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PSE Healthy Energy Comments on Draft Transportation Fuels Transition Plan

Additional submitted attachment is included below.

PSE Bringing science to energy policy

June 15, 2026

Subject: Comment on the Draft California Transportation Fuels Transition Plan

Dear California Energy Commission and California Air Resources Board:

We are submitting this letter to introduce and enter into the record a technical report relevant to the agencies' ongoing work on the Draft California Transportation Fuels Transition Plan.

On May 28, 2026, PSE, in collaboration with researchers at the University of California, Los Angeles, and the University of California, Berkeley, published the Refinery Risk Map, the first publicly available, facility-level interactive tool that provides estimates of annual $PM_{2.5}$-attributable premature deaths from nearly all active oil refineries across the contiguous United States. The tool also provides facility-level emissions data, demographic and socioeconomic characterization of fenceline communities, health vulnerability indicators, and links to regulatory and enforcement data. The Refinery Risk Map is publicly accessible at rrm.psehealthyenergy.org and is hereby submitted for the record. The accompanying technical report, attached hereto, describes the full methodology and key findings.

Among the findings in the technical report:

- Nationwide, an estimated 990 annual $PM_{2.5}$-related premature deaths are attributable to emissions from 116 oil refineries across 28 US states, resulting in an estimated $13.5B in annual economic damages.
    - When correction factors are used to account for documented underestimation in emissions, this number increases to over 1640 $PM_{2.5}$-attributable premature mortalities ($22.4B in annual economic damages).
    - Two-thirds of estimated refinery-attributable mortalities are concentrated in Texas and California.
- An estimated 4.3 million people across the U.S. live within a 5 km radius of at least one oil refinery featured on the Refinery Risk Map. An estimated 1760 daycare centers, 1600

schools, 370 nursing homes, 135 hospitals, and 75 prisons are located within a 5 km radius of at least one oil refinery on the Refinery Risk Map.

- Black, Asian, and Latino people face an estimated 1.3x, 1.4x, and 1.8x increased risk of mortality, respectively, compared to White people, and together account for 54% of the estimated refinery-attributable mortalities nationwide despite representing only 34% of the U.S. population.
- Five of the top 12 refineries, ranked by $PM_{2.5}$-related premature deaths, are located in Los Angeles. These five refineries are located within fenceline communities (≤5 km) where Latino populations are overrepresented at 2.8 times the national average.

We offer this research as a resource for the agencies' consideration and make no specific recommendations regarding the plan's provisions. Please do not hesitate to contact us with questions about our methodology or findings.

Respectfully submitted by,

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About PSE

PSE Healthy Energy (PSE) is a scientific research institute generating energy and climate solutions that protect public health and the environment. PSE provides expertise in public health, environmental science, and engineering and brings science to energy policy through actionable research, communications, and advising.

About MHI

PSE's Methane + Health Initiative (MHI) aims to improve the scientific and public understanding of the link between methane emissions, air pollution, and public health.

Refinery Risk Map - Technical Report

May 28, 2026

PSE

Bringing science to energy policy

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About PSE Healthy Energy

PSE Healthy Energy (PSE) is a scientific research institute generating energy and climate solutions that protect public health and the environment. PSE provides expertise in public health, environmental science, and engineering and brings science to energy policy through actionable research, communications, and advising. **Visit us at psehealthyenergy.org and follow us on LinkedIn**.

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Table of Contents

1.0 Introduction

Oil refineries produce petroleum products (such as gasoline, naphtha, and distillate fuel oils) from crude oil, unfinished oils, or other unfinished petroleum derivatives (U.S. Environmental Protection Agency [EPA], 2025d; U.S. Energy Information Administration [EIA], n.d.-b). The United States is the world's largest producer (EIA, n.d.-c) and consumer (EIA, n.d.-d) of petroleum and accounts for over 17.6% of the world's refining capacity (Energy Institute, 2024). Within the U.S., oil refineries are the third-largest source of fine particulate matter ($PM_{2.5}$) emissions among point source facility types (EPA, 2025c). In addition to $PM_{2.5}$, they also emit other pollutants that are harmful to human health, such as nitrogen oxides (NO_x), sulfur oxides (SO_x), and benzene (California Office of Environmental Health Hazard Assessment [OEHHA] & California Environmental Protection Agency [CalEPA], 2019).

As shifting fuel demand, aging infrastructure, and depleting oil fields cause California refineries to shut down (Hersbach et al., 2026), the Gulf Coast is preparing to construct the first major oil refinery in the U.S. in nearly half a century (Seba & Jao, 2026). Together, these trends reflect an evolving political and economic landscape that yields different pathways for the future of domestic oil refining. As decision makers navigate these pathways, the public health impacts of these refineries represent an often overlooked consideration.

