, United States

Technical Overview and Methods



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About PSE Healthy Energy

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Introduction

The petrochemicals industry processes crude oil and natural gas to make chemicals that are used to manufacture commercial products, including plastics, fertilizers, digital devices, medical equipment, and tires. They are also used in many parts of energy systems, including solar panels, wind turbine blades, batteries, thermal insulation for buildings, and electric vehicle parts (Speight, 2020). Currently, the petrochemical industry accounts for 14% and 8% of total global primary oil and gas demand, respectively, because oil, natural gas, and coal comprise the majority of fuels or feedstock consumed by the petrochemical industry (IEA, 2018). Demand for petrochemicals is increasing as demand for plastics, fertilizers, synthetic fibers, rubber, and other products continues to grow (IEA, 2018).

As fossil fuels are inextricably linked to petrochemicals, manufacturing of petroleum-based chemicals are also a major contributor to greenhouse gas (GHG) emissions and the global climate burden (Trowbridge et al., 2023). Globally, petrochemical manufacturing is estimated to have emitted 1.8 gigatons of CO_2-equivalents (CO_2e) in 2021, approximately 4% of total global GHG emissions (Bauer et al., 2022). The petrochemical industry also emits criteria air pollutants (CAPs) and hazardous air pollutants (HAPs) which are harmful to health. Evidence suggests that residents living near petrochemical complexes have a higher risk of cancer diagnosis across multiple cancer types (Boonhat et al., 2023; Boonhat and Lin, 2020; Jephcote et al., 2020; Lin et al., 2019, 2020; Williams et al., 2020) as well as a higher incidence of adverse respiratory symptoms and increased risk of adverse birth outcomes (Chang et al., 2020; Huang et al., 2021).

In this report, we characterize the climate, air quality, health, and equity implications of petrochemical facilities in the Ohio River Valley region (Ohio, Pennsylvania, and West Virginia) and the Gulf Coast region (Louisiana and Texas). We provide an overview of further proposed growth in the U.S. Section 1.0 includes key results and Section 2.0 details technical methods.

For existing facilities (2012-2021), we characterize greenhouse gas emissions, air pollutant emissions, and populations living near existing petrochemical facilities in each region (Section 1.1). For facilities that reported primary $PM_{2.5}$ emissions in 2020, we estimated the $PM_{2.5}$-attributable premature deaths and associated economic impacts of existing petrochemical facilities in these regions (Section 1.1.2.3).

We also describe proposed petrochemical projects in the Ohio River Valley and Gulf Coast, summarize their associated projected greenhouse gas and air pollutant emissions (net annual potential to emit), and characterize populations near these proposed petrochemical projects (Section 1.2).

An interactive data tool showcasing the data compiled in this assessment is available at: https://petrochemicals.psehealthyenergy.org/.

1.0 Technical Overview: Results

1.1 Existing Petrochemical Facilities

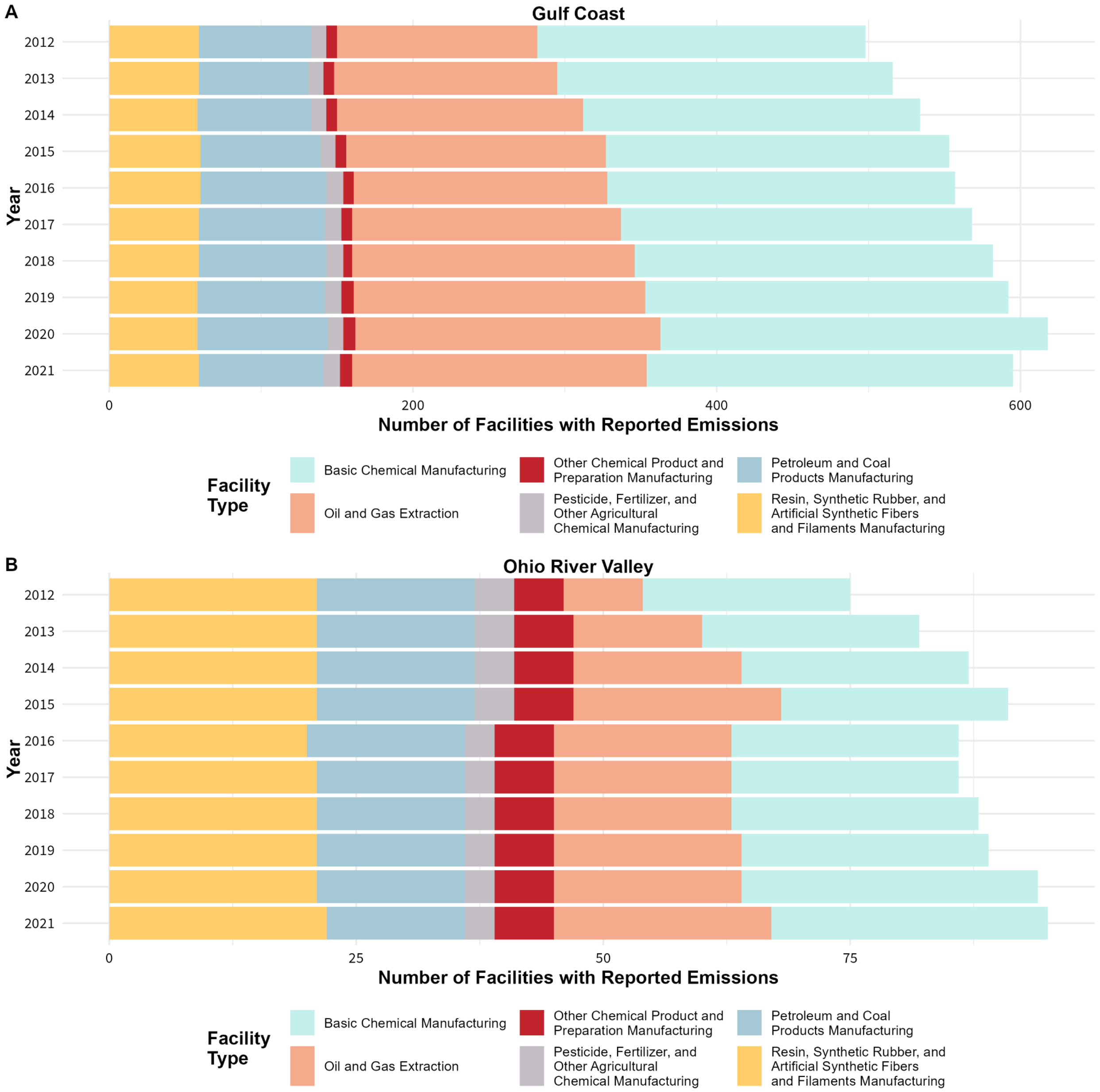
Combining data for all years (2012-2021) and states, we procured emissions data for 774 petrochemical facilities. We define petrochemical facilities as facilities that produce petroleum feedstocks, use feedstocks to produce primary petrochemicals, or use primary or intermediary petrochemicals to produce intermediary petrochemicals or other base materials products. For detailed data collection and analysis methods, see Section 2.2: Existing Petrochemical Facilities: Data Sources, Facility Identification, and Data Processing. Texas had the greatest number of petrochemical facilities. There are over six times the number of petrochemical facilities in the Gulf Coast region compared to the Ohio River Valley region. Overall, basic chemical manufacturing and oil and gas extraction facilities, as identified by their primary North American Industry Classification System (NAICS) codes (U.S. Census Bureau, 2024a), make up more than 70% of the petrochemical facilities in our assessment. In all states except for Pennsylvania, basic chemical manufacturing facilities were the most common type of facility (**Table 1**).

Table 1. Reporting facilities by region, state, and facility type across all years (2012 - 2021).

Facility Type	Gulf Coast		Ohio River Valley			Total
	LA	TX	OH	PA	WV	
Basic Chemical Manufacturing	75	190	14	6	12	297
Oil and Gas Extraction	40	189	8	7	10	254
Other Chemical Product and Preparation Manufacturing	2	6	2	2	2	14
Pesticide, Fertilizer, and Other Agricultural Chemical Manufacturing	6	5	3	1	0	15
Petroleum and Coal Products Manufacturing	29	60	6	8	3	106
Resin, Synthetic Rubber, and Artificial Synthetic Fibers and Filaments Manufacturing	19	46	13	5	5	88
State Total	**171**	**496**	**46**	**29**	**32**	**774**
Regional Total	**667**		**107**			

In the Gulf Coast region, the number of active facilities increased by 20% from 498 to 595 facilities, driven by increases in basic chemical manufacturing and oil and gas extraction facilities (**Figure 1a**). The Ohio River Valley experienced a similar trend—a 26% increase from 75 to 95 facilities, driven by the same industries (**Figure 1b**). In both regions, there was an increase in the number of reporting facilities in 2020 because we were able to include facilities that reported to the National Emissions Inventory (NEI) (U.S. EPA, 2023a).

Figure 1. Number of facilities with any reported emissions by year (2012 - 2021), stratified by facility type, (A) Gulf Coast Region and **(B)** Ohio River Valley region.

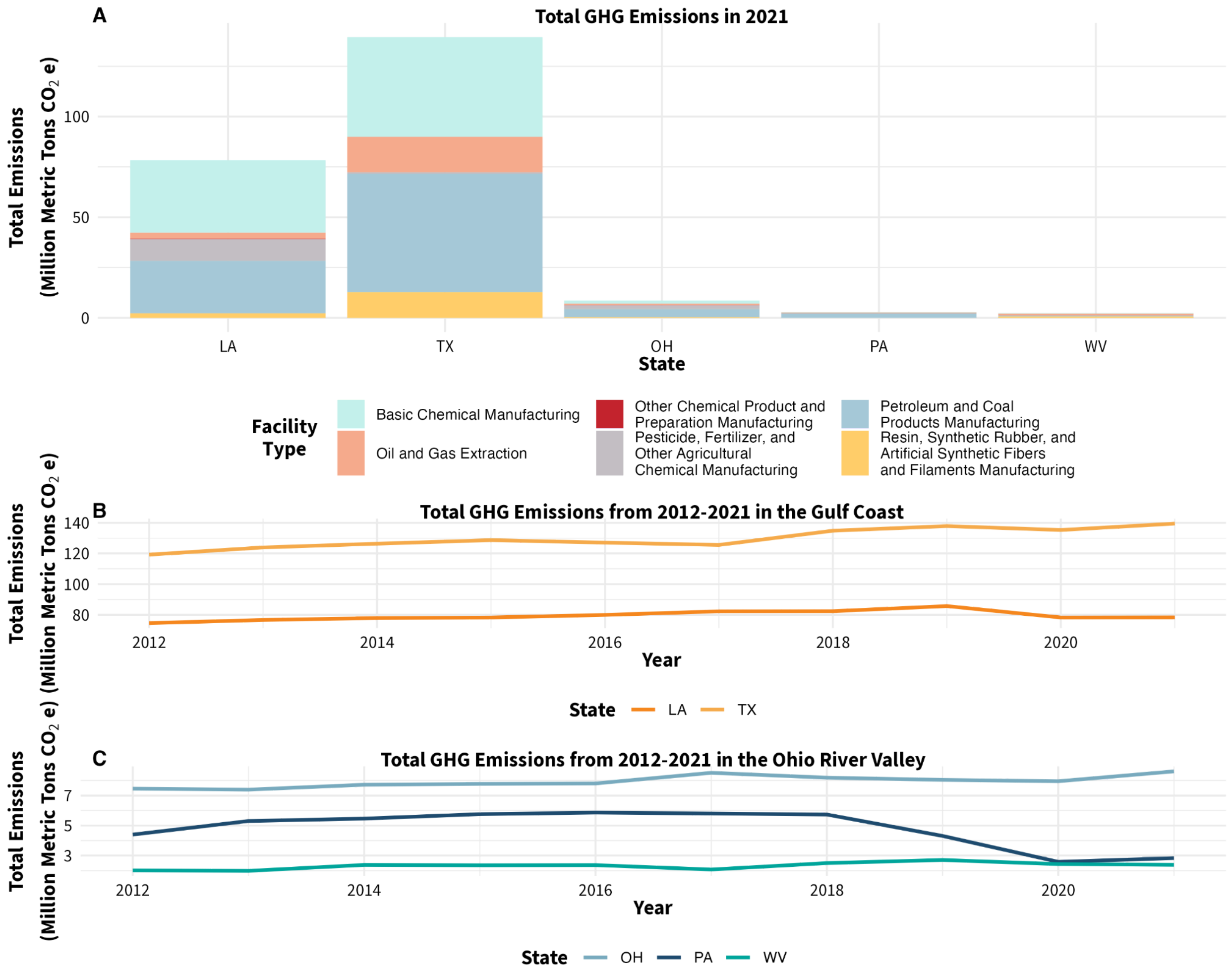


1.1.1 Existing Facilities: Greenhouse Gas Emissions

Greenhouse gases (GHGs) trap heat in the atmosphere and make the planet warmer. The most commonly emitted GHGs were carbon dioxide, methane, and nitrous oxide, with relatively smaller emissions of fluorinated gases and other compounds (U.S. EPA, 2015a). Total GHG emissions increased by 12% from 2012 to 2021 (from 208 to 232 MMT CO_2e), with the greatest increase of 17% in Texas and a slight decrease in Pennsylvania. In 2021, Texas and Louisiana had the highest total GHG emissions (**Figure 2**), with rankings consistent over the years.

Figure 2. Distribution of Total GHG Emissions.

(A) Total reported GHG emissions in 2021 by state and by facility type. Total reported GHG emissions over time by state, **(B)** in the Gulf Coast, and **(C)** in the Ohio River Valley.



Total GHG emissions were largely driven by non biogenic CO_2 (i.e., not from biomass combustion [Definitions, 2024]) emissions as opposed to methane and nitrous oxide. Median GHG emissions were higher in the Gulf Coast (**Table 2**). When comparing individual facilities, we observed a long-tailed distribution (e.g., across states and GHGs, mean emissions were far above median emissions), whereby some facilities had much higher GHG emissions (**Table S4**). A single facility sometimes contributed a substantial proportion of the state's total emissions. For example, one facility contributed about 20% of Ohio's total GHG emissions in 2021, out of 26 reporting facilities. In Texas one facility contributed 8.5% out of 290 reporting facilities.

Table 2. Total and Median Reported Greenhouse Gas (GHG) Emissions by Region and State in 2021.

Region / State	Total Reported Emissions[1] (Median Reported Emissions[2]) [Million Metric Tons CO_2e]				
	CH_4	Non biogenic CO_2	N_2O	Other GHGs[3]	Total GHG
Gulf Coast	1.77 (0.00121)	211 (0.12)	4.22 (0.0000501)	0.437 (0.0052)	218 (0.127)
Louisiana	0.381 (0.000344)	75.1 (0.162)	2.46 (0.0000817)	0.427 (0.018)	78.3 (0.165)
Texas	1.39 (0.00169)	136 (0.0987)	1.77 (0.0000444)	0.00979 (0.00489)	139 (0.104)
Ohio River Valley	0.0958 (0.000586)	12.6 (0.102)	0.45 (0.000048)	0.642 (0.0379)	13.8 (0.106)
Ohio	0.0342 (0.000103)	8.13 (0.115)	0.443 (0.0000456)	Not reported	8.61 (0.115)
Pennsylvania	0.0252 (0.000795)	2.8 (0.0459)	0.00581 (0.0000308)	Not reported	2.83 (0.0472)
West Virginia	0.0365 (0.00113)	1.7 (0.1)	0.00123 (0.0000548)	0.642 (0.0379)	2.38 (0.106)

[1] Sum of reported emissions from all facilities within a region or state.

[2] Median of facility-level emissions among reporting facilities within a region or state.

[3] Other GHGs include biogenic CO_2, HFC, HFE, PFC, short lived compounds, and other fluorinated GHG.

All facility types reported methane, non biogenic CO_2, and N_2O but only basic chemical manufacturing facilities and resin, synthetic rubber, and artificial synthetic fibers and filaments manufacturing facilities reported any emissions for other GHGs. Petroleum and coal products manufacturing emitting the most GHGs in 2021 (**Table 3**), followed by basic chemical manufacturing facilities, which had more facilities but lower average emissions (**Table S5**). In conjunction with the long-tail distribution of emissions, these findings illuminate the value of facility-level assessments in addition to industry-scale review.

Table 3. Total and Median Reported Greenhouse Gas (GHG) Emissions by Facility Type in 2021.

Facility Type	Total Reported GHG Emissions by Facility Type[1] (Median Reported Emissions[2]) [Million Metric Tons CO_2e]				
	CH_4	Non biogenic CO_2	N_2O	Other GHGs[3]	Total GHG
Basic Chemical Manufacturing	0.482 (0.0000574)	84.5 (0.313)	1.97 (0.0000702)	0.419 (0.00489)	87.4 (0.325)
Oil and Gas Extraction	0.864 (0.00235)	21.8 (0.0669)	0.0218 (0.0000322)	Not reported	22.7 (0.0717)
Other Chemical Product and Preparation Manufacturing	0.0000848 (0.0000424)	0.447 (0.223)	0.000101 (0.0000505)	Not reported	0.447 (0.223)
Pesticide, Fertilizer, and Other Agricultural Chemical Manufacturing	0.00197 (0.000122)	11.1 (0.662)	2.41 (0.000205)	Not reported	13.6 (0.594)
Petroleum and Coal Products Manufacturing	0.454 (0.00267)	90.7 (0.633)	0.238 (0.0014)	Not reported	91.4 (0.636)
Resin, Synthetic Rubber, and Artificial Synthetic Fibers and Filaments Manufacturing	0.062 (0.000039)	15.3 (0.0814)	0.0293 (0.0000465)	0.66 (0.0279)	16.1 (0.0831)

[1] Sum of reported emissions from all facilities of a specific facility type.

[2] Median of facility-level emissions among reporting facilities of a specific facility type.

[3] Other GHGs include biogenic CO_2, HFC, HFE, PFC, short lived compounds, and other fluorinated GHG.