Exposure to air pollution from oil refineries has been associated with an increased risk of a number of harmful health outcomes, including asthma, cardiovascular disease, emergency department visits and hospitalizations, cancer, and premature death (Villanueva et al., 2026). Children and people with pre-existing health conditions are particularly vulnerable to the health effects of air pollutants emitted by refineries.

Refineries are often located near major population centers to minimize transportation costs and ensure proximity to demand for their end products (EIA, n.d.-d). In 2015, the EPA estimated that 6 million people live within 3 miles of an oil refinery (EPA, 2015), a distance within which adverse health impacts have been well documented (Villanueva et al., 2026). The same report found that communities located near the fenceline of refineries had twice the proportion of low income and minority populations as the general population (EPA, 2015), which is especially important given that these populations are particularly vulnerable to environmental stressors, such as air pollution, due to co-exposures with other social stressors (Morello-Frosch et al., 2011).

While the scientific evidence linking proximity to oil refineries with negative health outcomes is well established, a refinery-specific nationwide analysis of attributable mortality risk from active U.S. oil refineries remains limited, and no publicly available tool synthesizes these impacts across facilities nationwide. The Refinery Risk Map was developed to provide fenceline communities, advocacy organizations, regulators, and policymakers with the air quality, health, and demographic data needed to assess the impacts of oil refineries and better inform decision-making about their future.

This interactive data visualization tool displays nearly all active oil refineries in the contiguous U.S. For each facility, the Refinery Risk Map provides emissions data, estimates of $PM_{2.5}$-related premature deaths, links to regulatory and enforcement data, and a summary of the surrounding area's demographic, socioeconomic, and health characteristics.

In this technical report, we describe the methodology used to develop the Refinery Risk Map, along with key findings and data limitations.

2.0 Methods

2.1 Facility Data

2.1.1 Identifying U.S. Oil Refineries

The Refinery Risk Map provides information on 126 oil refineries in the contiguous U.S. These facilities were selected based on 1) emissions data availability, 2) geographic modeling constraints, and 3) operational status.

We identified oil refineries and their coordinates using the U.S. EPA's 2021 National Emissions Inventory (NEI) Point Facility Summary dataset (EPA, 2025a) (hereafter referred to as the "2021 NEI") by filtering for facilities classified under the source type "petroleum refineries." While the full NEI is conducted every three years, the EPA publishes annual point facility summaries. We used the 2021 edition because it was the most recent nationwide dataset available at the time of analysis with regulatory-grade facility-specific emissions estimates and stack characteristics.

We did not include any oil refineries located in Hawaii or Alaska, as our modeling methods, described in **Section 2.3**, do not allow for modeling outside of the contiguous U.S.

We also did not include any oil refineries that shut down prior to 2020, as reported in the 2022 EIA Refinery Capacity Report, which reflects refinery capacity as of January 1, 2022. (EIA, 2022). Refineries that are reported as "shutdown" by the EIA may still report emissions to the NEI if they have since transitioned away from crude oil refining and toward other activities (i.e., biofuel refining, petroleum storage) or if their shutdown operations led to onsite emissions. Biofuel refineries were outside the scope of this study.

We included facilities that shut down during 2020 or 2021; however, we do not display estimates of $PM_{2.5}$-attributable mortalities (**Section 2.3.3**) on the Refinery Risk Map as these emissions estimates are likely to underestimate historical air quality and human health impacts posed by typical operations at that facility. This applies to nine of the 126 refineries included in the Refinery Risk Map. For facilities that shut down after 2021, we display $PM_{2.5}$-attributable mortality estimates as they are based on a typical operating year.

2.1.2 Facility & Company Name, Operating Status, and Operating Capacity

The Refinery Risk Map provides site and company names, operating status, and operating capacity for each facility. While the 2021 NEI lists the site and company names for each facility, ownership has since changed for some refineries. We used the 2025 EIA Refinery Capacity Report, which reflects refinery data as of January 1, 2025, to update the site and company names to better reflect how each refinery is commonly known today (EIA, 2025).

The EIA also reports on the number of operational barrels per day, idle barrels per day, and, for shutdown or converted refineries, the date of shutdown and the date of last operation, respectively. We used these data from the 2025 EIA Refinery Capacity report to categorize the operating status of each facility as either Active, Idle, Partially Idle, or Shutdown.

- **Active** refers to refineries with zero idle barrels per day and no noted shutdown or conversion.
- **Idle** refers to refineries with zero operating barrels per day but non-zero idle barrels per day and no noted shutdown or conversion.
- **Partially Idle** refers to refineries with non-zero operating barrels per day and non-zero idle barrels per day and no noted shutdown or conversion.
- **Shutdown** refers to refineries with unreported capacities and that are noted as shut down or converted to biofuel refining. For refineries that have shut down, we include the date of shutdown in the operating status. For refineries that have converted to biofuel refining, we note as such and include the date of last operation as an oil refinery.

The Refinery Risk Map displays the operational capacity for each active oil refinery, in barrels per calendar day of atmospheric crude oil distillation, as reported in the 2025 EIA Refinery Capacity Report. The barrels per calendar day represent the amount of crude oil that a distillation facility can process under usual operating conditions, within a 24-hour period (EIA, n.d.-a). As opposed to barrels per stream day, which represents the maximum number of barrels of crude oil that can be processed within a 24-hour period running under optimal conditions, barrels per calendar day accounts for limitations that may delay, interrupt, or slow down production, and therefore can be used to better predict annual operational capacity.

2.1.3 FRS ID & ECHO Database

The Refinery Risk Map also provides links to regulatory and enforcement data for each facility. The U.S. EPA assigns a Facilities Registry Service identification number (FRS ID) to any facility that submits site data to EPA and state programs (EPA, 2025b). The FRS ID allows users to find facility-specific data reported to the U.S. EPA and to state, local, and tribal environmental agencies on the U.S. EPA's Enforcement Compliance History Online (ECHO) website. Specifically, ECHO provides a "Detailed Facility Report," which includes facility inspection, enforcement, and compliance details regarding the Clean Air Act, Clean Water Act, and Resource Conservation and Recovery Act, as well as information on toxic releases from the site (EPA, n.d.-a). For each facility, we provide the FRS ID and a link to the ECHO website's "Detailed Facility Report."

2.1.4 Limitations in Facility Data

Using the 2021 NEI for facility data introduces several limitations. Although 2021 represents the most recently available year of data at the time of analysis, the data are now over four years old. According to the EIA Refinery Capacity Reports from 2022-2025, refinery operations have since shifted: five oil refineries became operational (four in Texas, one in California), one was reactivated (in New Jersey), and three shut down (two in California, one in Louisiana), none of which are reflected in this analysis (EIA, 2022; EIA, 2023; EIA, 2024; EIA, 2025).

Additionally, not all active oil refineries are available in the 2021 NEI. Facilities may be absent because they fall below the major source reporting threshold, are classified under a different source type in the NEI (such as asphalt production or chemical manufacturing), or were idled/shutdown in 2021.

2.2 Emissions Estimates

The Refinery Risk Map displays annual emissions of 1) individual criteria air pollutants consisting of $PM_{2.5}$ (filterable and condensible), PM_{10} (filterable and condensible), NO_x, SO_2, and carbon monoxide (CO), 2) additional particulate matter precursors, including volatile organic compounds (VOCs) and ammonia (NH_3), 3) total hazardous air pollutants (HAPs), and 4) total greenhouse gases (GHGs). See the tool tips on the Refinery Risk Map for more information about these pollutants and their health risks.

2.2.1 Reported Emissions

We used the 2021 NEI to obtain facility-wide annual emissions data. The EPA requires point sources (i.e., larger stationary sources of emissions, such as refineries) to submit emissions to the NEI on a triennial basis, with 2020 as the most recent official inventory year (EPA, 2026).

However, some larger sources are required to report emissions annually (EPA, n.d.-b). Between triennial inventories, the EPA updates the most recent NEI using these annual reports to produce interim datasets. For this analysis, we used data from 2021 as it was the most recent year available at the time of analysis. These data reflect updates to the 2020 NEI based on 2021 annual reporting (EPA, 2025c).

We used total $PM_{2.5}$ and total PM_{10} (i.e., filterable plus condensible) as reported in the 2021 NEI to represent $PM_{2.5}$ and PM_{10}, respectively. While the 2021 NEI reports emissions from each of the 188 hazardous air pollutants regulated by the EPA (EPA, n.d.-e), for simplicity, we show the sum total across all hazardous air pollutants, consistent with how the EPA defines a major source of pollution (EPA, n.d.-d). Greenhouse gases, specifically carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O), are represented as a sum total of carbon dioxide equivalents (CO_2e) using their 100-year global warming potentials (1, 30, 279, respectively) (EPA, 2025e).