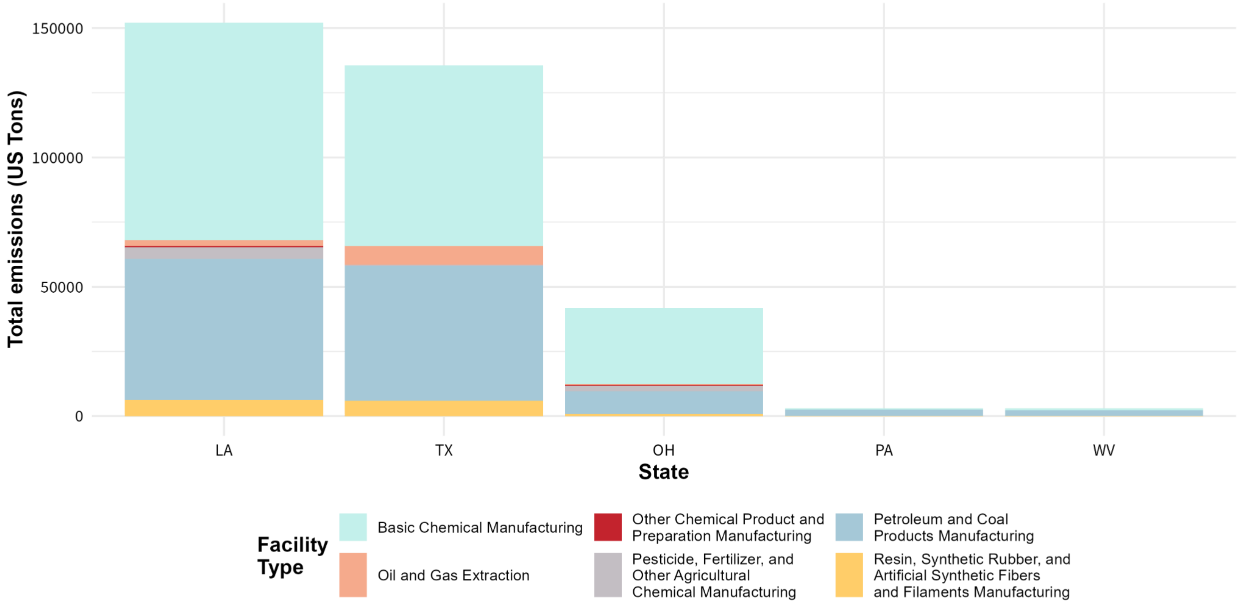
1.1.2 Existing Facilities: Air Pollutant Emissions and Human Health Implications

1.1.2.1 Criteria Air Pollutants (CAPs)

Under the Clean Air Act, the EPA set National Ambient Air Quality Standards (NAAQS) for each criteria air pollutant (CAP) to protect public health (U.S. EPA, 2014). They include carbon monoxide (CO), lead, nitrogen dioxide, particulate matter (PM), sulfur dioxide (SO_2), and ground-level ozone (O_3).

Total CAP emissions were highest in Louisiana and Texas compared to other states. In all states, the facility types with the highest emissions were basic chemical manufacturing and petroleum and coal products manufacturing (**Figure 3**).

Figure 3. Bar chart of total reported criteria air pollutants (CAPs) in 2020 by state and by facility type.



For all CAPs, the total and median reported emissions in the Gulf Coast was higher than the total and median emissions reported in the Ohio River Valley (**Table 4**). Within the Gulf Coast, median reported emissions for all CAPs in Louisiana was higher than in Texas but Texas had higher reported total emissions for CO, NO_x, PM_{10}, and $PM_{2.5}$. The average emissions for each state and pollutant tended to be several times higher than the median emissions. This was partially driven by the fact that a few facilities accounted for a majority of emissions in the state. For example, in Ohio, the CO emissions from one facility accounted for over 80% of total CO emissions reported in Ohio (**Table S6**).

Petroleum and coal products manufacturing facilities had the highest-reported median emissions for all CAPs (**Table 5**), and basic chemical manufacturing facilities had the highest reported total emissions for CO, NO_x, and SO_2. Only basic chemical manufacturing facilities and petroleum and coal products manufacturing reported any lead metal emissions (i.e., only lead mass emitted) s (**Table 5**, **Table S7**).

Table 4. Total and Median Reported Criteria Air Pollutant (CAP) Emissions by Region and State in 2020.

Region / State	Total Reported Emissions[1] (Median Reported Emissions[2]) [US Tons]						
	CO	Lead	NO_X[3]	PM_{10}	$PM_{2.5}$[3]	SO_2[3]	Total CAPs
Gulf Coast	72,500 (83)	0.132 (0.00222)	100,000 (97.7)	19,800 (19.5)	17,000 (15.3)	95,200 (2.26)	288,000 (250)
Louisiana	33,000 (120)	0.0877 (0.00363)	48,600 (133)	9,040 (37.7)	7,660 (28)	61,400 (5.56)	152,000 (338)
Texas	39,500 (59.9)	0.0439 (0.00115)	51,500 (81.3)	10,800 (11.9)	9,390 (9.22)	33,700 (1.34)	135,000 (171)
Ohio River Valley	32,500 (21.7)	0.00806 (0.00403)	8,900 (37.9)	2,280 (11.4)	2,100 (9.11)	4,160 (0.932)	47,900 (77)
Ohio	30,900 (41.6)	0.00806 (0.00403)	6,380 (71.8)	1,430 (23.1)	1,300 (19.1)	3,190 (1.99)	41,900 (131)
Pennsylvania	572 (14.4)	Not reported	1,320 (25.3)	590 (3.06)	555 (3.06)	509 (0.506)	2,990 (43.4)
West Virginia	1,100 (21.4)	Not reported	1,200 (28.9)	261 (3.73)	243 (3.73)	458 (0.579)	3,020 (80.3)

[1] Sum of reported emissions from all facilities within a region or state.

[2] Median of facility-level emissions among reporting facilities within a region or state.

[3] $PM_{2.5}$, NO_X, and SO_2 values shown (and Ammonia [NH_3] and VOCs reported from NEI [not shown]), are used in the InMap analysis below.

Table 5. Total and Median Reported Criteria Air Pollutant (CAP) Emissions by Facility Type in 2020.

Facility Type	Total Reported Emissions[1] (Median Reported Emissions[2]) [US Tons]						
	CO	Lead	NO_X	PM_{10}	$PM_{2.5}$	SO_2	Total CAPs
Basic Chemical Manufacturing	70,400 (54)	0.0468 (0.00239)	59,000 (58.5)	8,830 (13.6)	7,580 (11.6)	46,200 (1.34)	184,000 (130)
Oil and Gas Extraction	3,860 (79.4)	Not reported	4,340 (93.2)	505 (7.47)	499 (7.47)	1,350 (0.943)	10,100 (152)
Other Chemical Product and Preparation Manufacturing	119 (13.1)	Not reported	376 (19.6)	74.2 (5.61)	73 (4.56)	96.9 (0.368)	665 (38.1)
Pesticide, Fertilizer, and Other Agricultural Chemical Manufacturing	1,180 (236)	Not reported	4,950 (276)	919 (90.4)	825 (59.9)	34.9 (4.81)	7,080 (409)
Petroleum and Coal Products Manufacturing	24,500 (215)	0.0576 (0.00329)	34,600 (372)	10,400 (119)	9,050 (96.8)	50,400 (122)	120,000 (1,130)
Resin, Synthetic Rubber, and Artificial Synthetic Fibers and Filaments Manufacturing	5,030 (22.5)	0.0005 (0.0005)	5,700 (28.9)	1,370 (15)	1,120 (9.21)	1,240 (0.422)	13,300 (77.4)

[1] Sum of reported emissions from all facilities of a specific facility type.

[2] Median of facility-level emissions among reporting facilities of a specific facility type.

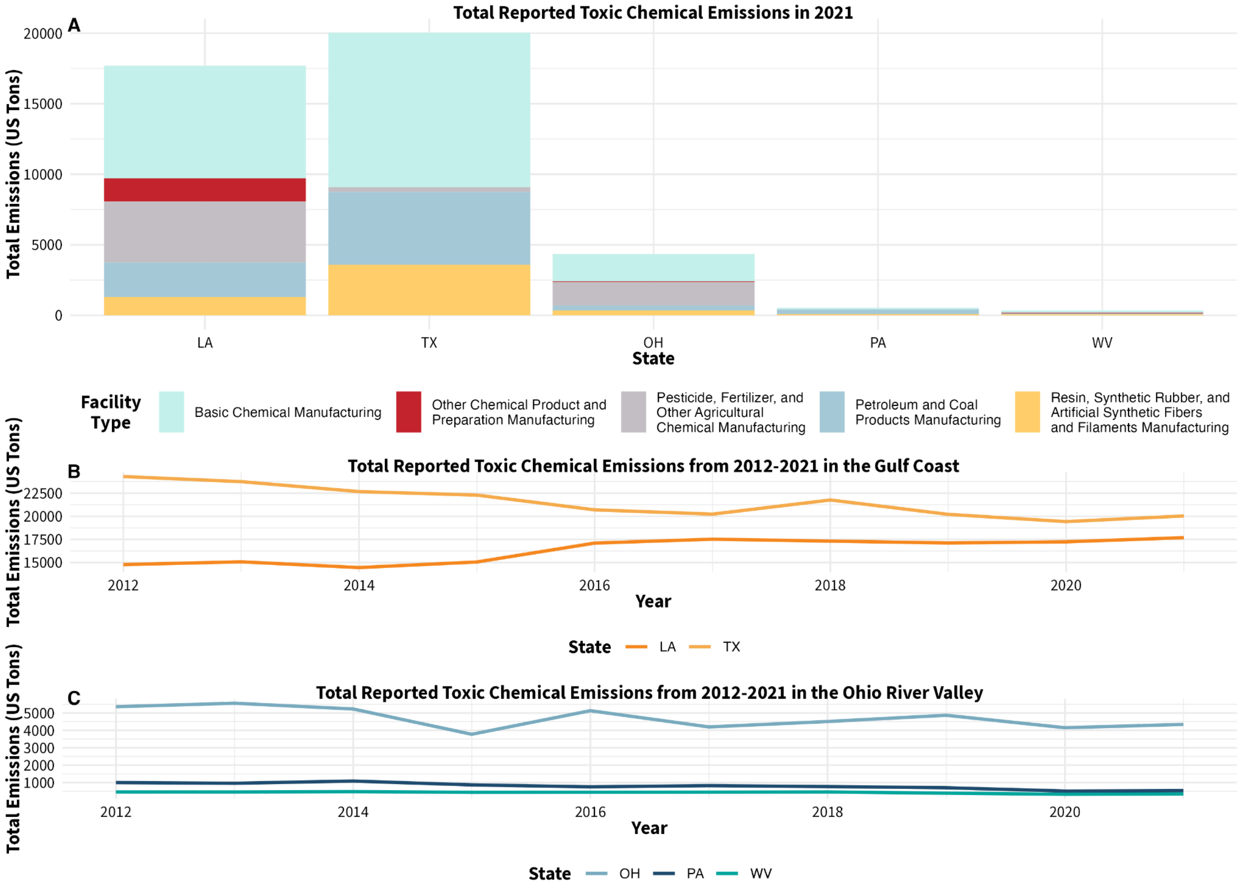
1.1.2.2 Hazardous Air Pollutants (HAPs) and Toxic Chemicals

Hazardous air pollutants (HAPs) are a set of 188 health-damaging air pollutants that the U.S. EPA regulates under the Clean Air Act (U.S. EPA, 2013). The Toxic Releases Inventory (TRI) includes emissions of HAPs and of other toxic pollutants (U.S. EPA, 2015b); herein we use the term “toxic chemicals” to describe any chemical covered by TRI (i.e., HAPs and non-HAP pollutants).

In 2021, total emissions of toxic chemicals were higher in Louisiana than in Texas even though Texas had more facilities (**Figure 4a**). Most of the emissions in Louisiana and Ohio were from basic chemical manufacturing facilities and pesticide, fertilizer, and other agricultural chemical manufacturing facilities. In Texas and Pennsylvania, emissions were mostly from basic chemical manufacturing facilities and petroleum and coal products manufacturing facilities. In West Virginia, emissions were mostly from basic chemical manufacturing facilities and resin, synthetic rubber, and artificial synthetic fibers and filaments manufacturing facilities. For all states except Louisiana, there was an overall decrease in total reported toxic chemical emissions over time (**Figure 4b**).

Figure 4. Distribution of Total Reported Toxic Chemical Emissions

(a) Total reported toxic chemical emissions in 2021 by state and by facility type. **(b)** Total reported toxic chemical emissions over time by state in the Gulf Coast and **(c)** in the Ohio River Valley. **Note:** We only included emissions from TRI to avoid discrepancies in 2020 due to availability of additional data from NEI. Natural gas extraction and natural gas liquid extraction facilities were out of scope for TRI from 2012-2021.



To identify the most concerning pollutants, we scaled emissions by toxicity by multiplying the total emissions for each HAP in 2021 by the inhalation toxicity weights from the Risk Screening Environmental Indicators (RSEI) Model. Ethylene oxide, 1,3-butadiene, benzene, chloroprene, and ethylene dichloride were the most concerning HAPs after scaling for toxicity. Ethylene oxide, 1,3-butadiene, and benzene are carcinogenic to humans and chloroprene and ethylene dichloride are likely to be carcinogenic to humans (**Table 6**; U.S. EPA, n.d.). All five pollutants are considered petrochemicals (Speight, 2020).

Table 6. Health Hazards and Outcomes Associated with Top Five HAPs.

Health Outcomes	Ethylene Oxide	1,3-Butadiene	Benzene	Chloroprene	Ethylene Dichloride
Carcinogenicity[1]	Carcinogenic to humans (lymphoid cancer, breast cancer for women)	Carcinogenic to humans (leukemia)	Carcinogenic to humans (leukemia)	Likely to be carcinogenic to humans (liver cancer)	Likely to be carcinogenic to humans
Impacted systems for non-cancer outcomes[2]	*Chronic exposure:* Nervous system	*Acute exposure:* Development, nervous system *Chronic exposure:* Reproductive system, cardiovascular system	*Acute exposure:* Reproductive/ development, immune system, hematologic system *Chronic exposure:* Reproductive/ development, immune system, hematologic system	*Acute exposure:* Nervous system, immune system *Chronic exposure:* Nervous system, cardiovascular system	*Acute exposure:* Nervous system *Chronic exposure:* Alimentary system (liver)

[1] Carcinogenicity classification from EPA's Integrated Risk Information System (IRIS) (U.S. EPA, n.d.).

[2] Non-cancer impacts from the California Office of Environmental Health Hazard Assessment (Cal EPA OEHHA, 2016) and EPA's health effects summary for each pollutant (U.S. EPA, 2016a).

Facilities in the Ohio River Valley did not report any chloroprene and ethylene dichloride emissions. Overall, the Gulf Coast region had higher total and median HAP emissions compared to the Ohio River Valley region (**Table 7**). Within the Gulf Coast, median reported emissions for all HAPs in Louisiana were higher than in Texas, but Texas had higher total reported emissions. In the Ohio River Valley, Ohio had the highest total and median HAP emissions. Similar to the GHGs and CAPs, the mean reported HAP emissions were higher than the median reported HAP emissions, again indicating the presence of a long tail of high-emitting facilities (**Table S8**). When comparing states and facility types, a key caveat is that HAP and other air toxics emissions from natural gas processing facilities were not included because they were exempt from TRI reporting requirements until November 2021 (U.S. EPA, 2021).

Table 7. Top 5 Total and Median Reported Hazardous Air Pollutant (HAP) Emissions by State and Region in 2021.

Region / State	Total Reported HAP Emissions[1] (Median Reported Emissions[2]) [US tons]					
	Ethylene Oxide	1,3-Butadiene	Benzene	Chloroprene	Ethylene Dichloride	Total HAPs
Gulf Coast	68.5 (0.762)	574 (0.788)	782 (2.79)	18.8 (0.00325)	198 (6.73)	12900 (14.5)
Louisiana	30.2 (1.75)	68.3 (0.742)	229 (2.81)	18.8 (0.0045)	153 (6.73)	4640 (23.6)
Texas	38.4 (0.646)	505 (0.87)	553 (2.56)	0.00912 (0.00131)	45.4 (3.46)	8300 (11.4)
Ohio River Valley	1.24 (0.113)	14.4 (0.078)	70.5 (3.3)	Not reported	Not reported	3150 (7.53)
Ohio	Not reported	12.3 (0.184)	16.5 (3.3)	Not reported	Not reported	2550 (9.98)
Pennsylvania	Not reported	2.03 (0.0065)	31.9 (3.7)	Not reported	Not reported	402 (7.45)
West Virginia	1.24 (0.113)	0 (0)	22.1 (11.1)	Not reported	Not reported	207 (5.35)

[1] Sum of reported emissions from all facilities within a region or state.

[2] Median of facility-level emissions among reporting facilities within a region or state.

Pesticide, fertilizer, and other agricultural manufacturing facilities did not report any emissions for the top five HAPs that we identified. Total HAPs emissions were highest in basic chemical manufacturing facilities and petroleum and coal manufacturing facilities. However, pesticide, fertilizer, and other agricultural manufacturing facilities had the highest median HAP emissions (**Table 8**, **Table S9**).

Table 8. Top Five Total and Median Reported Hazardous Air Pollutant (HAP) Emissions by Facility Type and Region in 2021.

Facility Type	Total Reported Emissions[1] (Median Reported Emissions[2]) [US tons]					
	Ethylene Oxide	1,3-Butadiene	Benzene	Chloroprene	Ethylene Dichloride	Total HAPs
Basic Chemical Manufacturing	65.8 (0.646)	476 (4.16)	431 (3.6)	0.0106 (0.00131)	136 (6.73)	7790 (9.72)
Other Chemical Product and Preparation Manufacturing	0.13 (0.065)	0.007 (0.007)	0.004 (0.004)	Not reported	Not reported	105 (0.25)
Pesticide, Fertilizer, and Other Agricultural Chemical Manufacturing	Not reported	Not reported	Not reported	Not reported	Not reported	467 (46)
Petroleum and Coal Products Manufacturing	Not reported	20.2 (0.0725)	386 (3.3)	Not reported	0.005 (0.0025)	5570 (32.1)
Resin, Synthetic Rubber, and Artificial Synthetic Fibers and Filaments Manufacturing	3.86 (1.93)	92 (3.23)	35.6 (0.694)	18.8 (0.00475)	62 (6.86)	2160 (12.8)

[1] Sum of reported emissions from all facilities of a specific facility type.

[2] Median of facility-level emissions among reporting facilities of a specific facility type.

1.1.2.3 $PM_{2.5}$- Attributable Health Impacts Using InMap

Calculating health impacts from atmospheric releases of harmful pollutants relies on obtaining changes in the concentration levels resulting from changes in emissions, along with epidemiological and demographic data to estimate certain metrics (i.e., for fine particulate matter, marginal avoided mortality). Reduced-complexity air quality models such as InMAP (Tessum et al., 2017) sacrifice detail in air quality relationships by using static relationships with standard national emission inventories (i.e. 2005 NEI) without the need of costly -both in terms of resources and compute/wall time- chemical transport models (CTMs). Reduced-complexity models can be refined to cover more up-to-date relationships, and InMap has been applied using different regional inventories and CTM's (Apte et al., 2019), demographic and pollutant-endpoint relationships, along with more recent, or projected monetized estimates.