2.2.2 Corrected Emissions

Across the U.S., emissions inventories, such as the NEI, have been found to systematically underestimate emissions from the petrochemical industry, including oil refineries (Ryerson et al., 2003; Wert et al., 2003; Johansson et al., 2014; Cowling et al., 2007; Parrish et al., 2009; Peters et al., 2026; Hoyt & Raun, 2015). With respect to refineries, several studies comparing measured ambient air concentrations with inventory-based modeled concentrations report significant discrepancies between reported and actual VOC (Mellqvist et al., 2017; Chambers et al., 2012; Mid-Atlantic Regional Air Management Association [MARAMA], 2003) and methane emissions (Guha et al., 2020; Mehrotra et al., 2017; Lavoie et al., 2017). One study also found discrepancies between reported and observed SO_2 and NO_2 emissions (Mellqvist et al., 2017). These differences have been attributed to outdated or incorrect calculation methodologies used in facility and inventory reporting (Environmental Integrity Project & Galveston-Houston Association for Smog Prevention, 2004), as well as underreporting of fugitive emissions from non-routine upset conditions (McCoy et al., 2010; Ozymy & Jarrell, 2011; Fraas & Egorenkov, 2017).

To account for this likely underestimation in reported emissions, we derived pollutant-specific correction factors for methane, VOCs, SO_2, NO_2, and benzene. We compiled discrepancy factors from a technical report commissioned by the South Coast Air Quality Management District (SCAQMD) and from peer-reviewed studies comparing estimated and observed concentrations for these pollutants, and calculated weighted averages based on the number of observations used to derive each factor (see **Table 1**). We then applied these as correction factors to the reported emissions from the 2021 NEI. Correction factors for benzene and methane were applied to their emissions before summing to represent total HAPs and total GHGs, respectively. Corrected emissions are included alongside reported emissions on the Refinery Risk Map to show the plausible range of emissions estimates for that facility. For VOCs, SO_2, and NO_2, which contribute to the formation of secondary PM2.5, correcting for potential underestimation will also increase estimated PM2.5 concentrations and attributable mortalities.

Table 1: GHG Correction Factors

Correction factors were derived from studies conducted on oil refineries in California (see **Section 2.2.3** for more details).

GHG Correction Factors			
Reference	Refinery	Discrepancy Factor	
		CH_4	# of Observations
Guha et al., 2020	Marathon Martinez	22	7
	Chevron Richmond	23	7
	Martinez Refining Company	4	10
	Valero Benicia	5	6
	Phillips 66 San Francisco	18	11
Mehrotra et al., 2017	Marathon Martinez	3	3
	Phillips 66 San Francisco	30	5
	Valero Benicia	13	7
Weighted Average Correction Factor		**14.9**	**56**

Table 2: Air Pollutant Correction Factors

Correction factors were derived from studies conducted on oil refineries in California (see **Section 2.2.3** for more details).

Air Pollutant Correction Factors						
Reference	Refinery	Discrepancy Factor				
		VOC	NO2	SO2	Benzene	# of Observations
Mellqvist et al., 2017	Tesoro Carson/Wilmington	6.4	1	1.2	43	15
	Philipps 66 Carson	8.3	0.8	1.5	33	5
	Philipps 66 Wilmington	11.8	1.1	2.7	202	4
	Valero Wilmington	10.5	1.1	1.7	39	7
	Chevron El Segundo	5.4	0.8	1.7	38	7
	Torrance Refinery	2.7	0.3	1.1	3.2	4
Weighted Average Correction Factor		**7.3**	**0.9**	**1.5**	**51.7**	**42**

2.2.3 Limitations in Emissions Data

The correction factors used in this analysis were developed for a forthcoming sister study that focuses on the air quality and public health impacts from oil refineries located in the San Francisco Bay and therefore rely on studies conducted in California. We use the same correction factors for the Refinery Risk Map to maintain consistency across studies. While site-specific or state-specific correction factors would be most appropriate, studies in Illinois, Indiana, Texas, and Utah have estimated discrepancies between observed and self-reported refinery emissions of methane, VOCs, SO_2, NO_2, and benzene with similar magnitudes as the correction factors we applied (Lavoie et al., 2017; Johansson et al., 2014).

Notably, we did not develop correction factors for primary $PM_{2.5}$ emissions, as peer-reviewed studies comparing measured and reported $PM_{2.5}$ emissions are limited. To the extent that primary $PM_{2.5}$ emissions are underreported, the emissions estimates and subsequent mortality estimates may be underestimated.

2.3 Air Quality Modeling and Mortality Estimates

2.3.1 Model Selection

We used the Intervention Model for Air Pollution (InMAP; version 1.9.6; Tessum, 2022) to estimate the number of $PM_{2.5}$-attributable premature mortalities associated with emissions from each oil refinery. InMAP is a reduced-form air quality model that estimates annual-average changes in ambient $PM_{2.5}$ concentrations from changes in total $PM_{2.5}$ emissions (Tessum et al., 2017). Total $PM_{2.5}$ includes primary $PM_{2.5}$, which is emitted directly to the atmosphere, and secondary $PM_{2.5}$, which is formed from emissions of NH_3, VOCs, NO_x, and SO_x.

InMAP relies on simplified representations of atmospheric chemistry derived from a comprehensive chemical transport model, using annual-average parameters. This makes InMAP ideal for analyzing marginal changes in emissions; however, it can also reproduce total observed concentrations of $PM_{2.5}$ within established air quality model performance criteria (Tessum et al., 2017).

We chose InMAP because it can recreate comprehensive model predictions while reducing computational complexity (Tessum et al., 2017). InMAP uses a variable-resolution grid, with grid cells ranging from 1 to 48 km, providing higher spatial resolution in urban areas and lower spatial resolution in rural areas. Refineries are often located near urban areas; InMAP's ability to generate more spatially detailed results than other reduced-form models while remaining computationally efficient makes it particularly well suited for this analysis.

InMAP also provides pre-formatted baseline mortality and population data by race and ethnicity, which allows users to estimate the demographic distribution of $PM_{2.5}$-attributable mortalities. Mortality rates are sourced from the CDC WONDER database, and population data are sourced from the U.S. Census Bureau's American Community Survey 5-Year Estimates (2011–2015), aggregated at the census block group level (Tessum et al., 2019). Additionally, InMAP allows users to specify stack parameters, improving the characterization of the source compared to other reduced-form models.

2.3.2 Stack Parametrization

Emissions from oil refineries typically come from a number of different emissions sources spread across the facility area. Each emissions source may be characterized by its stack parameters (stack height, stack diameter, stack velocity, stack temperature), which may vary across emissions sources.

While InMAP defaults allow users to omit stack parameters for simplicity and use ground-level parameters instead, including stack parameters may improve the accuracy of reduced-form models (EPA, 2019). To identify stack parameters for each emissions source, we applied a tiered approach. Where available, we used site-specific stack parameters as reported by facilities to the EPA (Community Modeling and Analysis System [CMAS], n.d.). For emissions points that did not have reported stack parameters, we used default stack parameters developed by the EPA based on the Source Classification Codes (EPA, 2018). For emissions points with neither reported nor default stack parameters, we used median values from that facility. For emissions points that did not have median facility values, we used medians across the entire oil refinery dataset.

2.3.3 Health Impact Function

As described in **Section 2.3.1**, InMAP provides the estimated change in total $PM_{2.5}$ concentration for each grid cell across its variable-resolution grid. The number of $PM_{2.5}$-attributable premature mortalities for a given grid cell can be calculated as follows:

$$Attributable\ Mortalities = (RR - 1) * P * M$$ **Equation 1**

where:

- RR is the relative risk of premature mortality among the exposed versus the unexposed
- P is the number of people in the grid cell
- M is the baseline mortality rate in the grid cell

We used a concentration-response function to calculate the relative risk of premature mortality due to $PM_{2.5}$ exposure in each modeled grid cell. This function assumes a log-linear relationship between the increase in $PM_{2.5}$ concentration and the relative risk of premature mortality, characterized below:

$$RR(x) = e^{\beta x}$$ **Equation 2**

where:

- x is the increase in annual-average $PM_{2.5}$ concentration
- β is a beta coefficient derived from epidemiological studies.

We use the single-pollutant analysis provided by Di et al. (2017), which estimates that for a 10 $\mu g/m^3$ increase in ambient $PM_{2.5}$ concentration, the relative risk of all-cause mortality is 1.084. Using equation 2, we calculate the beta coefficient β to be:

$$\beta = \frac{ln(1{,}084)}{10} \qquad \textbf{Equation 3}$$

Using equations 2 and 3, equation 1 then becomes:

$$Attributable\ Mortalities = (\ e^{\frac{ln(1.084)}{10}x} - 1)\ *\ P\ *\ M \qquad \textbf{Equation 4}$$

We then sum the mortalities across all modeled grid cells to estimate the total number of $PM_{2.5}$-attributable premature mortalities from one year of exposure to oil refinery emissions.