Acknowledging the limitations of InMap restricting our health impact analysis to one pollutant, we made sure to take full advantage of InMap capabilities that allow for configurations to capture fine particulate matter ($PM_{2.5}$) and precursor (NO_x, SO_x, VOCs, ammonia [NH_3]) related impacts for each individual petrochemical facility using all available emissions for year 2020. The calculations used estimates of relative risk for a single pollutant (Di et al., 2017) and value of statistical life for 2020 dollar value based on guidelines from the U.S. Department of Health and Human Services (U.S. DHHS, 2021). Simulations were performed based on emissions from the 2020 NEI that included 47 individual facilities over the Ohio River Valley, 25 of which are located in the state of Ohio, 13 in Pennsylvania, and the remaining nine in West Virginia. In the Gulf Coast Region, $PM_{2.5}$ and precursor annual emissions were included for 289 individual facilities, 187 of which are located in the state of Texas, and the remaining 102 in Louisiana (**Table 9**). In addition to facility-level simulations, the InMap framework allowed us to calculate grouped facility estimates at the state level and region-wide, and estimate combined impacts by performing separate simulations. For detailed methods and limitations, see Section 2.5: Air Quality Modeling Methods to Estimate $PM_{2.5}$-Attributable Impacts.

Table 9. Number of $PM_{2.5}$-Reporting Facilities by Region, State, and Facility Type for 2020.

Facility Type	Gulf Coast		Ohio River Valley			Total
	LA	TX	OH	PA	WV	
Basic Chemical Manufacturing	50	111	6	4	5	176
Oil and Gas Extraction	13	24	2	0	0	39
Other Chemical Product and Preparation Manufacturing	2	1	1	0	1	5
Pesticide, Fertilizer, and Other Agricultural Chemical Manufacturing	3	2	2	0	0	7
Petroleum and Coal Products Manufacturing	23	32	5	5	1	66
Resin, Synthetic Rubber, and Artificial Synthetic Fibers and Filaments Manufacturing	11	17	9	4	2	43
State Total	**102**	**187**	**25**	**13**	**9**	**336**
Regional Total	**289**		**47**			

Nationally-aggregated mortality estimates from individual InMAP simulations are provided for each of the 336 facilities and visualized in an interactive online web tool. State-level InMAP simulations provide nationally-aggregated mortality estimates presented in **Tables 10 and 11**. The region-wide InMap simulation (all 336 locations) estimates the annual premature mortality from $PM_{2.5}$ and precursor emissions to be 1491 deaths and an annual monetized impact of approximately 17 billion (2020 US$) for 2020.

Table 10. InMap $PM_{2.5}$-Attributable Mortality Estimates for the Ohio River Valley Region. Each state-level estimate is rounded to the nearest life and nearest $1 million based on facility-level simulations. Regional totals are modeled separately as concurrent emissions, and their impact may differ from summed estimates of each state/facility within a region.

	InMap $PM_{2.5}$-Attributable Mortality Estimates	
	Total Deaths	**Monetized Damages (Mil$)**
Ohio	36	410
Pennsylvania	81	923
West Virginia	16	182
Region Total	**134**	**1,528**

Table 11. InMap $PM_{2.5}$-Attributable Mortality Estimates for the Gulf Coast Region. Each state-level estimate is rounded to the nearest life and nearest $1 million based on facility-level simulations. Regional totals are modeled separately as concurrent emissions, and their impact may differ from summed estimates of each state/facility within a region.

	InMap $PM_{2.5}$-Attributable Mortality Estimates	
	Total Deaths	**Monetized Damages (Mil$)**
Texas	1020	11,628
Louisiana	557	6,350
Region Total	**1365**	**15,561**

1.1.3 Existing Facilities: Characterizing Nearby Populations

Based on our data, there are 774 petrochemical facilities in the Ohio River Valley and Gulf Coast regions, with the majority (86%) located along the Gulf Coast, primarily in Texas. We estimated the total population, percentage of People of Color (PoC)—including Hispanic, Asian, Black, Hawaiian, Pacific Islander, American Indian, and Alaskan Native individuals—and the environmental justice vulnerability of people living within a three mile radius of each of these facilities. For detailed methods, see Section 2.4: Demographic Analysis of Communities Near Existing Petrochemical Facilities and Proposed Petrochemical Projects.

On average, 27,556 people live within a three mile radius of a facility in the Ohio River Valley, and 16,268 people live within the same distance on the Gulf Coast. However, the population density varies greatly across facilities (**Table 12** and **Figure 5**). For some, this number can be as high as 336,000 people (Philadelphia Refinery). Among the states we analyzed, Pennsylvania and Texas had some of the facilities with the highest population counts within three miles (**Table 12** and **Figure 5**). The average percentage of PoC living nearby petrochemical facilities is 48% in the Gulf Coast and 13% in the Ohio River Valley. Similar to the total population, the percentage PoC also varies across facilities. Overall, and as expected given state demographics, Louisiana and Texas had some of the highest PoC percentages living nearby petrochemical facilities (**Table 12** and **Figure 5**). Regarding income, 83% of the petrochemical facilities we analyzed were surrounded by a population that has a per capita income below the national median of $41,000 (U.S. Census Bureau, 2024b). Ohio had the highest percentage of facilities (44/46) located in communities with a low per capita income (< $41,000) (**Figure 6b**).

Figure 5. Total Population and Percent People of Color. Each point in the scatterplot represents a petrochemical facility. The x-axis represents the percentage of people of color within a 3-miles radius of the facility and the y-axis the total population.

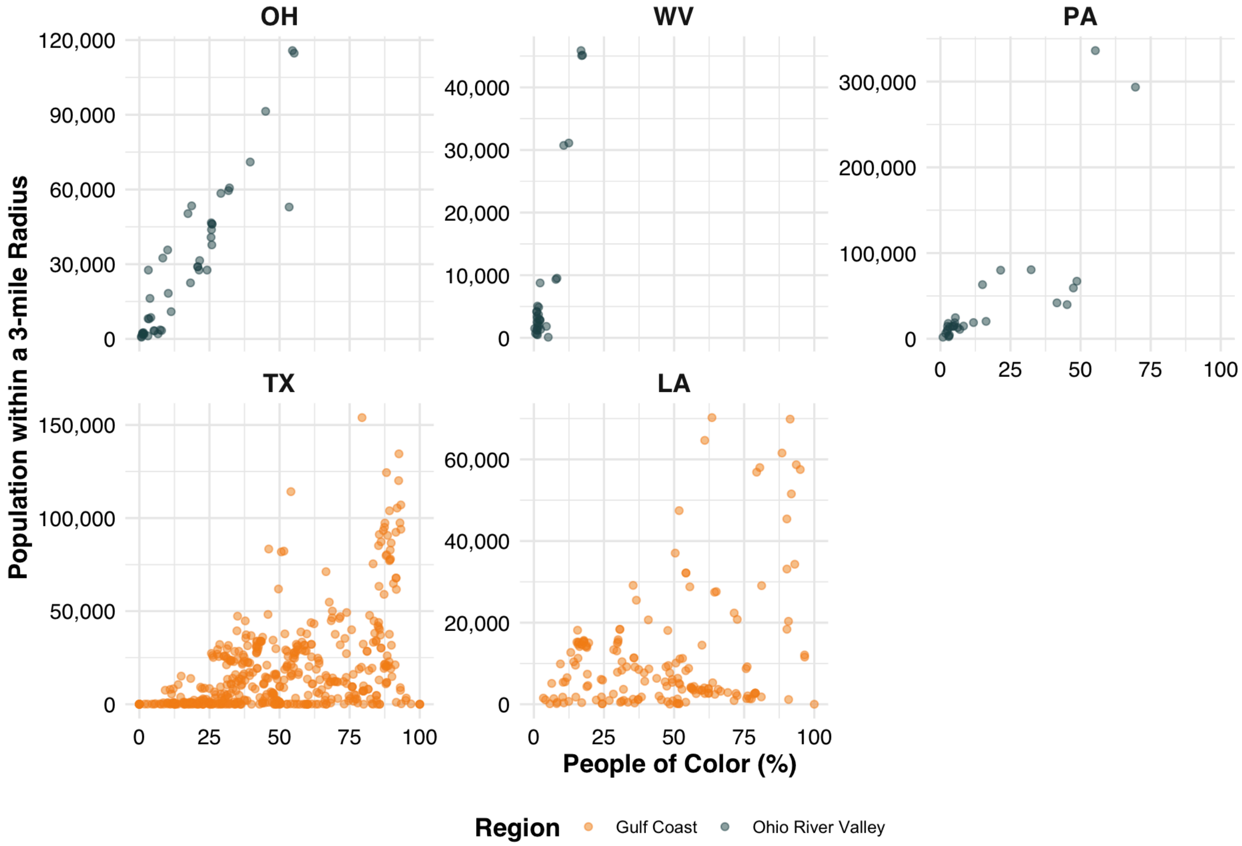
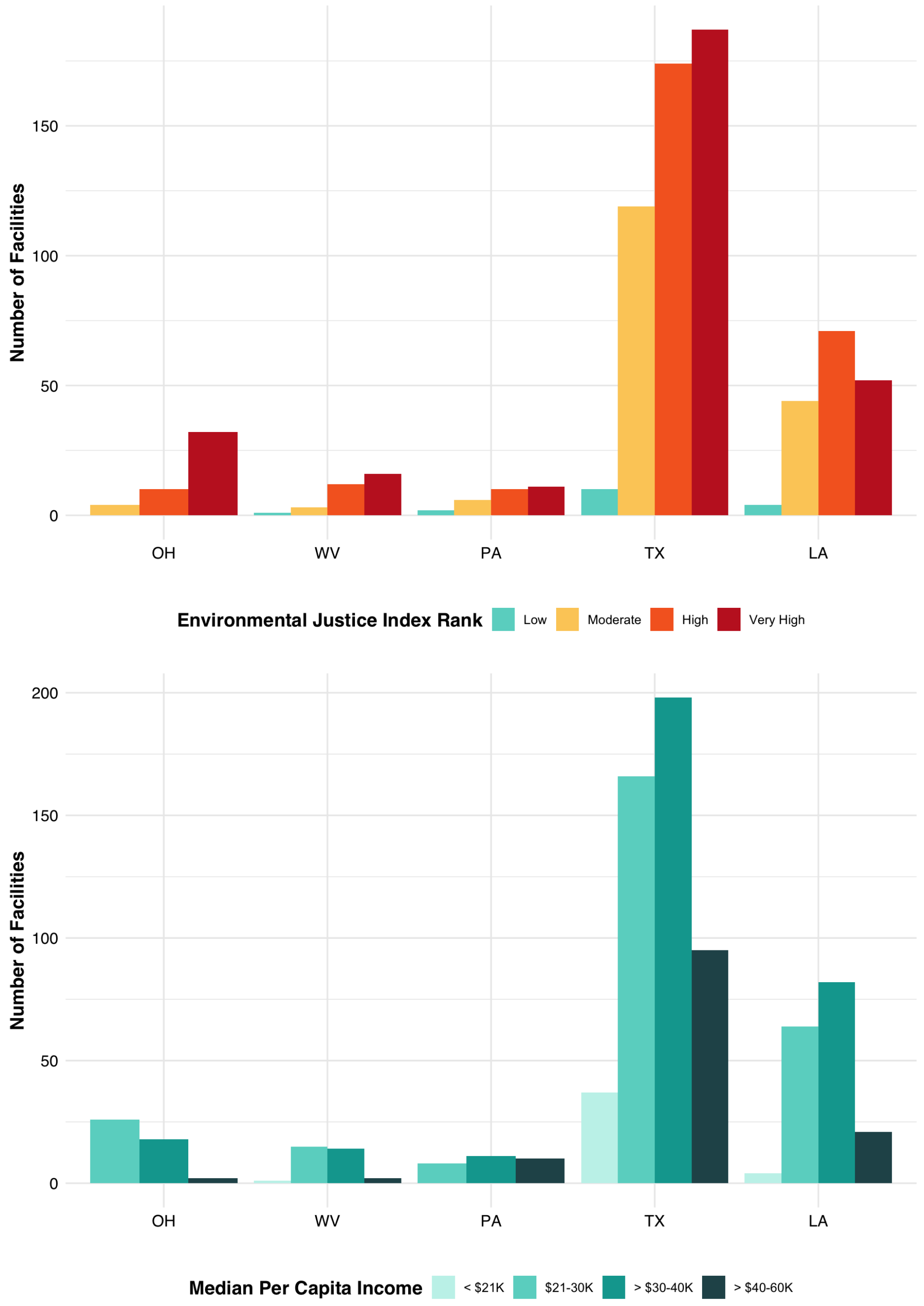


Table 12. Characteristics of the Population Living Within a Three mile Radius of Petrochemical Facilities for Each State, Region, and Across Both Regions.

	Number of facilities	Median population (IQR)	Median percentage People of Color (IQR)	Number of facilities with Very High Environmental Justice Index Rank (%)
Both Regions	774	8,479 (1,159–25,268)	42 (21–64)	298 (38%)
Ohio River Valley	**107**	**10,949 (2,678–38,791)**	**5 (2–20)**	**59 (55%)**
Ohio	46	27,632 (3,219–46,111)	11 (3–26)	32 (69%)
Pennsylvania	29	15,484 (10,949–41,889)	5 (3–21)	11 (38%)
West Virginia	32	2,883 (1,545–5,989)	2 (1–5)	16 (50%)
Gulf Coast	**667**	**8,089 (838–23,054)**	**47 (29–68)**	**239 (36%)**
Texas	496	9,235 (443–26,487)	48 (30–70)	187 (38%)
Louisiana	171	5,916 (2,027–14,658)	48 (24–62)	52 (30%)

Using data from the CDC Environmental Justice Index (EJI) and the EPA's EJScreen methodology, we estimated an EJI for the area within a three mile radius of each petrochemical facility. The EJI provides a relative estimate of cumulative population vulnerability by considering environmental burden, social vulnerability, and health vulnerability. A higher EJI percentile rank indicates greater overall vulnerability, categorized as Low (0-25th percentile), Moderate (25-50th percentile), High (50-75th percentile), and Very High (75-100th percentile). Our analysis showed that 36% of petrochemical facilities on the Gulf Coast had nearby populations with a Very High EJI rank, while this percentage rises to 55% in the Ohio River Valley. Among all states, Ohio had the highest percentage of facilities (69%) in communities with a Very High EJI rank (**Table 12** and **Figure 6a**).

Figure 6. (a) Environmental Justice Index (EJI) Rank. The bars represent the number of petrochemical facilities (y-axis) within each EJI category for each state (x-axis) in the Ohio River Valley (Ohio, West Virginia, and Pennsylvania) and Gulf Coast (Texas and Louisiana). The higher the EJI rank, the higher the population vulnerability. **(b) Median per capita income**. The bars represent the number of petrochemical facilities within each of the per capita income brackets for each state (x-axis) in the Gulf Coast and Ohio River Valley.



1.2 Proposed Petrochemical Projects

There were 116 proposed projects and 22 project types (i.e., types of facilities). For data sources and detailed methods, see Section 2.3: Proposed Petrochemical Projects: Data Sources, Facility Identification, and Data Processing. Most projects are in Louisiana and Texas. Carbon capture use and storage and natural gas liquids fractionator projects were the most common (**Figure 7**). The proposed petrochemical projects fell into six sectors as categorized by EIP. Most proposed projects were in the petrochemicals and plastics sector (**Figure 8**).

Figure 7. Number of Proposed Projects by Facility Type and State. Some proposed projects are double counted because a project could be categorized as more than one facility type. There are 116 proposed projects in total.

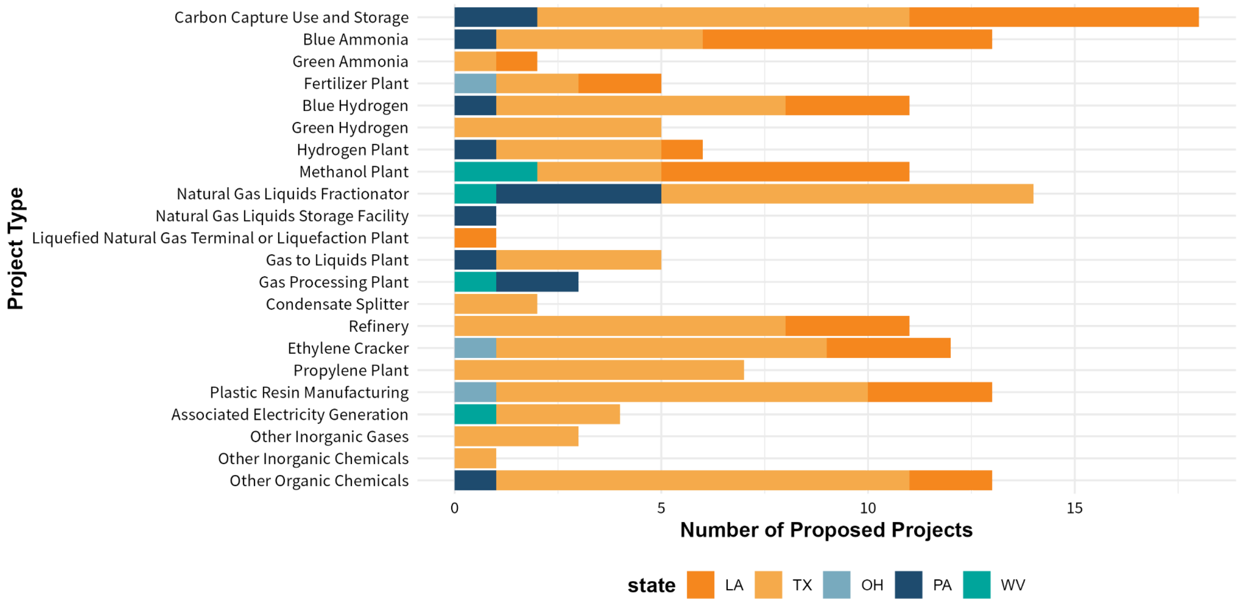
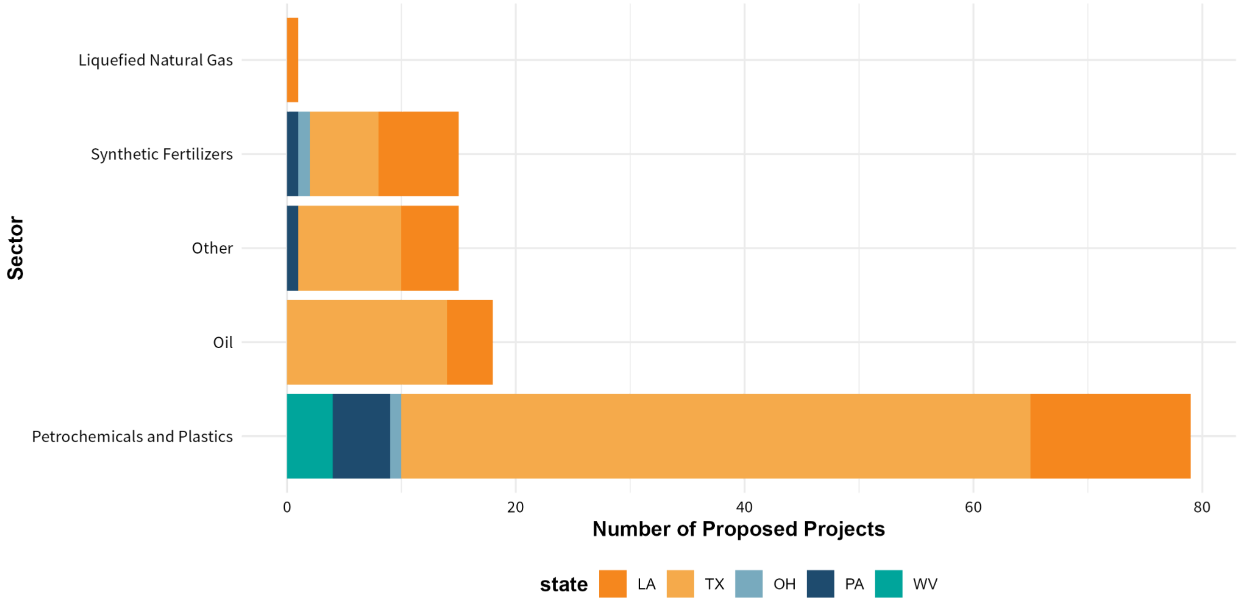


Figure 8. Number of Proposed Projects by Sector and State. Some proposed projects are double counted because a project could be categorized as more than one sector. There are 116 proposed projects in total.