2.3.4 Model Runs and Visualization

We ran InMAP with the emissions from one oil refinery at a time to simulate the change in mortality attributable to each individual refinery, in isolation from other oil refineries in the area. We did this twice, once using reported emissions and once using corrected emissions. The Refinery Risk Map shows the annual-average change in $PM_{2.5}$ concentration from each facility's corrected emissions as a grey-scale plume, with concentrations ranging from 0.05 to 2 $\mu g/m^3$. This visualization shows the direction of dispersion on an annual average basis, so users can better see which communities are typically downwind of the facility.

We also conducted a nationwide InMAP run with emissions from all oil refineries on the Refinery Risk Map simultaneously to analyze their combined impacts across the contiguous U.S. We did this twice, once using reported emissions and once using corrected emissions. We then estimated the associated economic damages of the mortality risks using the 2025 central estimate of the value per statistical life, $13.6 million (U.S. Department of Health and Human Services [HHS], 2025). Results from this analysis are included in **Section 3**.

2.3.5 Limitations in Air Quality Modeling

Section 2.3.1 briefly introduced InMAP's inherent limitations; this section elaborates on two of them in greater detail. First, InMAP uses simplifying assumptions about the relationship between emissions and ambient $PM_{2.5}$ concentrations. While state-of-the-science chemical transport models (CTMs) more accurately model complex chemical and physical atmospheric processes, reduced-form models, including InMAP, provide significant computational advantages with only a minor loss in fidelity and have been validated against full CTMs (Gilmore et al., 2019; Tessum et al., 2017).

Second, InMAP's baseline chemical transport model simulation uses the 2005 NEI emissions inventory. While updating the baseline simulation to use the 2021 NEI would improve accuracy, this was not feasible due to resource constraints. Importantly, InMAP is designed to estimate relative changes in outdoor $PM_{2.5}$ concentrations attributable to changes in emissions, rather than to replicate absolute ambient concentrations. The use of 2005 baseline data, therefore, remains valid for a comparative assessment of facility-level $PM_{2.5}$ impacts.

2.3.6 Limitations in Health Impact Assessment

The Refinery Risk Map focuses on mortality risks associated with exposure to changes in $PM_{2.5}$ concentrations. However, emissions from oil refineries are associated with additional mortality risks beyond $PM_{2.5}$. Ozone, a criteria pollutant linked to increased mortality risk (Lim et al., 2019), is produced from refinery emissions of ozone precursors, such as VOCs, NO_x, and SO_2. Hazardous air pollutants, such as benzene, a known carcinogen, pose additional mortality risks. Estimated mortalities from these pollutants are not currently quantified on the Refinery Risk Map, and their inclusion would likely increase the estimated total mortality burden attributable to air pollution from oil refineries.

Additionally, $PM_{2.5}$ and co-emitted pollutants from refinery operations are associated with a range of non-mortality health outcomes not currently represented in the Refinery Risk Map. These include asthma exacerbations, cardiovascular disease, lung cancer, and stroke, among others. Including other health outcomes in future iterations would provide a more comprehensive characterization of the public health burden posed by oil refining.

2.4 Population Characterization

2.4.1 Buffer Area

To characterize fenceline communities, we drew a 5 km buffer around each oil refinery based on evidence that communities within 5 km of refineries experience the most adverse health effects (Villanueva et al., 2026). We then summarized the population demographics, health vulnerability characteristics, and number of sensitive facilities within the 5 km buffer area, as described below.

2.4.2 Population Demographics

The Refinery Risk Map provides the estimated number of people living within 5 km of each oil refinery, based on the 2020 Census (U.S. Census Bureau, n.d.-b). To generate these estimates, we identified census blocks within the 5 km buffer area using their geometric centroids and summed their population counts. Census blocks also provide data on demographic subpopulations (i.e., White, Black, American Indian or Alaska Native, Asian, Native Hawaiian or Other Pacific Islander, Hispanic/Latino, under age 5, over age 65). We summed the subpopulation counts from each census block within the buffer area and calculated them as percentages of the total estimated population.

For additional subpopulation categories which are not available in the 2020 Census (i.e., number of households living in poverty, number of outdoor workers over 16 years of age, number of people that do not have health insurance, and number of people over age 25 that do not have a high school diploma), we relied on the American Community Survey conducted for 2019-2023 (U.S. Census Bureau, n.d.-a). For these variables, which are not available at the census block level, we identified the census block groups that are within the 5 km buffer area using the census block group's population centroid (i.e., the geographic point representing the average location where people live within the block group; U.S. Census Bureau, 2021). We summed the subpopulation counts, and calculated them as percentages of the total population.

On the Refinery Risk Map, population demographics for each 5 km buffer are compared with national and state averages, which were calculated using the same methods.

2.4.3 Health Vulnerability

For each facility, we also estimated the percentage of the population over the age of 18 within a 5 km radius with health conditions that may be exacerbated by air pollution exposure. These health conditions include asthma, cancer, chronic obstructive pulmonary disease (COPD), heart disease, diabetes, and stroke (National Institute of Environmental Health Sciences [NIEHS], n.d.).

To do this, we relied on the Centers for Disease Control and Prevention's PLACES dataset (Centers for Disease Control and Prevention [CDC], 2025). PLACES uses models to estimate the crude prevalence of health outcomes based on health data from telephone surveys and population data from the Census and American Community Survey five-year summaries (CDC, n.d.). PLACES provides prevalence data at the census tract level, which is too large a spatial resolution for the 5 km buffers; therefore, we used census block data to estimate the proportion of the census tract population within the buffer.

First, we identified the census blocks within the 5 km buffer using their geometric centroids. Then, we calculated a population weight by dividing the population of the blocks within the buffer by the census tract's total population, using Equation 5.

$$W_T = \Sigma P_B / P_T$$ **Equation 5**

where

- W_T is the population-weighted factor representing the fraction of the census tract population within the buffer
- P_B is the population of each block in the census tract that falls within the buffer
- P_T is the population of the census tract

Then, we converted the tract-level health outcome prevalence percentages into counts using Equation 6.

$$C_T = \% \, Prev_T \times P_T$$ **Equation 6**

where

- C_T is the number of cases of each health outcome in the census tract
- $\% \, Prev_T$ is the percent prevalence of each health outcome in the census tract
- P_T is the population of the census tract

Then, we apportioned the census tract prevalence to the buffer using Equation 7.

$$C_{T \, in \, Buffer} = C_T \times W_T$$ **Equation 7**

where

- $C_{T\ in\ Buffer}$ is the number of cases of each health outcome in the portion of the census tract within the buffer
- C_T is the number of cases of each health outcome in the census tract
- W_T is the population-weighted factor representing the fraction of the census tract population within the buffer

Finally, for cases with more than one census tract within the buffer area, we sum the number of cases from census tracts within the buffer using Equation 8.

$$C_{Buffer} = \Sigma C_{T\ in\ Buffer}$$ **Equation 8**

where

- C_{Buffer} is the total number of cases of each health outcome within the buffer
- $C_{T\ in\ Buffer}$ is the number of cases of each health outcome in the portion of the census tract within the buffer

On the Refinery Risk Map, we present the prevalence of each health outcome as a percentage of the total population over the age of 18 and compare this prevalence with state and national averages. These prevalence rates are not adjusted for age and should be interpreted as indicators of vulnerability to pollution rather than as indicators of direct health impacts from refinery pollution.

2.4.4 Sensitive Facilities

For each facility, the Refinery Risk Map shows the estimated number of facilities within a 5 km radius that serve populations that are particularly sensitive to the effects of air pollution, such as infants, children, older adults, institutionalized populations, and people with pre-existing health conditions (EPA, n.d.-c). These sensitive facilities include schools, childcare centers, nursing homes, hospitals, and prisons.

We relied on the Homeland Infrastructure Foundation-Level Data (HIFLD), a geospatial dataset maintained by the Department of Homeland Security (DHS). We merged HIFLD datasets that provide coordinates for hospitals, child care centers, public and private schools, nursing homes, and prisons into a single dataset (DHS, n.d.-a; DHS, n.d.-b; DHS, n.d.-c; DHS, n.d.-d; DHS, n.d.-e; DHS, n.d.-f). For each oil refinery, we identified which sensitive facilities were located within the 5 km buffer and provided the name and distance from the oil refinery for each. We also provide the total count of sensitive facilities and the number of each sensitive facility type on the Refinery Risk Map.

2.4.5 Nationwide Estimates

To estimate the number of people and sensitive facilities within 5 km of at least one oil refinery across the contiguous U.S., we merged the buffer areas for each refinery into one polygon and repeated the methods described in **Section 2.4.2** and **Section 2.4.4** for the combined area. Results are presented in **Section 3.0**.

3.0 Key Findings

Using the methodology described in **Section 2.4.5**, we estimate that more than 4.3 million people live within 5 km of at least one refinery on the Refinery Risk Map—a distance associated with elevated risks of several adverse health outcomes. We also find approximately 1760 childcare centers, 1600 schools, 370 nursing homes, 135 hospitals, and 75 prisons within 5 km of at least one refinery, highlighting the presence of populations that are particularly vulnerable to the health effects of air pollution.