1.2.1 Proposed Projects: Net Annual Potential to Emit

Emissions from proposed projects were reported as maximum potential emissions. For all pollutants and pollutant types, the net annual potential emissions from proposed projects in the Gulf Coast are much higher than in the Ohio River Valley (**Table 13**). Not every proposed project reported emissions for each pollutant and 44 projects (38%) did not report emissions at all (**Table S10**). Four projects reported negative net annual potential emissions. Of those four projects, two projects in Louisiana and one project in Texas reported net-negative NO_x emissions and one project in Texas reported net-negative $PM_{2.5}$ emissions. Such negative emissions reflect projects on current facilities that are anticipated to reduce net emissions.

Table 13. Potential Total and Median Reported Net Potential Emissions by State

Note: all emissions are reported as U.S. tons, except for GHGs which are reported as metric tons of CO_2e per year.

Region/State	Total Reported Potential Emissions[1] (Median Reported Potential Emissions[2]) [US tons]						
	GHGs[3]	CO	NO_X	$PM_{2.5}$	SO_2	HAPs	NMVOCs
Gulf Coast	57,500,000 (507,000)	29,300 (134)	9,070 (43.2)	4,340 (22.1)	6,210 (9.22)	765 (4.1)	14,100 (42.8)
LA	27,500,000 (563,000)	5,670 (130)	2,640 (95.2)	946 (19)	301 (1.84)	642 (321)	2,790 (28.3)
TX	30,100,000 (507,000)	23,700 (138)	6,430 (38.4)	3,400 (22.6)	5,910 (14.1)	122 (3.52)	11,300 (44.3)
Ohio River Valley	3,110,000 (57,800)	766 (31.8)	401 (21.2)	198 (5.1)	57.8 (0.555)	70.5 (5.22)	510 (12)
OH	1,620,000 (1,620,000)	546 (273)	162 (81)	87.8 (43.9)	23 (11.5)	36 (18)	386 (193)
PA	155,000 (31,500)	69.2 (16)	47.4 (8.12)	11.4 (1.56)	1.54 (0.405)	2.21 (1.1)	65.2 (10.4)
WV	1,340,000 (1340000)	150 (75.1)	192 (96)	98.8 (49.4)	33.3 (16.6)	32.3 (16.1)	58.6 (29.3)

[1] Sum of reported potential emissions from all facilities within a region or state.

[2] Median of facility-level emissions among reporting facilities within a region or state.

[3] Emissions of GHGs reported in metric tons. All other emissions reported as U.S. tons.

1.2.2 Proposed Projects: Characterizing Nearby Populations

Our analysis identified 116 petrochemical facilities currently in the proposal stage, with the majority (66%) located in the Gulf Coast region, particularly in Texas, which already had the highest number of existing facilities among the states we studied. For each proposed facility, we estimated the total population, the percentage of PoC, and the environmental justice vulnerability of communities living within a three mile radius. For detailed methods, see Section 2.4: Demographic Analysis of Communities Near Existing Petrochemical Facilities and Proposed Petrochemical Projects.

On average, 13,920 people live within a three mile radius of a proposed facility in the Ohio River Valley, compared to 16,666 in the Gulf Coast. The average nearby population for the proposed facilities in the Ohio River Valley was slightly lower than for existing facilities; however, there is variation, with populations ranging from zero to 133,435. The project with the highest population within the three mile radius was located in Texas (TPC Group - BD Expansion Project) (**Table 14**, **Figure 9**). The average PoC percentage for communities near the proposed facilities was 55% in the Gulf Coast and 13% in the Ohio River Valley, which is consistent with the demographic patterns observed around existing facilities (**Table 14** and **Figure 9**). In terms of income, 78% of the proposed facilities were near communities with a per capita income below the national median of $41,000 (U.S, Census Bureau, 2024b) (**Figure 10b**).

Lastly, the Environmental Justice Index (EJI) we estimated for populations living within a three mile radius of proposed facilities showed that nearly half (44%) of the proposed projects would be located in communities with an already Very High EJI rank (above the 75th percentile) (**Table 14** and **Figure 10b**).

Figure 9. Population and Percent People of Color. Each point in the scatterplot represents a proposed petrochemical facility. The x-axis represents the percentage of people of color within a 3-miles radius of the facility and the y-axis the population.

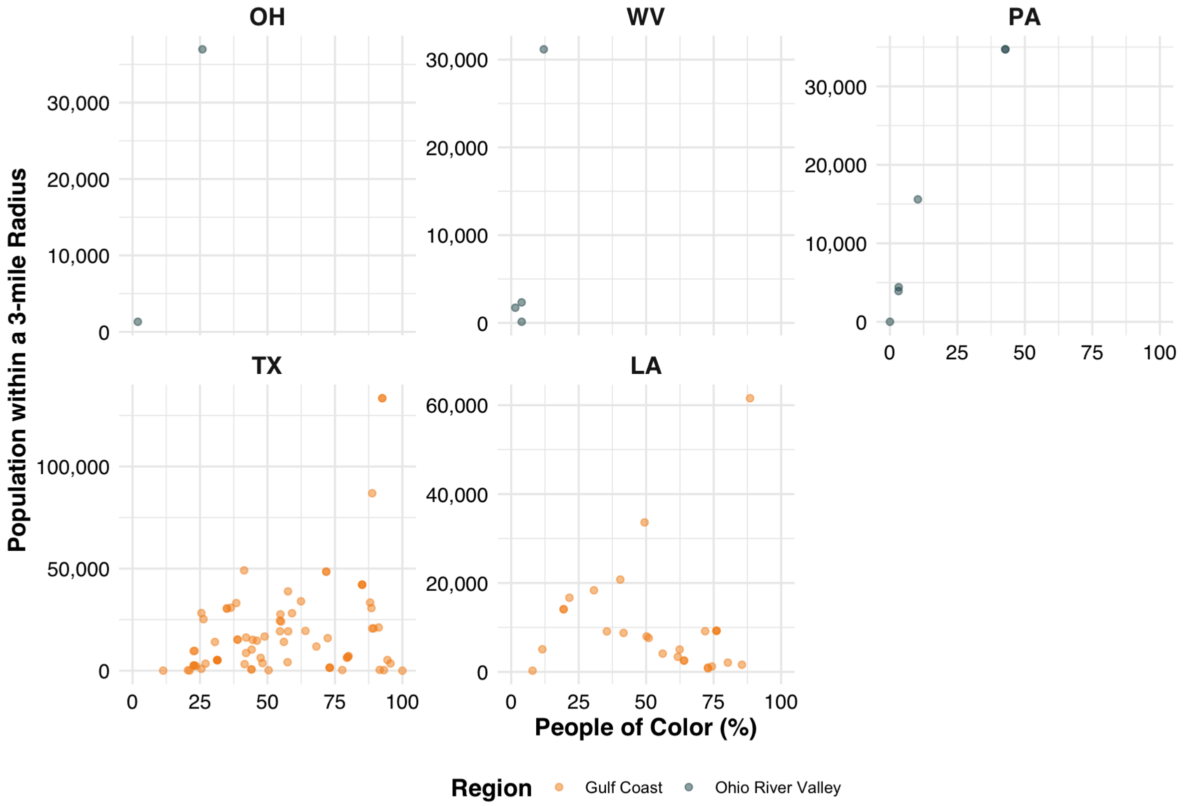
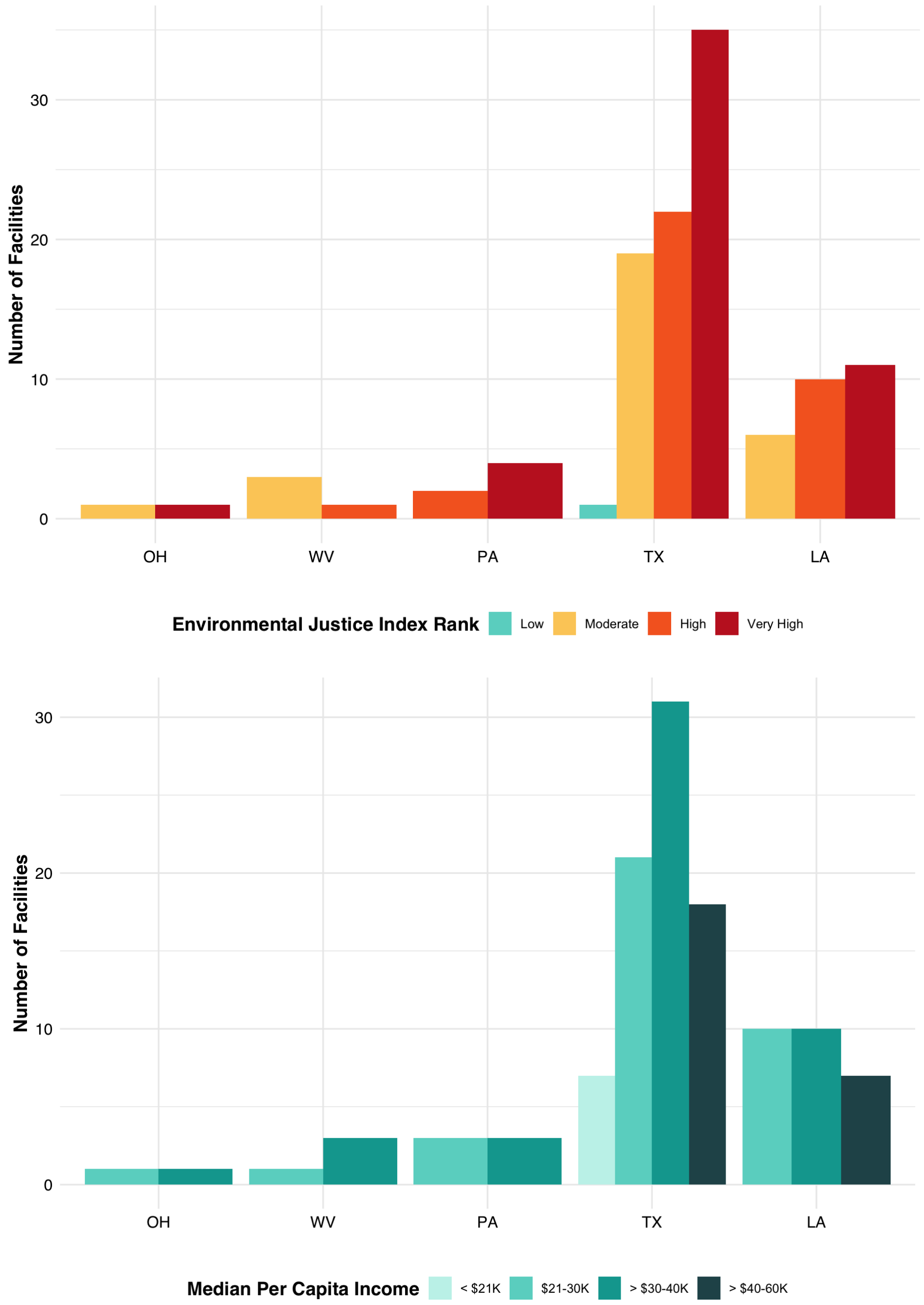


Table 14. Characteristics of the population living within a three mile radius of proposed petrochemical projects for each state, region, and across both regions.

	Number of facilities	**Median population (IQR)**	**Median percentage People of Color (IQR)**	**Number of facilities with Very High Environmental Justice Index Rank (%)**
Both Regions	116	9,124 (2,550–21,880)	49 (31–73)	51 (44%)
Ohio River Valley	**12**	**4,171 (1,627–32,056)**	**4 (3–15)**	**5 (42%)**
Ohio	2	19,145 (10,229–28,061)	14 (8–20)	1 (50%)
Pennsylvania	6	10,011 (4,046–29,938)	7 (3–35)	4(66%)
West Virginia	4	2,035(1,331–9,545)	4 (3–6)	0 (0%)
Gulf Coast	**104**	**9,197 (3,048–20,868)**	**55 (35–76)**	**46 (44%)**
Texas	77	11,841 (3,446–27,622)	55 (35–79)	35 (45%)
Louisiana	27	7,983 (2,538–11,669)	62 (38–74)	11 (41%)

Figure 10. (a) Environmental Justice Index (EJI) Rank. The bars represent the number of proposed petrochemical facilities (y-axis) within each EJI category for each state (x-axis) in the Ohio River Valley (Ohio, West Virginia, and Pennsylvania) and Gulf Coast (Texas and Louissiana). The higher the EJI rank, the higher the population vulnerability. **(b) Median per capita income**. The bars represent the number of proposed petrochemical facilities within each of the per capita income brackets for each state (x-axis) in the Gulf Coast and Ohio River Valley.



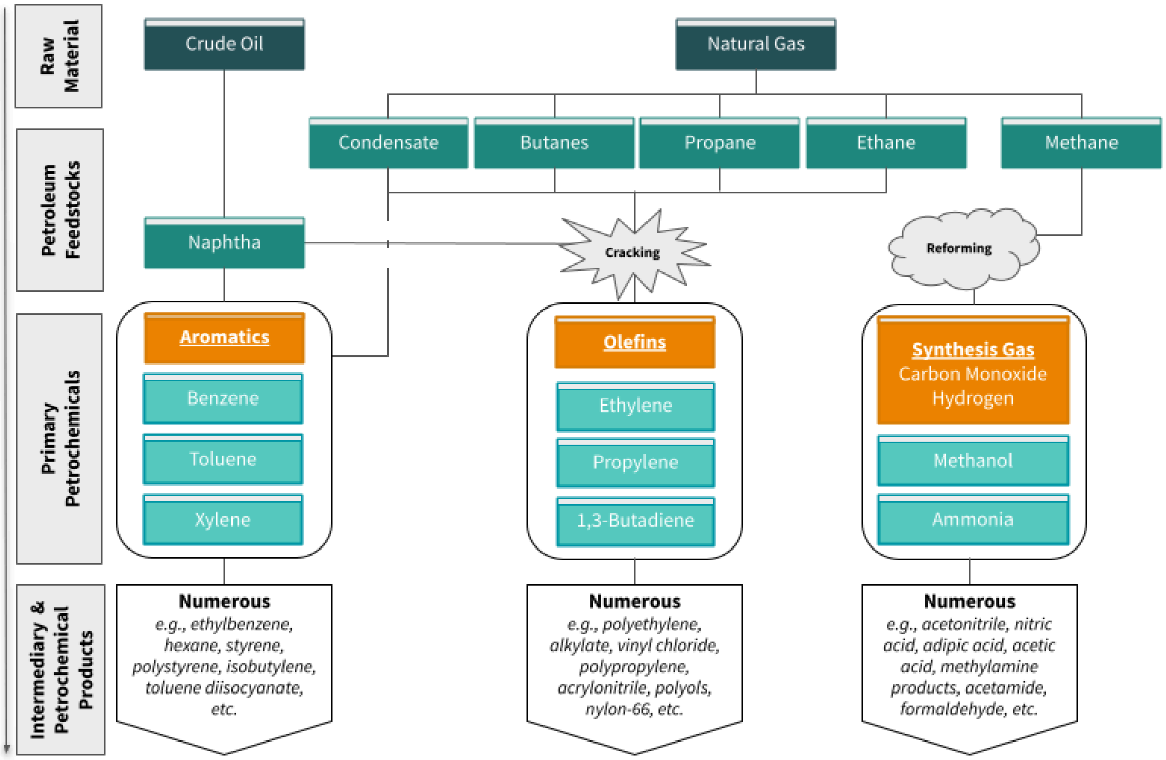
2.0 Methods

2.1 Operational Definition of Petrochemical Facilities

According to the *Handbook of Petrochemical Processes* (Speight, 2019), a petrochemical facility is a facility that uses petroleum-derived feedstocks to produce chemicals. These facilities are usually located adjacent to, or within the vicinity of a petroleum refinery in an effort to limit the transportation of feedstocks produced by the refinery to the petrochemical plant. The definition excludes facilities that do not directly use fossil-based feedstocks (i.e., plastic recycling plants and biomass-based petrochemical production), or only produce end-use commercial products, including gasoline or distillate oils. In our analysis, we expand upon this definition to also include facilities that produce petroleum, gas, and/or coal feedstocks (e.g., oil refineries, natural gas fractionation plants). Feedstock manufacturers are essential to the entire petrochemical industry, and including these facilities will yield a more comprehensive assessment. This expansion still excludes oil and gas facilities that do not produce petrochemicals, including natural gas production well pads, compressor stations, pipelines, and storage facilities.

Following **Figure 11**, our scope includes facilities that produce petroleum feedstocks, use feedstocks to produce primary petrochemicals, or use primary or intermediary petrochemicals to produce intermediary petrochemicals or other base materials products.

Figure 11. Diagram Showing the High-Level Process of Manufacturing Petrochemicals from Oil and Gas Raw Materials.[1]



Shown in **Figure 11** above, primary petrochemicals fall into three general categories: olefins; aromatics; and chemicals made from synthesis gas ('SynGas') (Speight, 2019).Olefins (ethylene, propylene, butadiene) can be produced from petroleum via fluid catalytic cracking or coking processes. Olefins can also be produced from steam cracking of natural gas. Butadiene is used to make synthetic rubber while ethylene and propylene are used to create plastic products and other industrial chemicals. Aromatics (benzene, toluene, xylene) can be produced through catalytic reforming of naphtha (a petroleum-based feedstock derived from crude oil) or through fluid catalytic cracking or coking processes. These chemicals are used to manufacture a variety of products. Benzene, for example, is used to make dyes and detergents, toluene is used to make polyurethane foam and explosives, and xylenes are used to make plastics and synthetic fibers. Finally, methanol and ammonia can be produced from synthesis gas, in which a mixture of carbon monoxide and hydrogen are converted into methanol, ammonia, or other hydrocarbon derivatives through a series of catalyzed chemical

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[1] Additional feedstocks & petrochemicals in this analysis not shown in Figure 11 include coal-based feedstocks (e.g., coke, coal tar) and petrochemicals, petroleum coke (feedstock) and calcined petcoke (petrochemical). Figure 11 adapted from SafeRack (2023).

reactions. A typical plant includes three overall processes: (1) production of synthesis gas from methane through steam reforming, also referred to as steam methane reforming; (2) production of methanol, ammonia, or other hydrocarbon derivatives; and (3) production of fuel-grade fractions from long-chain (waxy) synthetic hydrocarbon derivatives through hydrocracking. Methanol is used to produce other industrial chemicals while ammonia is used to make explosives and synthetic fertilizers (Speight, 2019).

2.2 Existing Petrochemical Facilities: Data Sources, Facility Identification, and Data Processing

2.2.1 Existing Petrochemical Facilities: Facility and Emissions Data Sources

2.2.1.1 Federal Registry System (FRS) Datasets

Facility metadata, (e.g., unique identity, facility name, and location) were collected from the U.S. EPA's Federal Registry System (FRS), which systematizes facility information across reporting programs (U.S. EPA, 2016b). EPA reporting programs require emissions reporting at different industrial scales, and thus a single facility, as identified by FRS, may separately report emissions from different activities.

2.2.1.2 Toxics Release Inventory (TRI)

Data on HAP emissions from existing petrochemical facilities comes from the U.S. EPA's Toxics Release Inventory (TRI) (U.S. EPA, 2024a). Facilities are required to report a chemical to the TRI program if the facility's primary NAICS code is covered by the TRI or it is a federal facility, the facility has 10 or more full-time employees, the facility manufactures, processes, or otherwise uses chemicals in the TRI-listed chemicals, and the facility uses quantities of a chemical above the reporting threshold (U.S. EPA, 2023b). If all reporting criteria are met, facilities report annually the amount of chemicals that they release and this information is compiled into the TRI. We downloaded the data files for the entire U.S. for 2012 to 2021 on September 6, 2024.

2.2.1.3 Greenhouse Gas Reporting Program (GHGRP)

GHG emissions data were collected from the U.S. EPA Greenhouse Gas Reporting Program (GHGRP), which requires reporting of GHG data from large emission sources, fuel and industrial gas suppliers, and carbon dioxide (CO_2) injection sites in the United States (U.S. EPA, 2024b). Emissions from facilities are estimated through a variety of methods, including direct monitoring, mass balance approach, or site-specific/default emissions factors (U.S. EPA, 2017). These emissions are reported as metric tons of carbon dioxide equivalents (CO_2e) – the global warming impact over 100 years, relative to carbon dioxide. GHGRP reports CO_2e based on the Intergovernmental Panel on Climate Change (IPCC)'s Fourth Assessment Report (U.S. EPA, 2024b); to reflect the most up-to-date science, we re-calculated CO_2e using factors from the IPCC's Sixth Assessment Report (IPCC, 2023). We downloaded 2012-2021 GHGRP data on September 6, 2024.

2.2.1.4 National Emissions Inventory (NEI)

We collected additional CAP, HAP, and GHG emissions data from the U.S. EPA's National Emissions Inventory (NEI) which covers point, onroad, nonroad, and nonpoint sources. Emissions sources required to report to NEI include those covered under the Air Emissions Reporting Rule (AERR) (40 CFR Part 51, Subpart A) (U.S. EPA, 2020). The NEI is released every three years and is primarily based upon data provided by State, Local, and Tribal air agencies for sources in their jurisdictions, and supplemented by U.S. EPA data. Many of these reported emissions overlap with other regulatory programs; we reconciled these reported emissions as described in section 2.2.2. We relied on 2020 data, the most recent year available – while COVID-19 may have impacted emissions, these data likely provide a more accurate snapshot of the industry by better capturing its rapid growth and change. We downloaded the NEI 2020 "facility-level by pollutant" dataset under "Other Emissions Summaries", which we downloaded on September 6, 2024 (U.S. EPA, 2023a).

2.2.2 Existing Petrochemical Facility Identification and Emissions Data Processing

Facilities and associated metadata were defined by the Federal Registry System, and categorized as a petrochemical facility if at least one sub facility (i.e., reporting unit to one of the emissions reporting programs) met our petrochemical definition. Only facilities located within the five states of interest, according to FRS, were considered, as FRS uses more validated location information (e.g., confirming facility location via satellite imagery). We excluded mobile sources and nonpoint sources because they are very unlikely to meet our definition of petrochemical facility.

Across datasets, we first categorized sub facilities by primary NAICS code as (a) definitely not petrochemical, (b) potentially petrochemical, and (c) definitely petrochemical (following **Table S1**). Because petrochemicals are utilized to manufacture a wide array of end-use products (e.g., plastics, paints, rubber products, pesticides, etc.) and are derived from petroleum and/or coal feedstocks, NAICS codes relevant to oil, gas, and/or petrochemical product manufacturing were numerous. In total, 50 codes were identified as being potentially relevant to petroleum feedstock and/or petrochemical production. Two NAICS codes were considered to include only petrochemical facilities: “324110 - Petroleum Refineries” and “325110 - Petrochemical Manufacturing.” Facility names were reviewed to identify facilities that used biogenic feedstocks such as corn-produced ethanol (e.g., facility names with the term “biodiesel”).

For facilities reporting to TRI, we also identified petrochemical facilities as facilities that (a) produced and manufactured petrochemicals according to TRI, which began collecting this information in 2018, and (b) belonged to the sensitive NAICS category. The sensitive NAICS categories are categories within which this chemicals-based approach yielded a false positive rate <+ 10% in a validation test. For facilities reporting to GHGRP, we additionally categorized facilities according to GHGRP sector and subtype and conducted a parallel process with NEI facilities types (see **Table S2**).

To help validate these approaches and evaluate some of the ambiguous facilities, we conducted manual review of multiple facilities, which included reviewing publicly-available information about facility activities. Due to the large number of ambiguous facilities, not all ambiguous facilities were manually reviewed. For each industry, we extracted facility types relevant to the manufacturing of primary petrochemicals (e.g., ethylene crackers, propylene plants), intermediary petrochemicals (e.g., methyl methacrylate production, VCM plants), and polymers, resins, chemicals, and other base products made from petrochemicals (e.g., PVC manufacturing, polyethylene plants). For example, for NAICS codes “211112 - Natural Gas Liquid Extraction” and “211130 - Natural Gas Extraction”, we identified gas-to-liquid plants, natural gas processing plants, gas treating plants, and natural gas liquids fractionators using the facility name as a guide. These facilities are involved in creating petroleum feedstocks from natural gas (e.g., butanes, propane, ethane, methane). Another example, for NAICS codes “325120 - Industrial Gas Manufacturing” and “325311 - Nitrogenous Fertilizer Manufacturing,” we identified facilities involved in the production of hydrogen, methanol, ammonia—which may also extend to urea and nitrogen plants—and synthesis gas (syngas). For “NAICS code 325199 - All Other Basic Organic Chemical Manufacturing,” those facilities involved in resin, plastics, rubber, methanol, ethylene manufacturing, manufacturing of high-value chemicals, use of ammonia to create chemicals, identified as ethane crackers, among others, were included. For “325211 - Plastics Material and Resin Manufacturing”, facilities that have ethylene crackers and/or propylene plants on-site were included. This extends to polypropylene and polyethylene plants (categorized as a petrochemical plant) and all derivatives of.

Each sub facility was then categorized according to the following information, in order of decreasing influence: (a) biogenic feedstock, (b) manual review, (c) NAICS codes, (d) GHGRP sector, (e) GHGRP facility subtype, (f) NEI facility type, and (g) TRI chemical usage and manufacturing plus NAICS code. Ultimately, if we did not have sufficient evidence that a facility was a petrochemical facility, then we did not include it in our list of petrochemical facilities. For each facility, uniquely identified by FRS ID, we first excluded any facility whose sub facilities indicated biogenic feedstock. For each facility, we assessed whether any sub facilities were identified as petrochemical facilities using data from 2020 or the most recent year available. If any sub facilities were a petrochemical facility, then the facility was considered a petrochemical facility – except for sub facilities that indicated biogenic feedstocks, which triggered exclusion. The primary NAICS code of the sub facility with strongest inclusion evidence was used to characterize the facility type of the overall facility.

We combined emissions across datasets in the following manner, following the protocol of Young et al. (2022). First, we converted, as possible, HAP and air toxics pollutants to HAP categories in order to best capture HAP emissions. Second, we aggregated emissions within each dataset, under the assumption that such emissions are mutually exclusive. Third, for each year-facility-pollutant combination, we selected the emissions reported from the most relevant dataset, as available: greenhouse gases from GHGRP, CAPs from NEI, and all other pollutants from TRI.

2.2.4 Existing Facilities Data and Approach: Limitations

Our approach to identify petrochemical facilities may not fully capture all petrochemical manufacturing industrial activity. In particular, we excluded facilities that did not have a relevant primary NAICS code, which may exclude facilities that manufacture petrochemicals as a secondary activity. Additionally, we excluded facilities with relevant NAICS codes but no other confirmatory evidence of petrochemical role—some of these facilities may manufacture petrochemicals. We may underestimate the total number of facilities and associated emissions involved in the petrochemicals industry, however we expect our results to include the vast majority of relevant facilities and emissions given our use of multiple sources of inclusion criteria.

The emissions analyses may underestimate emissions because they rely on reported emissions from EPA. Critically, unreported emissions should not be assumed to be zero. These reporting programs do not require all facilities to report emissions of every pollutant—most programs have reporting thresholds whereby reporting requirements are triggered when emissions exceed the threshold. Furthermore, not all facility types are required to report to all programs. In particular, natural gas processing facilities were not required to report to TRI until November 2021—thus our data does not include any HAP emissions from natural gas processing facilities (U.S. EPA, 2021). Even reported emissions can include errors and quality assurance of these data were outside of the scope of this project. Future iterations may include uncertainty analysis of unreported emissions as well as emissions for facilities that now meet reporting requirements.

Our assessment of the top five HAPs (considering mass emitted and pollutant toxicity) may not be fully comprehensive because the inhalation toxicity weights from RSEI are not available for all pollutants. Additionally, we excluded the compounds from the ranking because RSEI recommends using the most toxic compound to assess the toxicity of the compound mixture. In our case, this would have overestimated the net toxicity of the compound category HAPS by overweighting a single compound while the composition total emissions mixture is unknown for the toxicity. For the four single-pollutant HAPs without an inhalation toxicity weight, we estimated how toxic a pollutant would need to be to be included in the top five HAPs, given their emissions. Dimethyl phthalate, the most emitted HAP lacking a RSEI weight, had a total emissions of 0.47 U.S. tons in 2021, and thus would have required a toxicity weight at least four times that of chloroprene to be included in the top five—an extremely unlikely scenario.

Our 2020 data is not fully comparable to other years. First, we only included emissions data from NEI for 2020 and thus our assessment of CAPs was limited to 2020 and could not include time trend analysis. Additionally, we identified 19 petrochemical facilities that reported to NEI in 2020, but not to GHGRP or TRI. For these facilities, HAPS emissions are only available for 2020. These facilities may be unique (e.g., potentially lower emissions) because they are not meeting the reporting requirements for the other datasets. Furthermore, emissions in 2020 are not representative of the emissions in a typical year due to the COVID-19 pandemic.

2.3 Proposed Petrochemical Projects: Data Sources, Facility Identification, and Data Processing

2.3.1 Proposed Projects: Facility and Emissions Data Sources

2.3.1.1 Environmental Integrity Project (EIP) Oil & Gas Watch

We relied upon the Environmental Integrity Project (EIP) Oil & Gas Watch Database (EIP, 2024a) to assess the potential emissions from proposed petrochemical projects, as this is the only publicly-available database that provides pollutant and GHG information for proposed but not yet active petrochemical projects. EIP provides associated permit and pollutant information for projects proposed from 2012 to present that plan to build or expand facilities using or processing oil or gas to make petrochemicals, plastics, fertilizer, and fuel.

Project information incorporated into EIP's Oil & Gas Watch Database comes from many different sources and varies based on regulatory jurisdiction (e.g., local, state, federal). In addition to permit information (e.g., Clean Air Act New Source Review permits, Clean Air Act operating permits, etc.), EIP uses industry press releases, company documents/statements, public datasets (U.S. EPA, U.S. Energy Information Administration), and research from other nonprofit organizations and community groups (EIP, 2024b).

Using this database, we extracted all projects for the U.S. (accessed March 9, 2023 and updated with new facilities February 9, 2024). When we downloaded this project list, we found that the only emissions estimate provided in the output spreadsheet was potential aggregated GHG emissions in carbon dioxide equivalents (CO_2e).[2] However, each project included in the Oil & Gas Watch Database has an associated facility page, where additional information related to the project is provided, including actual/expected completion year and maximum permitted emissions estimates for two additional pollutant types: aggregated HAPs and speciated CAPs. Therefore, for relevant projects, we manually transcribed speciated CAP and aggregate HAP emissions estimates, as well as the actual/expected completion year using the corresponding facility page.

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[2] Individual GHGs have different global warming potentials (GWP). For example, N_2O has a GWP equivalent to 273 times that of CO_2 over a 100-year period. In an effort to standardize the differing warming potentials of various GHGs to CO_2, GWPs are applied and then aggregated to obtain a total value in carbon dioxide equivalents.

We included all project statuses, although during the filtering step, only projects with a status of “Announced,” “On Hold,” “Pre-Construction,” and “Under Construction” were retained. All other statuses were excluded.

2.3.3 Proposed Projects Data and Approach: Limitations

For proposed projects, EIP updated their data so that data made publicly available after February 9, 2024 were not incorporated into our analysis.

It should be noted that the annual emissions estimates presented in this database represent the maximum potential emissions pulled from publicly-available permits (i.e., potential to emit), and thus, may not reflect the facilities actual emissions once operational. As a result, we may be underestimating potential emissions because the proposed projects data were not compiled by a regulatory agency. Facility identification and emissions information is limited to what EIP was able to collect from publicly-available permits and documents. For many of the proposed facilities, GHG emissions estimates were “unknown” or not listed. This is likely due to the source of the emissions data, which comes primarily from federal air construction permits and applications. EIP states,

> *“We may be missing greenhouse gas numbers for some projects because the company hasn’t yet applied for an air construction permit, or the project doesn’t require an air permit because it won’t directly emit air pollution (like a seawater desalination plant).”* (EIP, 2024b).

This is the only data source currently available for proposed facilities and therefore provides necessary insight into the emissions profiles for proposed and future petrochemical projects.

2.4 Demographic and Environmental Justice Characterization of Communities Near Existing Petrochemical Facilities and Proposed Petrochemical Projects

Environmental justice (EJ) upholds the belief that every community should have equal access to protection when it comes to the development, implementation, and enforcement of environmental laws, regulations, and policies. EJ communities are neighborhoods that disproportionately bear the burden of environmental hazards and/or experience a significantly reduced quality of life relative to other communities—oftentimes, these populations are people of color. Industrial facilities—and their associated pollutant releases–are often disproportionately located in EJ communities, resulting in disparate adverse health impacts for those residing within (Bullard, 1996).

Several regulatory agencies provide frameworks and tools to help policymakers and other organizations assess environmental justice and identify potentially overburdened communities (CalEPA OEHHA, 2023; CEQ, 2024; U.S. EPA, 2024c). Most frameworks are at the census tract level and are based on compiling various socioeconomic, environmental, and health indicators and aggregating them into an EJ score(s). None of the available EJ frameworks is perfect and each has advantages and disadvantages. The Centers for Disease Control and Prevention (CDC) and Agency for Toxic Substances Control and Disease Registry's (ATSDR) Environmental Justice Index (CDC EJI) (CDC & ATSDR, 2024) and the Environmental Protection Agency's Environmental Justice Screening tool (EJScreen) (U.S. EPA, 2024c) are two widely used EJ frameworks. The CDC EJI is a nationwide census tract ranked based on various social, environmental, and health vulnerability indicators, which are then aggregated into a single EJ score. The percentile rank of census tracts is used to provide insight into the vulnerability of a given tract relative to other tracts in the United States (McKenzie et al., 2022). The EJScreen provides block group values for various EJ-related indicators (e.g., income, education, $PM_{2.5}$ and other pollutant concentrations, etc.) and integrates some of the environmental burden indicators with socioeconomic population characteristics but does not provide an overall EJ score that encompasses all the vulnerability indicators (U.S. EPA, 2022). However, a valuable component of EJScreen is its web tool, which allows users to enter an address or coordinates (e.g., location of a pollution source) and specify a radius distance to generate an EJ report for the area surrounding the coordinates. The EJ report includes demographic characteristics and EJ indicator values specifically for the area within the specified distance.

Here, we leverage data and methods from the CDC EJI and EPA's EJScreen to characterize the overall demographics and estimate an environmental justice index for the communities living within a three-mile radius of each existing and proposed petrochemical facility in the Ohio River Valley and Gulf Coast.

2.4.1 Environmental Justice Index

We used the CDC EJI and associated data to calculate an EJI for the communities near petrochemical facilities (CDC & ATSDR, 2024). The CDC EJI was developed to help identify areas most at risk for the health impacts of environmental burden, and it integrates environmental burden, social vulnerability, and health vulnerability data. It includes data on 14 social vulnerability indicators, 17 environmental burden indicators, and five health vulnerability indicators (CDC & ATSDR, 2024). **Table 14** provides a list of all the indicators included in the CDC EJI, and, consequently, in the EJI, we estimated.

Table 14. CDC EJI Indicators: Social Vulnerability, Environmental Burden, and Health Vulnerability.