As described in **Section 2.3.4**, we conducted individual InMAP model runs for each oil refinery — once using reported emissions and once using corrected emissions — to estimate the premature mortality impacts of each refinery in isolation. We also conducted nationwide InMAP model runs using both reported and corrected emissions to estimate the combined impacts across all oil refineries in the contiguous U.S. This section presents the key findings from both analyses. While we provide a comparison between mortalities using reported emissions and mortalities using corrected emissions in **Section 3.1**, all other mortalities in this section use reported emissions unless otherwise noted. Mortality burdens should be interpreted as a function of refinery emissions, meteorological conditions, underlying mortality rates, and the size and distribution of the exposed population.

3.1 Nationwide Analysis

Nationwide, we estimate that 990 annual $PM_{2.5}$-related premature deaths are attributable to emissions from oil refineries, resulting in an estimated $13.5B in annual economic damages. When correction factors, described in **Section 2.2.2**, are used to account for likely underestimation of emissions, this number increases to over 1640 $PM_{2.5}$-attributable premature deaths ($22.4B annually).

To estimate each state's share of total nationwide mortalities, we identified modeled grid cells within state boundaries using their geometric centroids and summed the estimated mortalities. We found that nearly two-thirds of estimated refinery-attributable mortalities (~610 mortalities) are concentrated in Texas and California. However, when adjusted for state population, we found that Louisiana bears the highest per-capita estimated mortality burden, followed by Texas and then California.

As mentioned in **Section 2.3.1**, InMAP allows users to evaluate the demographic breakdown of estimated $PM_{2.5}$-attributable mortalities. Specifically, InMAP provides mortality estimates for Asian, Black, Latino, Native, and non-Latino White populations. To assess the mortality burden across these racial/ethnic groups, we compared each group's total mortality relative to its share of the population. To assess disproportionate mortality burden, we calculated a disparity ratio for each racial/ethnic group, defined as the group's share of total attributed mortalities divided by its share of the U.S. population. A ratio greater than 1.0 indicates that a group bears a disproportionate share of the mortality burden relative to its population size.

We found that Black, Asian, and Latino people face an estimated 1.3-, 1.4-, and 1.8-fold increased risk of mortality, respectively, compared to White people, and together account for 54% of the estimated refinery-attributable mortalities nationwide despite representing only 34% of the U.S. population.

3.2 Facility-Level Analysis

The results of each facility's analysis are available on the Refinery Risk Map. We conducted two facility comparison analyses to better understand the range of impacts from oil refineries.

First, we compared the total number of $PM_{2.5}$-attributable mortalities and the share of total nationwide mortalities from each oil refinery. While most facilities (57%) had fewer than 5 attributable mortalities, we found that the top 10% of facilities may be responsible for more than 50% of estimated mortalities nationwide. These 12 refineries represent 20% of total crude distillation capacity in the U.S. (EIA, 2025). Notably, nearly half of these facilities are located in Los Angeles. These Los Angeles refineries are located within fenceline communities (≤5 km) where Latino populations are overrepresented at 2.8 times the national average.

Next, we estimated the number of mortalities within a 5 km radius from the facility to understand the mortality impacts on fenceline communities. We did this by summing the mortalities from any grid cell that overlapped the buffer area. For five refineries, we estimate between 5 and 12 premature mortalities within the fenceline community, representing 19-58% of the total mortality attributable to these facilities. This indicates that for a small number of facilities, fenceline communities may bear a disproportionate share of mortalities. However, for most facilities (78/116, 67%), we estimated less than one mortality within a 5 km radius.

3.3 Conclusion

We estimate that over 4.3 million people and nearly 4000 sensitive facilities reside within 5 km of at least one refinery found on the Refinery Risk Map. While $PM_{2.5}$-attributable mortality impacts extend well beyond these fenceline communities — carried downwind to broader regional populations — those living closest to refineries may face additional and compounding health burdens. We estimate that between 990 and 1640 $PM_{2.5}$-related deaths can be attributable to emissions from oil refineries and that, even considering mortality risks alone, these facilities present quantifiable economic damages ($13.5-22.4B annually). Lastly, we find that mortality impacts from refineries are not distributed equally across communities. As the landscape of domestic oil refining continues to shift, the Refinery Risk Map equips users with facility-specific data to better inform decisions about refinery operations and retirements.

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