Module	Indicator	Data Year(s)	Description
Social Vulnerability	Minority Status	2015-2019	Percentage of minority persons (all persons except white, non-Hispanic)
	Socioeconomic Status	2015-2019	Percentage below 200% poverty
	No High School Diploma	2015-2019	Percentage of persons with no high school diploma (age 25+) estimate
	Unemployment	2015-2019	Percentage of persons who are unemployed
	Housing Tenure	2015-2019	Percentage of persons who rent
	Housing Burdened Lower-Income Households	2015-2019	Percentage of households that make less than $75,000
	Lack of Health Insurance	2015-2019	Percentage of persons who are uninsured
	Lack of Broadband Access	2015-2019	Percentage of persons without internet
	Age 65 and Older	2015-2019	Persons aged 65 and older
	Age 17 and Younger	2015-2019	Persons aged 17 and younger
	Civilian with a Disability	2015-2019	Percentage of civilian noninstitutionalized population with a disability
	Speak English “Less than Well”	2015-2019	Percentage of persons (age 5+) who speak English "less than well"
	Group Quarters	2015-2019	Percentage of persons in group quarters
	Mobile Homes	2015-2019	Percentage of mobile homes

Module	Indicator	Data Year(s)	Description
Environmental Burden	Ozone	2014-2016	Annual mean days above ozone regulatory standard (3-year average)
	$PM_{2.5}$	2014-2016	Annual mean days above $PM_{2.5}$ regulatory standard (3-year average)
	Diesel Particulate Matter	2014	Ambient concentrations of diesel particulate matter/m^3
	Air Toxics Cancer Risk	2014	The probability of contracting cancer over the course of a lifetime, assuming continuous exposure
	National Priority List Sites	2021	Proportion of tract's area within 1-mi buffer of EPA National Priority List site
	Toxic Release Inventory Sites	2021	Proportion of tract's area within 1-mi buffer of EPA Toxic Release Inventory site
	Treatment, Storage, and Disposal Sites	2021	Proportion of tract's area within 1-mi buffer of EPA Treatment, Storage, and Disposal site
	Risk Management Plan Sites	2021	Proportion of tract's area within 1-mi buffer of EPA risk management plan site
	Coal Mines	2021	Proportion of tract's area within 1-mi buffer of coal mines
	Lead Mines	2021	Proportion of tract's area within 1-mi buffer of lead mines
	Recreational Parks	2020	Proportion of tract's area within 1-mi buffer of green space
	House Built Pre-1980	2015-2019	Percentage of houses built pre1980 (lead exposure)
	Walkability	2021	A nationwide geographic data resource that ranks block groups according to their relative walkability
	High-Volume Roads	2020	Proportion of tract's area within 1-mi buffer of high-volume road or highway
	Railways	2020	Proportion of tract's area within 1-mi buffer of railroad
	Airports	2020	Proportion of tract's area within 1-mi buffer of airport
	Impaired Surface Water	2019	Percent of tract that intersects an impaired / impacted watershed at the hydrologic unit code 12 level

Module	Indicator	Data Year(s)	Description
Health Vulnerability	Asthma (18 yrs or older)	2020	Percentage of individuals with asthma
	Cancer	2020	Percentage of individuals with cancer
	High Blood Pressure	2020	Percentage of individuals with raw high blood pressures values
	Diabetes	2020	Percentage of individuals with diabetes
	Poor Mental Health	2020	Percentage of individuals reporting not good mental health

We adapted the CDC's EJI methods to estimate an EJI for each census tract in the Ohio River Valley and Gulf Coast states, with a few modifications. Instead of ranking tracts nationwide, we ranked them statewide and used a different method to incorporate health vulnerability indicators into the overall EJI. First, we ranked each census tract on all 36 indicators. Then, we averaged the ranks by module—social vulnerability, environmental burden, and health vulnerability—to generate module scores. Next, we summed the module scores to calculate an overall EJI score. Finally, we ranked the census tracts based on their EJI scores to produce the final EJI rank for each tract. These methods are aligned with the CDC EJI methods, except that the CDC EJI uses a different approach to integrate the health indicators into a Health Vulnerability module score.

The CDC EJI flags census tracts for a health indicator if they are in the top tertile (33%) nationwide. Each flag is assigned a value of one, and the flags are then summed for each tract, with the total score multiplied by 0.2 to create the final Health Module score. For more details refer to the CDC EJI Technical Manual (McKenzie et al., 2022). This approach constricts the contribution of the health indicators to the total EJI score. The health data contributes to the total EJI score only in census tracts with the highest health indicator values nationwide. We conducted a percentile rank and average to calculate the Health Vulnerability module score, the same as for the Social Vulnerability and Environmental Burden modules, to ensure health indicators contribute to the EJI in all tracts and to avoid using an arbitrary cut-off. Furthermore, the averaging and ranking approach is more straightforward to understand for a general audience. We also compared this approach to the flag system used in the CDC EJI and found only minor differences across the results.

2.4.2 Estimating Environmental Justice Index and Demographics of Frontline Communities

After estimating the census tracts' EJI score using the CDC EJI data and methods, we followed the EPA's EJScreen tool methods to calculate an EJI score specifically for the population living within three miles of each petrochemical facility. From here on, we refer to this analysis as the *buffer analysis*. Below, we describe our adaptation of the EJScreen buffer analysis and how we integrated it with the CDC EJI data.

2.4.2.1 Estimating Environmental Justice Indicator Values for Frontline Communities

The EJScreen tool uses population weights based on census block population to estimate EJ indicator averages for a buffer of a given radius (U.S. EPA, 2022). We followed this approach. First, we gave each census block within a census tract the indicator value of the parent census tract. That is, all blocks within a census tract have the same value for each of the 36 indicators. Then, we identified the census blocks within the three-mile buffer area. If a census block area is only partially within the buffer zone, the block is still classified as within the buffer. Next, we used the following equation to estimate the buffer area population-weighted average for each of the 36 indicators:

Equation 1:

$$\sum \frac{census\ block\ population \times block\ indicator\ value}{buffer\ zone\ total\ pop} = \ indicator\ population\ weighted\ avg.$$

The census block population is not collected in the American Community Surveys (ACS), only in the Decennial Census. The CDC EJI data is based on the 2010 spatial census delineations; thus, in Equation 1, we could theoretically only use 2010 census population counts. However, to have a more recent population estimate, the EJScreen tool uses the 2010 census block to census tract population ratio and the 2015-2019 ACS census tract population to estimate a 2015-2019 census block population, as shown in Equation 2. The population estimated with Equation 2 is then used in Equation 1. We followed the same approach.

Equation 2:

$$\frac{2010\ block\ population}{2010\ census\ tract\ population} \times 2015 - 2019\ ACS\ tract\ population = 2015 - 2019\ block\ population$$

2.4.2.2 Estimating an Environmental Justice Index for Frontline communities

We used the buffer zone's EJ indicator values estimated in Section 2.4.2.1 to calculate the overall buffer EJI score following the methods described in Section 2.4.1. For the buffer zone percentile rankings, we ranked the buffer zone on all 36 indicators relative to other census tracts within the state where the petrochemical facility is located. We also ranked the buffer area relative to other census tracts in the state based on its EJI score to obtain the final buffer EJI rank.

Lastly, we classified each petrochemical facility into one of the following four categories based on the EJI rank of its three mile buffer: Low: 0-25th percentile rank; Moderate: >25-50th; High: >50-75th; and Very High: 75-100th. These categories provide a general description of the environmental justice vulnerability of the populations living near petrochemical facilities relative to the rest of the state's population.

2.4.2.3 Estimating the Overall Demographics of Frontline Communities

We used 2015–2019 census block population estimates to set weights in the EJ buffer analysis (Equations 1 and 2). To obtain a more accurate and up-to-date estimate of the population size within three miles of each petrochemical facility, we used 2020 Census block data (Manson et al., 2023) to calculate the total buffer population, the percentage of people of color (Hispanic, Asian, Black, Hawaiian or Pacific Islander, and Native American or Alaskan Native), the percentage of people under five years old, the percentage of people over 65 years old, and the median per capita income. To calculate the total population and subgroup populations, we summed the 2020 Census block total population and subgroup populations across all blocks fully or partially within a given buffer zone. We then divided the subgroup population by the total population to determine the percentage for each subgroup (people of color and age breakdowns). For the median per capita income, we averaged the median per capita incomes of the census blocks within each buffer.

2.4.3 Demographic and Environmental Justice Analysis Limitations

The methods we used for the demographic and EJ analysis were adapted from the CDC EJI and EPA's EJScreen. These are two widely used EJ frameworks, and the CDC EJI was developed using community input. However, as with any other EJ framework, they have limitations. The vulnerability indicators in the CDC EJI we used for our analysis don't comprehensively capture the burdens and vulnerabilities communities experience. The CDC EJI is limited to quantitative data, which doesn't fully capture the experience and challenges historically disadvantaged communities might experience. The buffer analysis requires classifying census blocks as inside or outside the three-mile radius. Following the EJScreen methodology, we classified a block as inside the buffer based on the geographical overlap of the block with the buffer area. However, population distribution within a block is not homogenous, and the block population might not necessarily live in the portion of the block located within the buffer. This method also assumes that the entire block population is within the buffer, even if only a small portion of the block area is within the buffer. Thus, the demographic values presented in our report and web tool should be considered estimates rather than absolute true values. Lastly, we ranked the buffer area surrounding each petrochemical facility based on the estimated EJI score and relative to census tracts in the state where the petrochemical facility is located. The buffer zone is not always comparable to census tracts in population size. On average, census tracts have a population of around 4,000; however, buffer zone population size might range from zero up to 300,000.

2.5 Air Quality Modeling to Estimate $PM_{2.5}$-Attributable Impacts

2.5.1 Overview of Modeling Approach Using InMAP

We used the Intervention Model for Air Pollution (InMAP) version 1.9.6 (Tessum et al., 2017) to estimate excess mortality risks from exposure to $PM_{2.5}$ emissions from each one of the petrochemical facilities discussed above (Section 1.1.2.3). InMAP is a reduced-form air quality model designed to estimate the health impacts due to changes in outdoor $PM_{2.5}$ concentrations, which are driven by changes in emissions. It calculates relative changes in annual average $PM_{2.5}$ concentrations attributable to changes in precursor emissions, leveraging pre-processed physical and chemical relationships from the Weather Research and Forecasting with Chemistry (WRF-Chem) model. This allows InMAP to maintain reliable predictive performance while running efficiently. The model configuration in this study was designed to perform single pollutant ($PM_{2.5}$) analysis, capturing the effect of direct precursor emissions (NO_x, SO_x, VOC, NH_3), and aligning with recent epidemiological data for the U.S.

2.5.2 Health Impact Function

The equation used in InMap to calculate the annual $PM_{2.5}$-attributable premature mortalities from primary $PM_{2.5}$ petrochemical facility emissions is given below:

$$\Delta \text{Mortality} = \text{Pop}(\exp^{\beta \cdot \Delta X} - 1)Y_0$$

In this equation, the change in $PM_{2.5}$-attributable mortality is calculated using the population (Pop), the baseline mortality rate (Y_0), and a concentration-response function. This function includes the change in concentration of annual-average $PM_{2.5}$ (ΔX) and a beta coefficient (β). β is determined using relative risk (RR) associated with a 10 $\mu g\ m^{-3}$ increase in annual-average outdoor $PM_{2.5}$. β has the following functional form:

$$\beta = \ln(RR) / 10\ \mu g\ m^{-3}$$

where the RR estimate is derived from the epidemiological literature. We used the center value of the single-pollutant RR estimate range (1.089) provided by Di et al. (2017), which was derived using a mixed effects model (COXME).

2.5.3 Monetary Impacts

The benefit of preventing a fatality is measured by the term Value of a Statistical Life (VSL), defined as the additional cost that individuals would be willing to bear for improvements in safety (reductions in risk) that, in the aggregate, reduce the expected number of fatalities by one. We used the central value estimate of VSL of $11.4 million derived by the U.S. Department of Health and Human Services, accounting for inflation and changes in real income in 2020 (U.S. DHHS, 2021).

2.5.4 Context for Presentation of Results and Limitations

Results Available on the Webtool

To assess the impact of each facility individually, we performed individual InMAP simulations for each facility separately, calculating both the $PM_{2.5}$-attributable mortalities and monetized impacts (due to primary $PM_{2.5}$ emissions). These results are presented on the webtool.

Simulations to Capture the Combined Effect of Multiple Facilities at the State Level

Although InMAP uses linear equations to estimate relative $PM_{2.5}$ changes, the health impacts derived from these changes are nonlinear due to the nature of the exposure-response relationship between $PM_{2.5}$ and mortality (see above). Therefore, to estimate regional and total impacts, we combined emissions sources into a single input set and InMap simulation for each State. Consequently, we performed state-level InMAP simulations, the results of which are provided in Tables 10 and 11 above (Section 1.1.2.3). Furthermore, to assess the total impacts of all facilities, a single InMAP simulation was generated to include the combined effect of all 336 petrochemical facilities (also reported in Section 1.1.2.3).

Underlying Source-Receptor Relationships in InMap

The baseline simulation uses the NEI 2005 emissions inventory and associated air quality modeling results are produced through a built-in WRF-Chem simulation. While more recent datasets exist, updating to a newer inventory was not feasible due to time and resource constraints, as it would require running a full chemical transport model (e.g., CMAQ) with compatible emissions, evaluating results, and updating InMAP's underlying data to generate updated source-receptor relationships. However, InMAP's purpose is to provide a realistic estimate of relative changes in outdoor $PM_{2.5}$ concentrations due to emission changes, not to replicate real-world absolute concentrations. Therefore, the use of 2005 baseline data still offers a valid estimate of the facilities' impacts on $PM_{2.5}$ for comparison purposes.

Supplemental Materials

Table S1. NAICS Codes that Include Petrochemical Facilities.[1]

NAICS Code	Definition	NAICS Code	Definition
211112	Natural Gas Liquid Extraction	**325220**	Artificial and Synthetic Fibers and Filaments Manufacturing
211130	Natural Gas Extraction	**325311**	Nitrogenous Fertilizer Manufacturing
324110*	**Petroleum Refineries***	**325312**	Phosphatic Fertilizer Manufacturing
324121	Asphalt Paving Mixture and Block Manufacturing	**325314**	Fertilizer (Mixing Only) Manufacturing
324122	Asphalt Shingle and Coating Materials Manufacturing	**325315**	Compost Manufacturing
324191	Petroleum Lubricating Oil and Grease Manufacturing	**325320**	Pesticide and Other Agricultural Chemical Manufacturing
324199	All Other Petroleum and Coal Products Manufacturing	**325411**	Medicinal and Botanical Manufacturing
325110*	**Petrochemical Manufacturing***	**325412**	Pharmaceutical Preparation Manufacturing
325120	Industrial Gas Manufacturing	**325413**	In-Vitro Diagnostic Substance Manufacturing
325130	Synthetic Dye and Pigment Manufacturing	**325414**	Biological Product (except Diagnostic) Manufacturing
325180	Other Basic Inorganic Chemical Manufacturing	**325510**	Paint and Coating Manufacturing
325193	Ethyl Alcohol Manufacturing	**325520**	Adhesive Manufacturing
325194	Cyclic Crude, Intermediate, and Gum and Wood Chemical Manufacturing	**325611**	Soap and Other Detergent Manufacturing
325199	All Other Basic Organic Chemical Manufacturing	**325612**	Polish and Other Sanitation Good Manufacturing
325211	Plastics Material and Resin Manufacturing	**325613**	Surface Active Agent Manufacturing
325212	Synthetic Rubber Manufacturing	**325620**	Toilet Preparation Manufacturing

NAICS Code	Definition	NAICS Code	Definition
325910	Printing Ink Manufacturing	**326140**	Polystyrene Foam Product Manufacturing
325920	Explosives Manufacturing	**326150**	Urethane and Other Foam Product (except Polystyrene) Manufacturing
325991	Custom Compounding of Purchased Resins	**326160**	Plastics Bottle Manufacturing
325992	Photographic Film, Paper, Plate, Chemical, and Copy Toner Manufacturing	**326191**	Plastics Plumbing Fixture Manufacturing
325998	All Other Miscellaneous Chemical Product and Preparation Manufacturing	**326199**	All Other Plastics Product Manufacturing
326111	Plastics Bag and Pouch Manufacturing	**326211**	Tire Manufacturing (except Retreading)
326112	Plastics Packaging Film and Sheet (including Laminated) Manufacturing	**326212**	Tire Retreading
326113	Unlaminated Plastics Film and Sheet (except Packaging) Manufacturing	**326220**	Rubber and Plastics Hoses and Belting Manufacturing
326121	Unlaminated Plastics Profile Shape Manufacturing	**326291**	Rubber Product Manufacturing for Mechanical Use
326122	Plastics Pipe and Pipe Fitting Manufacturing	**326299**	All Other Rubber Product Manufacturing
326130	Laminated Plastics Plate, Sheet (except Packaging), and Shape Manufacturing		

[1] Any facility with one of these NAICS codes was assumed to be a petrochemical facility without further review.

Table S2. GHGRP Industry Subtypes and NEI Facility Types that Include Petrochemical Facilities.

Program	Industry Subtype	Includes Only Petrochemical Facilities?
GHGRP	Adipic Acid, Nitric Acid Production	Yes
	Ammonia Production	Yes
	Hydrogen Production	Yes
	Natural Gas Fractionator	Yes
	Natural Gas Processing	Yes
	Nitric Acid Production	Yes
	Petrochemical Production	Yes
	Petroleum Refinery	Yes
	Phosphoric Acid Production	Yes
Program	**Facility Type**	**Includes Only Petrochemical Facilities?**
NEI	Calcined Pet Coke Plant	Yes
	Carbon Black Plan	Yes
	Carbon or Graphite Plant	Yes
	Chlor-alkai Plant	Yes
	Petroleum Refinery	Yes

Table S3. Petrochemicals Included in Facility Activity Review. Note: We determined petrochemical status by checking for the presence of petrochemical feedstock in the Methods of Manufacturing section from PubChem (PubChem, 2024).

Petrochemicals

- 1-Bromo-1-(bromomethyl)-1,3-propanedicarbonitrile
- 1-Bromopropane
- 1-Chloro-1,1-difluoroethane (HCFC-142b)
- 1-Chloro-1,1,2,2-tetrafluoroethane (HCFC-124a)
- 1,1-Dichloro-1-fluoroethane (HCFC-141b)
- 1,1-Dimethylhydrazine
- 1,1,1-Trichloroethane
- 1,1,1,2-Tetrachloroethane
- 1,1,2-Trichloroethane
- 1,1,2,2-Tetrachloro-1-fluoroethane (HCFC-121)
- 1,1,2,2-Tetrachloroethane
- 1,2-Butylene oxide
- 1,2-Dibromoethane
- 1,2-Dichloro-1,1-difluoroethane (HCFC-132b)
- 1,2-Dichloro-1,1,2-trifluoroethane (HCFC-123a)
- 1,2-Dichlorobenzene
- 1,2-Dichloroethane
- 1,2-Dichloroethylene
- 1,2-Dichloropropane
- 1,2-Phenylenediamine
- 1,2,3-Trichloropropane
- 1,2,4-Trichlorobenzene
- 1,2,4-Trimethylbenzene
- 1,3-Butadiene
- 1,3-Dichloro-1,1,2,2,3-pentafluoropropane (HCFC-225cb)
- 1,3-Dichlorobenzene
- 1,3-Dichloropropylene
- 1,3-Phenylenediamine
- 1,4-Dichloro-2-butene
- 1,4-Dichlorobenzene
- 1,4-Dioxane
- 2-Chloro-1,1,1-trifluoroethane (HCFC-133a)
- 2-Chloro-1,1,1,2-tetrafluoroethane (HCFC-124)
- 2-Ethoxyethanol
- 2-Mercaptobenzothiazole
- 2-Methoxyethanol
- 2-Methyllactonitrile
- 2-Methylpyridine
- 2-Nitrophenol
- 2-Nitropropane
- 2-Phenylphenol
- 2,2-Bis(bromomethyl)-1,3-propanediol
- 2,2-Dichloro-1,1,1-trifluoroethane (HCFC-123)
- 2,3-Dichloropropene
- 2,4-D
- 2,4-D 2-butoxyethyl ester
- 2,4-D 2-ethylhexyl ester
- 2,4-Diaminotoluene
- 2,4-Dichlorophenol
- 2,4-Dimethylphenol
- 2,4-Dinitrophenol
- 2,4-Dinitrotoluene
- 2,4,6-Trichlorophenol
- 2,6-Dinitrotoluene
- 2,6-Xylidine
- 3-Chloro-1,1,1-trifluoropropane (HCFC-253fb)
- 3,3-Dichloro-1,1,1,2,2-pentafluoropropane (HCFC-225ca)
- 3,3'-Dichlorobenzidine dihydrochloride
- 4-Aminoazobenzene
- 4-Aminobiphenyl
- 4-Nitrophenol
- 4,4'-Diaminodiphenyl ether
- 4,4'-Isopropylidenediphenol
- 4,4'-Methylenebis(2-chloroaniline)
- 4,4'-Methylenedianiline
- Acetaldehyde
- Acetamide
- Acetonitrile
- Acetophenone
- Acrolein
- Acrylamide

Petrochemicals

- Acrylic acid
- Acrylonitrile
- Allyl alcohol
- Allyl chloride
- Ammonia
- Aniline
- Anthracene
- Benfluralin
- Benzal chloride
- Benzene
- Benzo[g,h,i]perylene
- Benzoyl chloride
- Benzyl chloride
- Biphenyl
- Bis(2-chloro-1-methylethyl) ether
- Bis(2-chloroethyl) ether
- Bis(chloromethyl) ether
- Bromochlorodifluoromethane (Halon 1211)
- Bromoform
- Bromomethane
- Bromotrifluoromethane (Halon 1301)
- Bromoxynil octanoate
- Butyl acrylate
- Butyraldehyde
- Carbaryl
- Carbon disulfide
- Carbon tetrachloride
- Carbonyl sulfide
- Catechol
- Certain glycol ethers
- Chlordane
- Chloroacetic acid
- Chlorobenzene
- Chlorodifluoromethane (HCFC-22)
- Chloroethane
- Chloroform
- Chloromethane
- Chlorophenols
- Chloropicrin
- Chloroprene
- Chlorothalonil
- Chlorotrifluoromethane (CFC-13)
- Creosote
- Cresol (mixed isomers)
- Crotonaldehyde
- Cumene
- Cumene hydroperoxide
- Cyanide compounds
- Cyclohexane
- Cyclohexanol
- Dazomet
- Decabromodiphenyl oxide
- Di(2-ethylhexyl) phthalate
- Diaminotoluene (mixed isomers)
- Diazinon
- Dibenzofuran
- Dibutyl phthalate
- Dicamba
- Dichlorobenzene (mixed isomers)
- Dichlorobromomethane
- Dichlorodifluoromethane (CFC-12)
- Dichloromethane
- Dichlorotetrafluoroethane (CFC-114)
- Dichlorotrifluoroethane
- Dicyclopentadiene
- Diethanolamine
- Diethyl sulfate
- Diglycidyl resorcinol ether
- Diisocyanates
- Dimethyl phthalate
- Dimethyl sulfate
- Dimethylamine
- Dinitrobutyl phenol
- Dinitrotoluene (mixed isomers)
- Dioxin and dioxin-like compounds
- Diphenylamine
- Diuron
- Epichlorohydrin
- Ethyl acrylate
- Ethyl chloroformat

Petrochemicals

- Ethylbenzene
- Ethylene
- Ethylene glycol
- Ethylene oxide
- Ethylene thiourea
- Ethylenebisdithiocarbamic acid, salts and esters
- Ethylidene dichloride
- Fenpropathrin
- Fomesafen
- Formaldehyde
- Formic acid
- Freon 113 (CFC-113)
- Glycidol
- Hexachloro-1,3-butadiene
- Hexachlorobenzene
- Hexachlorocyclopentadiene
- Hexachloroethane
- Hexafluoropropylene oxide dimer acid
- Hexafluoropropylene oxide dimer acid ammonium salt
- Hexazinone
- Hydrazine
- Hydrazine sulfate (1:1)
- Hydrogen cyanide
- Hydrogen sulfide
- Hydroquinone
- Isobutyraldehyde
- Isoprene
- Isopropyl alcohol (only persons who manufacture by the strong acid process are subject, no supplier notification)
- Lactofen
- m-Cresol
- m-Dinitrobenzene
- m-Xylene
- Malathion
- Maleic anhydride
- Malononitrile
- Mecoprop
- Methacrylonitrile
- Metham sodium
- Methanol
- Methoxone sodium salt
- Methyl acrylate
- Methyl chlorocarbonate
- Methyl hydrazine
- Methyl iodide
- Methyl isobutyl ketone
- Methyl isocyanate
- Methyl isothiocyanate
- Methyl methacrylate
- Methyl parathion
- Methyl perfluorooctanoate
- Methyl tert-butyl ether
- Methylene bromide
- Monochloropentafluoroethane (CFC-115)
- Myclobutanil
- n-Butyl alcohol
- n-Hexane
- N-Methyl-2-pyrrolidone
- N-Methylolacrylamide
- N-Nitrosodiphenylamine
- N,N-Dimethylaniline
- N,N-Dimethylformamide
- Nabam
- Naphthalene
- Nitric acid
- Nitrilotriacetic acid
- Nitrobenzene
- Nitroglycerin
- Nitromethane
- Nonylphenol
- Nonylphenol Ethoxylates
- o-Cresol
- o-Toluidine
- o-Xylene
- Octachloronaphthalene
- Octachlorostyrene
- Oryzalin
- Oxadiazon
- Oxyfluorfen
- p-Cresol
- p-Nitroaniline
- p-Phenylenediamine
- p-Xylene
- Paraldehyde

Petrochemicals

- Paraquat dichloride
- Pendimethalin
- Pentachlorobenzene
- Pentachloroethane
- Pentachlorophenol
- Peracetic acid
- Perfluorooctanoic acid
- Perfluorooctyl iodide
- Permethrin
- Phenanthrene
- Phenol
- Phosphine
- Phthalic anhydride
- Picloram
- Picric acid
- Piperonyl butoxide
- Polychlorinated alkanes (C10-C13)
- Polychlorinated biphenyls
- Polycyclic aromatic compounds
- Profenofos
- Propargyl alcohol
- Propiconazole
- Propionaldehyde
- Propylene
- Propylene oxide
- Propyleneimine
- Pyridine
- Quinoline
- Quinone
- Quintozene
- Resmethrin
- S,S,S-Tributyltrithiophosphate
- sec-Butyl alcohol
- Simazine
- Sodium dicamba
- Sodium dimethyldithiocarbamate
- Sodium nitrite
- Sodium o-phenylphenoxide
- Styrene
- Tebuthiuron
- tert-Butyl alcohol
- Tetrabromobisphenol A
- Tetrachloroethylene
- Tetrafluoroethylene
- Thiabendazole
- Thiobencarb
- Thiodicarb
- Thiols, C8-20, Œ≥-œâ-perfluoro, telomers with acrylamide
- Thiourea
- Thiram
- Toluene
- Toluene diisocyanate (mixed isomers)
- Toluene-2,4-diisocyanate
- Toluene-2,6-diisocyanate
- trans-1,3-Dichloropropene
- trans-1,4-Dichloro-2-butene
- Triadimefon
- Trichloroacetyl chloride
- Trichloroethylene
- Trichlorofluoromethane (CFC-11)
- Triclopyr-triethylammonium salt
- Triethylamine
- Trifluralin
- Urethane
- Vinyl acetate
- Vinyl bromide
- Vinyl chloride
- Vinyl fluoride
- Vinylidene chloride
- Xylene (mixed isomers)

Table S4. Summary of GHG Emissions in 2021 by State and Region. Emissions are measured in millions of metric tons of CO_2e. Total emissions reflect the sum of reported emissions of a pollutant from all reporting facilities within a region or state. Average, median, standard deviation and maximum emissions are calculated from facility-level emissions among all facilities that report emissions for that pollutant. % Max Emissions reflects the proportion of pollutant emissions attributable to the highest emitting facility for that pollutant within the region or state.

Region / State	Pollutant	Number of Facilities that Reported	Total Emissions	Average Emissions	Median Emissions	Standard Deviation	Maximum Emissions	% Max Emissions
Gulf Coast	CH_4	380	1.77	0.00465	0.00121	0.0115	0.144	8.14
	CO_2 non biogenic	406	211	0.521	0.12	1.14	11.7	5.54
	N_2O	379	4.22	0.0111	0.0000501	0.12	1.84	43.6
	Other GHGs	4	0.437	0.109	0.0052	0.18	0.409	93.6
	Total GHGs	407	218	0.535	0.127	1.18	11.8	5.42
LA	CH_4	105	0.381	0.00362	0.000344	0.0123	0.11	28.9
	CO_2 non biogenic	117	75.1	0.642	0.162	1.19	7.21	9.61
	N_2O	105	2.46	0.0234	0.0000817	0.185	1.84	74.9
	Other GHGs	2	0.427	0.214	0.018	0.231	0.409	95.8
	Total GHGs	117	78.3	0.669	0.165	1.29	9.05	11.6
TX	CH_4	275	1.39	0.00505	0.00169	0.0112	0.144	10.4
	CO_2 non biogenic	289	136	0.472	0.0987	1.12	11.7	8.58
	N_2O	274	1.77	0.00645	0.0000444	0.0823	1.36	77
	Other GHGs	2	0.00979	0.00489	0.00489	0.000431	0.0052	53.1
	Total GHGs	290	139	0.481	0.104	1.13	11.8	8.46

Region / State	Pollutant	Number of Facilities that Reported	Total Emissions	Average Emissions	Median Emissions	Standard Deviation	Maximum Emissions	% Max Emissions
Ohio River Valley	CH_4	53	0.0958	0.00181	0.000586	0.00241	0.00956	9.98
	CO_2 non biogenic	56	12.6	0.226	0.102	0.346	1.38	10.9
	N_2O	53	0.45	0.00849	0.000048	0.0488	0.347	77.1
	Other GHGs	1	0.642	0.642	0.0379	0.17	0.388	60.5
	Total GHGs	56	13.8	0.247	0.106	0.373	1.73	12.5
OH	CH_4	23	0.0342	0.00149	0.000103	0.00242	0.00956	27.9
	CO_2 non biogenic	26	8.13	0.313	0.115	0.418	1.38	17
	N_2O	23	0.443	0.0193	0.0000456	0.0736	0.347	78.3
	Other GHGs	0	Not reported	Not reported	Not reported	Not reported	Not reported	Not reported
	Total GHGs	26	8.61	0.331	0.115	0.456	1.73	20.1
PA	CH_4	14	0.0252	0.0018	0.000795	0.00202	0.00652	25.9
	CO_2 non biogenic	14	2.8	0.2	0.0459	0.364	1.34	47.8
	N_2O	14	0.00581	0.000415	0.0000308	0.00101	0.00375	64.5
	Other GHGs	0	Not reported	Not reported	Not reported	Not reported	Not reported	Not reported
	Total GHGs	14	2.83	0.202	0.0472	0.365	1.34	47.3
WV	CH_4	16	0.0365	0.00228	0.00113	0.00276	0.00918	25.2
	CO_2 non biogenic	16	1.7	0.107	0.1	0.0707	0.272	16
	N_2O	16	0.00123	0.0000771	0.0000548	0.0000636	0.000241	19.5
	Other GHGs	1	0.642	0.642	0.0379	0.17	0.388	60.5
	Total GHGs	16	2.38	0.149	0.106	0.155	0.671	28.1

Table S5. Summary of GHG Emissions in 2021 by Facility Type. Emissions are measured in millions of metric tons of CO_2e. Total emissions reflect the sum of reported emissions of a pollutant from all reporting facilities of a specific facility type.Average, median, standard deviation and maximum emissions are calculated from facility-level emissions among all facilities that report emissions for that pollutant. % Max Emissions reflects the proportion of pollutant emissions attributable to the highest emitting facility of that pollutant for the facility type.

Facility Type	Pollutant	Number of Facilities that Reported	Total Emissions	Average Emissions	Median Emissions	Standard Deviation	Maximum Emissions	% Max Emissions
Basic Chemical Manufacturing	CH_4	112	0.482	0.0043	0.0000574	0.018	0.144	29.9
	CO_2 non biogenic	137	84.5	0.617	0.313	0.829	4.97	5.88
	N_2O	112	1.97	0.0176	0.0000702	0.135	1.36	68.9
	Other GHGs	3	0.419	0.14	0.00489	0.203	0.409	97.7
	Total GHGs	137	87.4	0.638	0.325	0.854	5.09	5.82
Oil and Gas Extraction	CH_4	212	0.864	0.00408	0.00235	0.00505	0.0324	3.75
	CO_2 non biogenic	216	21.8	0.101	0.0669	0.118	0.906	4.15
	N_2O	210	0.0218	0.000104	0.0000322	0.000819	0.0119	54.6
	Other GHGs	0	Not reported	Not reported	Not reported	Not reported	Not reported	Not reported
	Total GHGs	216	22.7	0.105	0.0717	0.119	0.907	3.99

Facility Type	Pollutant	Number of Facilities that Reported	Total Emissions	Average Emissions	Median Emissions	Standard Deviation	Maximum Emissions	% Max Emissions
Other Chemical Product and Preparation Manufacturing	CH_4	2	0.0000848	0.0000424	0.0000424	0.0000557	0.0000818	96.5
	CO_2 non biogenic	2	0.447	0.223	0.223	0.0708	0.273	61.1
	N_2O	2	0.000101	0.0000505	0.0000505	0.0000664	0.0000974	96.4
	Other GHGs	0	Not reported	Not reported	Not reported	Not reported	Not reported	Not reported
	Total GHGs	2	0.447	0.223	0.223	0.0707	0.273	61.1
Pesticide, Fertilizer, and Other Agricultural Chemical Manufacturing	CH_4	8	0.00197	0.000246	0.000122	0.00043	0.00129	65.6
	CO_2 non biogenic	8	11.1	1.39	0.662	2.4	7.21	64.7
	N_2O	9	2.41	0.268	0.000205	0.602	1.84	76.4
	Other GHGs	0	Not reported	Not reported	Not reported	Not reported	Not reported	Not reported
	Total GHGs	9	13.6	1.51	0.594	2.88	9.05	66.7
Petroleum and Coal Products Manufacturing	CH_4	66	0.454	0.00688	0.00267	0.0105	0.0491	10.8
	CO_2 non biogenic	66	90.7	1.37	0.633	2.03	11.7	12.9
	N_2O	66	0.238	0.00361	0.0014	0.0054	0.0313	13.1
	Other GHGs	0	Not reported	Not reported	Not reported	Not reported	Not reported	Not reported
	Total GHGs	66	91.4	1.39	0.636	2.04	11.8	12.9

Facility Type	Pollutant	Number of Facilities that Reported	Total Emissions	Average Emissions	Median Emissions	Standard Deviation	Maximum Emissions	% Max Emissions
Resin, Synthetic Rubber, and Artificial Synthetic Fibers and Filaments Manufacturing	CH_4	33	0.062	0.00188	0.000039	0.00648	0.0322	51.9
	CO_2 non biogenic	33	15.3	0.464	0.0814	1.12	4.94	32.2
	N_2O	33	0.0293	0.000886	0.0000465	0.00261	0.00973	33.3
	Other GHGs	2	0.66	0.33	0.0279	0.159	0.388	58.8
	Total GHGs	33	16.1	0.487	0.0831	1.12	4.99	31

Table S6. Summary of CAP Emissions in 2020 by State and Region. Emissions are measured in US tons. Total emissions reflect the sum of reported emissions of a pollutant from all reporting facilities within a region or state. Average, median, standard deviation and maximum emissions are calculated from facility-level emissions among all facilities that report emissions for that pollutant. % Max Emissions reflects the proportion of pollutant emissions attributable to the highest emitting facility for that pollutant within the region or state.

Region/State	Pollutant	Number of Facilities that Reported	Total Emissions	Average Emissions	Median Emissions	Standard Deviation	Maximum Emissions	% Max Emissions
Gulf Coast	CO	285	72500	254	83	434	2640	3.64
	Lead	20	0.132	0.00658	0.00222	0.0113	0.046	34.9
	NO_x	285	100000	351	97.7	607	4510	4.51
	PM_{10}	289	19800	68.6	19.5	115	878	4.43
	$PM_{2.5}$	289	17000	59	15.3	103	736	4.32
	SO_2	281	95200	339	2.26	1320	12300	12.9
	Total CAPs	295	288000	975	250	1810	13100	4.56
LA	CO	100	33000	330	120	516	2390	7.24
	Lead	9	0.0877	0.00974	0.00363	0.0154	0.046	52.5
	NO_x	100	48600	486	133	822	4510	9.28
	PM_{10}	102	9040	88.6	37.7	125	743	8.22
	$PM_{2.5}$	102	7660	75.1	28	111	736	9.61
	SO_2	99	61400	621	5.56	1890	12300	20
	Total CAPs	103	152000	1480	338	2450	13100	8.61

Region/State	Pollutant	Number of Facilities that Reported	Total Emissions	Average Emissions	Median Emissions	Standard Deviation	Maximum Emissions	% Max Emissions
TX	CO	185	39500	213	59.9	378	2640	6.69
	Lead	11	0.0439	0.004	0.00115	0.00594	0.0156	35.5
	NO$_x$	185	51500	278	81.3	436	2240	4.35
	PM$_{10}$	187	10800	57.7	11.9	108	878	8.14
	PM$_{2.5}$	187	9390	50.2	9.22	96.5	708	7.54
	SO$_2$	182	33700	185	1.34	839	9230	27.4
	Total CAPs	192	135000	706	171	1270	9870	7.29
Ohio River Valley	CO	47	32500	692	21.7	3900	26800	82.4
	Lead	2	0.00806	0.00403	0.00403	0.000194	0.00417	51.7
	NO$_x$	46	8900	193	37.9	336	1680	18.9
	PM$_{10}$	48	2280	47.5	11.4	76.6	276	12.1
	PM$_{2.5}$	48	2100	43.7	9.11	72.5	268	12.8
	SO$_2$	44	4160	94.5	0.932	283	1530	36.8
	Total CAPs	49	47900	977	77	3880	27100	56.6
OH	CO	25	30900	1230	41.6	5330	26800	86.9
	Lead	2	0.00806	0.00403	0.00403	0.000194	0.00417	51.7
	NO$_x$	24	6380	266	71.8	424	1680	26.3
	PM$_{10}$	25	1430	57.3	23.1	81.3	276	19.3
	PM$_{2.5}$	25	1300	52	19.1	76.8	268	20.6
	SO$_2$	23	3190	139	1.99	372	1530	47.9
	Total CAPs	26	41900	1610	131	5270	27100	64.7

Region/State	Pollutant	Number of Facilities that Reported	Total Emissions	Average Emissions	Median Emissions	Standard Deviation	Maximum Emissions	% Max Emissions
PA	CO	12	572	47.7	14.4	82.3	283	49.5
	Lead	0	Not reported	Not reported	Not reported	Not reported	Not reported	Not reported
	NO_x	12	1320	110	25.3	172	558	42.2
	PM_{10}	13	590	45.4	3.06	82.6	229	38.8
	$PM_{2.5}$	13	555	42.7	3.06	79.6	229	41.3
	SO_2	12	509	42.4	0.506	109	377	74.1
	Total CAPs	13	2990	230	43.4	394	1150	38.4
WV	CO	10	1100	110	21.4	255	829	75.2
	Lead	0	Not reported	Not reported	Not reported	Not reported	Not reported	Not reported
	NO_x	10	1200	120	28.9	198	596	49.7
	PM_{10}	10	261	26.1	3.73	55.6	178	68.1
	$PM_{2.5}$	10	243	24.3	3.73	51.3	164	67.4
	SO_2	9	458	50.9	0.579	151	454	99.1
	Total CAPs	10	3020	302	80.3	632	2060	68.2

Table S7. Summary of CAP Emissions in 2020 by Facility Type. Emissions are measured in US tons. Total emissions reflect the sum of reported emissions of a pollutant from all reporting facilities of a specific facility type. Average, median, standard deviation and maximum emissions are calculated from facility-level emissions among all facilities that report emissions for that pollutant. % Max Emissions reflects the proportion of pollutant emissions attributable to the highest emitting facility of that pollutant for the facility type.

Facility Type	Pollutant	Number of Facilities that Reported	Total Emissions	Average Emissions	Median Emissions	Standard Deviation	Maximum Emissions	% Max Emissions
Basic Chemical Manufacturing	CO	173	70400	407	54	2070	26800	38.1
	Lead	10	0.0468	0.00468	0.00239	0.00708	0.0226	48.3
	NO_x	172	59000	343	58.5	658	4510	7.64
	PM_{10}	177	8830	49.9	13.6	81.7	508	5.75
	$PM_{2.5}$	177	7580	42.8	11.6	69.8	365	4.82
	SO_2	169	46200	273	1.34	1110	7560	16.4
	Total CAPs	180	184000	1020	130	2610	27100	14.7
Oil and Gas Extraction	CO	39	3860	99.1	79.4	88.3	379	9.81
	Lead	0	Not reported	Not reported	Not reported	Not reported	Not reported	Not reported
	NO_x	39	4340	111	93.2	103	401	9.25
	PM_{10}	39	505	13	7.47	15.7	62	12.3
	$PM_{2.5}$	39	499	12.8	7.47	15.6	60.9	12.2
	SO_2	37	1350	36.6	0.943	173	1050	77.5
	Total CAPs	39	10100	258	152	252	1270	12.6

Facility Type	Pollutant	Number of Facilities that Reported	Total Emissions	Average Emissions	Median Emissions	Standard Deviation	Maximum Emissions	% Max Emissions
Other Chemical Product and Preparation Manufacturing	CO	5	119	23.7	13.1	19.9	51.7	43.6
	Lead	0	Not reported	Not reported	Not reported	Not reported	Not reported	Not reported
	NO_x	5	376	75.1	19.6	94.7	228	60.7
	PM_{10}	5	74.2	14.8	5.61	22.4	54	72.7
	$PM_{2.5}$	5	73	14.6	4.56	22.4	53.8	73.7
	SO_2	5	96.9	19.4	0.368	42.5	95.3	98.4
	Total CAPs	5	665	133	38.1	170	414	62.2
Pesticide, Fertilizer, and Other Agricultural Chemical Manufacturing	CO	6	1180	197	236	150	349	29.5
	Lead	0	Not reported	Not reported	Not reported	Not reported	Not reported	Not reported
	NO_x	7	4950	707	276	930	2340	47.3
	PM_{10}	7	919	131	90.4	163	460	50.1
	$PM_{2.5}$	7	825	118	59.9	155	432	52.4
	SO_2	6	34.9	5.81	4.81	6.41	17.7	50.8
	Total CAPs	7	7080	1010	409	1200	3120	44
Petroleum and Coal Products Manufacturing	CO	65	24500	376	215	481	2640	10.8
	Lead	11	0.0924	0.0084	0.00329	0.0137	0.046	49.8
	NO_x	65	34600	532	372	559	2780	8.04
	PM_{10}	66	10400	158	119	169	878	8.43
	$PM_{2.5}$	66	9050	137	96.8	155	736	8.13
	SO_2	65	50400	776	122	2040	12300	24.4
	Total CAPs	69	120000	1740	1100	2270	13100	10.9

Facility Type	Pollutant	Number of Facilities that Reported	Total Emissions	Average Emissions	Median Emissions	Standard Deviation	Maximum Emissions	% Max Emissions
Resin, Synthetic Rubber, and Artificial Synthetic Fibers and Filaments Manufacturing	CO	44	5030	114	22.5	206	930	18.5
	Lead	1	0.0005	0.0005	0.0005	Not reported	0.0005	100
	NO_x	43	5700	133	28.9	293	1370	24
	PM_{10}	43	1370	31.8	15	54.5	316	23.1
	$PM_{2.5}$	43	1120	26	9.21	47.1	270	24.1
	SO_2	43	1240	28.8	0.422	141	881	71
	Total CAPs	44	13300	303	77.4	611	2930	22

Table S8. Summary of HAP Emissions in 2021 by State and Region. Emissions are measured in US tons. Total emissions reflect the sum of reported emissions of a pollutant from all reporting facilities within a region or state. Average, median, standard deviation and maximum emissions are calculated from facility-level emissions among all facilities that report emissions for that pollutant. % Max Emissions reflects the proportion of pollutant emissions attributable to the highest emitting facility for that pollutant within the region or state.

Region / State	Pollutant	Number of Facilities that Reported	Total Emissions	Average Emissions	Median Emissions	Standard Deviation	Maximum Emissions	% Max Emissions
Gulf Coast	1,3-Butadiene	103	574	5.57	0.788	12	83.2	14.5
	Benzene	142	782	5.51	2.79	7.01	37.6	4.81
	Chloroprene	12	18.8	1.57	0.00325	5.21	18.1	96.3
	Ethylene Dichloride	23	198	8.62	6.73	10.5	36.7	18.5
	Ethylene Oxide	31	68.5	2.21	0.762	2.96	9.49	13.8
	Total HAPs	320	12900	40.4	14.5	72	552	4.27
LA	1,3-Butadiene	25	68.3	2.73	0.742	6.91	34.8	50.9
	Benzene	45	229	5.09	2.81	6.53	37.6	16.4
	Chloroprene	6	18.8	3.13	0.0045	7.34	18.1	96.4
	Ethylene Dichloride	11	153	13.9	6.73	12.9	36.7	24
	Ethylene Oxide	11	30.2	2.74	1.75	2.98	7.7	25.5
	Total HAPs	95	4640	48.8	23.6	72.2	500	10.8
TX	1,3-Butadiene	78	505	6.48	0.87	13.1	83.2	16.5
	Benzene	97	553	5.7	2.56	7.25	35.7	6.46
	Chloroprene	6	0.00912	0.00152	0.00131	0.00172	0.0045	49.3
	Ethylene Dichloride	12	45.4	3.78	3.46	3.95	8.89	19.6
	Ethylene Oxide	20	38.4	1.92	0.646	2.98	9.49	24.7
	Total HAPs	225	8300	36.9	11.4	71.8	552	6.65

Region / State	Pollutant	Number of Facilities that Reported	Total Emissions	Average Emissions	Median Emissions	Standard Deviation	Maximum Emissions	% Max Emissions
Ohio River Valley	1,3-Butadiene	12	14.4	1.2	0.078	1.94	5.1	35.5
	Benzene	13	70.5	5.42	3.3	6.28	21.2	30.1
	Chloroprene	0	Not reported	Not reported	Not reported	Not reported	Not reported	Not reported
	Ethylene Dichloride	0	Not reported	Not reported	Not reported	Not reported	Not reported	Not reported
	Ethylene Oxide	6	1.24	0.206	0.113	0.195	0.495	40
	Total HAPs	58	3150	54.4	7.53	215	1630	51.7
OH	1,3-Butadiene	7	12.3	1.76	0.184	2.34	5.1	41.4
	Benzene	5	16.5	3.3	3.3	2.19	5.79	35.1
	Chloroprene	0	Not reported	Not reported	Not reported	Not reported	Not reported	Not reported
	Ethylene Dichloride	0	Not reported	Not reported	Not reported	Not reported	Not reported	Not reported
	Ethylene Oxide	0	Not reported	Not reported	Not reported	Not reported	Not reported	Not reported
	Total HAPs	28	2550	90.9	9.98	307	1630	64
PA	1,3-Butadiene	4	2.03	0.509	0.0065	1.01	2.02	99.3
	Benzene	6	31.9	5.32	3.7	5.65	12	37.6
	Chloroprene	0	Not reported	Not reported	Not reported	Not reported	Not reported	Not reported
	Ethylene Dichloride	0	Not reported	Not reported	Not reported	Not reported	Not reported	Not reported
	Ethylene Oxide	0	Not reported	Not reported	Not reported	Not reported	Not reported	Not reported
	Total HAPs	15	402	26.8	7.45	34.2	84.6	2.1.

Table S9. Summary of HAP Emissions In 2021 by Facility Type. Emissions are measured in US tons. Total emissions reflect the sum of reported emissions of a pollutant from all reporting facilities of a specific facility type. Average, median, standard deviation and maximum emissions are calculated from facility-level emissions among all facilities that report emissions for that pollutant. % Max Emissions reflects the proportion of pollutant emissions attributable to the highest emitting facility of that pollutant for the facility type.

Facility Type	Pollutant	Number of Facilities that Reported	Total Emissions	Average Emissions	Median Emissions	Standard Deviation	Maximum Emissions	% Max Emissions
Basic Chemical Manufacturing	1,3-Butadiene	54	476	8.81	4.16	15.1	83.2	17.5
	Benzene	74	431	5.82	3.6	7.65	37.6	8.73
	Chloroprene	6	0.0106	0.00177	0.00131	0.00188	0.004	37.7
	Ethylene Dichloride	15	136	9.08	6.73	12.1	36.7	26.9
	Ethylene Oxide	33	65.8	1.99	0.646	2.9	9.49	14.4
	Total HAPs	211	7790	36.9	9.72	123	1630	20.9
Oil and Gas Extraction	1,3-Butadiene	0	Not reported	Not reported	Not reported	Not reported	Not reported	Not reported
	Benzene	0	Not reported	Not reported	Not reported	Not reported	Not reported	Not reported
	Chloroprene	0	Not reported	Not reported	Not reported	Not reported	Not reported	Not reported
	Ethylene Dichloride	0	Not reported	Not reported	Not reported	Not reported	Not reported	Not reported
	Ethylene Oxide	0	Not reported	Not reported	Not reported	Not reported	Not reported	Not reported
	Total HAPs	0	Not reported	Not reported	Not reported	Not reported	Not reported	Not reported

Facility Type	Pollutant	Number of Facilities that Reported	Total Emissions	Average Emissions	Median Emissions	Standard Deviation	Maximum Emissions	% Max Emissions
Other Chemical Product and Preparation Manufacturing	1,3-Butadiene	1	0.007	0.007	0.007		0.007	100
	Benzene	1	0.004	0.004	0.004		0.004	100
	Chloroprene	0	Not reported	Not reported	Not reported	Not reported	Not reported	Not reported
	Ethylene Dichloride	0	Not reported	Not reported	Not reported	Not reported	Not reported	Not reported
	Ethylene Oxide	2	0.13	0.065	0.065	0.0575	0.106	81.5
	Total HAPs	13	105	8.05	0.25	13.5	42.1	40.2
Pesticide, Fertilizer, and Other Agricultural Chemical Manufacturing	1,3-Butadiene	0	Not reported	Not reported	Not reported	Not reported	Not reported	Not reported
	Benzene	0	Not reported	Not reported	Not reported	Not reported	Not reported	Not reported
	Chloroprene	0	Not reported	Not reported	Not reported	Not reported	Not reported	Not reported
	Ethylene Dichloride	0	Not reported	Not reported	Not reported	Not reported	Not reported	Not reported
	Ethylene Oxide	0	Not reported	Not reported	Not reported	Not reported	Not reported	Not reported
	Total HAPs	7	467	66.7	46	95.4	270	57.8
Petroleum and Coal Products Manufacturing	1,3-Butadiene	46	20.2	0.44	0.0725	1.1	5.91	29.2
	Benzene	71	386	5.43	3.3	6.17	30.5	7.91
	Chloroprene	0	Not reported	Not reported	Not reported	Not reported	Not reported	Not reported
	Ethylene Dichloride	2	0.005	0.0025	0.0025	0	0.0025	50
	Ethylene Oxide	0	Not reported	Not reported	Not reported	Not reported	Not reported	Not reported
	Total HAPs	81	5570	68.7	32.1	94.8	552	9.92

Facility Type	Pollutant	Number of Facilities that Reported	Total Emissions	Average Emissions	Median Emissions	Standard Deviation	Maximum Emissions	% Max Emissions
Resin, Synthetic Rubber, and Artificial Synthetic Fibers and Filaments Manufacturing	1,3-Butadiene	14	92	6.57	3.23	8.45	26.2	28.5
	Benzene	9	35.6	3.96	0.694	7.12	21.8	61.2
	Chloroprene	6	18.8	3.12	0.00475	7.34	18.1	96.4
	Ethylene Dichloride	6	62	10.3	6.86	6.38	18.9	30.5
	Ethylene Oxide	2	3.86	1.93	1.93	2.73	3.86	100
	Total HAPs	66	2160	32.7	12.8	62.1	432	20

Table S10. Summary of Net Annual Potential Emissions by State. Emissions are measured in US tons. Total emissions reflect the sum of reported emissions of a pollutant from all reporting facilities within a region or state. Average, median, standard deviation and maximum emissions are calculated from facility-level emissions among all facilities that report emissions for that pollutant.% Max Emissions reflects the proportion of pollutant emissions attributable to the highest emitting facility for that pollutant within the region or state.

Region/State	Pollutant	Number of Facilities that Reported	Total Emissions	Average Emissions	Median Emissions	Standard Deviation	Maximum Emissions	% Max Emissions
Gulf Coast	CO	64	29300	458	134	864	4950	16.9
	GHGs	40	57500000	1440000	507000	2300000	12400000	21.6
	HAPs	11	765	69.5	4.1	189	634	82.9
	NO_x	63	9070	144	43.2	251	1240	13.7
	$PM_{2.5}$	64	4340	67.8	22.1	131	891	20.5
	SO_2	64	6210	97	9.22	214	1220	19.6
	VOCs	63	14100	224	42.8	418	1870	13.3
LA	CO	17	5670	334	130	646	2770	48.9
	GHGs	14	27500000	1960000	563000	3380000	12400000	45.1
	HAPs	2	642	321	321	442	634	98.8
	NO_x	17	2640	155	95.2	291	1240	47
	$PM_{2.5}$	17	946	55.6	19	83.4	340	35.9
	SO_2	17	301	17.7	1.84	36.7	137	45.5

Region/State	Pollutant	Number of Facilities that Reported	Total Emissions	Average Emissions	Median Emissions	Standard Deviation	Maximum Emissions	% Max Emissions
	VOCs	17	2790	164	28.3	395	1670	59.9
TX	CO	47	23700	504	138	932	4950	20.9
	GHGs	26	30100000	1160000	507000	1430000	5180000	17.2
	HAPs	9	122	13.6	3.52	31	95.7	78.4
	NO_x	46	6430	140	38.4	238	1130	17.6
	$PM_{2.5}$	47	3400	72.3	22.6	145	891	26.2
	SO_2	47	5910	126	14.1	243	1220	20.6
	VOCs	46	11300	246	44.3	428	1870	16.5
Ohio River Valley	CO	8	766	95.8	31.8	183	542	70.8
	GHGs	6	3110000	518000	57800	749000	1620000	52.1
	HAPs	6	70.5	11.8	5.22	14.8	36	51.1
	NO_x	8	401	50.1	21.2	60.5	162	40.4
	$PM_{2.5}$	8	198	24.8	5.1	37.1	87	43.9
	SO_2	8	57.8	7.22	0.555	12.4	30.8	53.3
	VOCs	8	510	63.8	12	130	382	74.9
OH	CO	2	546	273	273	380	542	99.3
	GHGs	1	1620000	1620000	1620000		1620000	100
	HAPs	2	36	18	18	25.5	36	100
	NO_x	2	162	81	81	115	162	100
	$PM_{2.5}$	2	87.8	43.9	43.9	61	87	99.1
	SO_2	2	23	11.5	11.5	16.3	23	100

Region/State	Pollutant	Number of Facilities that Reported	Total Emissions	Average Emissions	Median Emissions	Standard Deviation	Maximum Emissions	% Max Emissions
	VOCs	2	386	193	193	267	382	99
PA	CO	4	69.2	17.3	16	17	34.8	50.3
	GHGs	4	155000	38800	31500	25200	72900	47
	HAPs	2	2.21	1.1	1.1	0.7	1.6	72.4
	NO_x	4	47.4	11.8	8.12	13.2	30.3	63.9
	$PM_{2.5}$	4	11.4	2.85	1.56	3.57	8.08	70.9
	SO_2	4	1.54	0.385	0.405	0.259	0.68	44.2
	VOCs	4	65.2	16.3	10.4	15.3	38.4	58.9
WV	CO	2	150	75	75.1	23.6	91.8	61.2
	GHGs	1	1340000	1340000	1340000		1340000	100
	HAPs	2	32.3	16.2	16.1	10.3	23.5	72.8
	NO_x	2	192	96	96	4.2	98.9	51.5
	$PM_{2.5}$	2	98.8	49.4	49.4	44.9	81.1	82.1
	SO_2	2	33.3	16.6	16.6	20.1	30.8	92.5
	VOCs	2	58.6	29.3	29.3	28.5	49.4	84.3

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