THE REAL URBAN EMISSIONS INITIATIVE

Seattle drayage truck emissions and environmental justice analysis

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JANUARY 2026

ACKNOWLEDGMENTS

The authors would like to thank Mia Ayala-Marshall and the Duwamish River Community Coalition for supporting the methodology development, sharing community knowledge, and reviewing the report. Thank you also to the Northwest Seaport Alliance for providing valuable feedback. Finally, thank you to Lingzhi Jin, Ray Minjares, and Hamilton Steimer at the ICCT for their review and constructive feedback.

This study was funded through the generous support of the FIA Foundation.

FIA Foundation and the International Council on Clean Transportation established The Real Urban Emissions (TRUE) Initiative. The TRUE Initiative seeks to supply cities with data regarding the real-world emissions of their vehicle fleets and equip them with technical information that can be used for strategic decision-making.

TRUE
THE REAL URBAN EMISSIONS INITIATIVE

EXECUTIVE SUMMARY

Drayage trucks, or tractor-trailers serving ports, are a source of local air pollution, emitting fine particulate matter ($PM_{2.5}$) and nitrogen oxides (NO_X) that cause adverse health impacts such as childhood asthma and premature death. Drayage truck activity associated with the Port of Seattle is concentrated within the Duwamish Valley, an area with elevated air pollution and disproportionate health burdens. Recent policies from Washington State and the Northwest Seaport Alliance (NWSA), a marine cargo partnership of the Ports of Seattle and Tacoma, prioritize addressing drayage truck emissions to reduce health impacts and promote environmental justice.

Washington State has adopted policies like the Advanced Clean Trucks (ACT) rule to transition to zero-emission vehicles (ZEVs), policies that are now under threat due to federal opposition and industry lobbying. Nonetheless, the state's Climate Commitment Act and various multi-stakeholder groups have made meaningful progress in reducing drayage truck emissions. In 2019, NWSA implemented a policy requiring trucks entering the Port of Seattle's international container terminals to have 2007 model year (MY) or newer engines, helping to greatly reduce diesel particulate matter emissions. Additionally, the Puget Sound Zero-Emission Truck Collaborative has developed a roadmap to phase out emissions from drayage services by 2050, identifying key strategies to support adoption of zero-emission drayage trucks.

While strategies exist for reducing overall emissions, designing policies that reduce health disparities requires understanding where emissions are concentrated geographically. This report addresses this need by combining real-world traffic and emissions data from the TRUE Initiative U.S. database to model drayage truck emissions across Seattle, with a particular focus on NO_X emissions due to their impact on public health and tendency to form highly localized hotspots. We analyze spatial patterns of drayage truck idling and driving emissions alongside health data and environmental justice indicators to assess where high levels of drayage emissions align with worse health outcomes. We also identify key strategies to target emission reductions in the most overburdened areas.

Key findings include:

- **Drayage trucks are an important source of port-related NO_X emissions and associated health impacts.** Current policies have helped to greatly reduce tailpipe $PM_{2.5}$ emissions, but substantial levels of NO_X emissions in residential neighborhoods remain a public health issue.
- **There is a racial/ethnic disparity in levels of drayage truck NO_X emissions.** Native American, Latino, and Asian residents are overrepresented in neighborhoods with the highest levels of drayage truck NO_X emissions. Emissions are largely concentrated in the Duwamish Valley, one of the region's most racially diverse areas.
- **Idling emissions are a major source of NO_X pollution in overburdened neighborhoods.** Idling accounts for 45%–55% of drayage-related NO_X emissions in the neighborhoods of Georgetown and South Park, well above the citywide average of 32%.
- **Areas of Seattle with elevated drayage truck emissions experience disparate health outcomes.** Neighborhoods with the highest idling emissions have overall premature mortality rates over 50% higher than areas with no idling emissions.
- **Older trucks contribute a disproportionate share of total emissions.** Requiring MY 2007 or newer engines helps reduce the number of older, higher-emitting vehicles; still, MY 2010 and older trucks comprise 22% of the fleet and nearly half of total NO_X due to higher real-world emissions.

Based on these findings, two complementary approaches can be used to address drayage truck emissions and their impacts:

Transitioning to zero-emission drayage trucks is a key strategy for reducing overall drayage truck emissions. While pursuing legal action to protect the ACT, Washington State can adopt alternative measures to incentivize manufacturers to increase zero-emission truck production. Supporting the development of a variety of financial models, such as leasing, can create competitive options suited for individual owner-operators or small fleet owners for whom upfront costs are prohibitive. Additionally, rebate programs can be carefully designed to reduce drayage truck purchase costs while also improving overall affordability across the market. Finally, building a coordinated regional charging infrastructure

strategy across utility service territories can support and encourage the growth of zero-emission vehicle adoption.

Targeted interventions to reduce drayage truck emissions in overburdened neighborhoods are important for environmental justice. Expanding data collection and monitoring of drayage trucks with disaggregation by operating location where possible can help address air pollution hotspots. To address idling emissions, collaboration across stakeholders, including truck drivers and neighborhood groups, can help to identify the best solutions to reduce idling, particularly in the South Park and Georgetown neighborhoods. Potential approaches include expanding education on the health and fuel-cost effects of idling, developing anti-idling legislation, and electrifying temperature control and other power needs.

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INTRODUCTION

Diesel drayage trucks serving the Port of Seattle—one of the busiest container ports on the U.S. West Coast—are a significant source of local air pollution, emitting fine particulate matter ($PM_{2.5}$), nitrogen oxides (NO_X), and other pollutants linked to serious health issues.[1] The burden of this environmental impact falls disproportionately on communities within the Duwamish Valley,[2] which are exposed to higher levels of air pollution.[3] Residents of this area have significantly higher rates of childhood asthma hospitalizations and reduced life expectancy compared with wealthier North Seattle neighborhoods.[4] While the port has implemented some measures to reduce truck emissions, substantial pollution remains. Addressing drayage truck emissions is critical for reducing these environmental justice disparities while advancing regional air quality and climate goals.

Past research has shown that low-speed urban driving conditions can elevate real-world emissions on local roads,[5] and drayage truck idling is a known contributor to air pollution in the Duwamish Valley,[6] yet comprehensive spatial analysis quantifying these impacts at the neighborhood level has been lacking.

This report addresses these gaps through spatial analysis of drayage truck emissions and their impacts on overburdened communities near the Port of Seattle. Drawing on The Real-World Urban Emissions (TRUE) U.S. database—which compiles remote sensing emissions data from heavy-duty vehicles (HDVs) nationwide—as well as real-world driving and idling activity from drayage trucks, we model drayage truck NO_X and $PM_{2.5}$ emissions at a high spatial resolution.[7] We analyze this inventory alongside demographic data and health indicators from the Washington Tracking Network to assess where high levels of drayage emissions align with worse health outcomes. Based on these results, we identify key strategies to accelerate emission reductions and address disparities.

BACKGROUND

The Port of Seattle transports over 3 million standard 20-foot equivalent shipping containers each year[8] and operates approximately 4,000 drayage trucks,[9] which transport containers between marine terminals and regional warehouses, distribution centers, and rail yards. These heavy-duty diesel-powered trucks make frequent trips between the port and inland destinations.

The majority of the port's cargo operations are concentrated at terminals in the Duwamish Valley. This geographic distribution means that drayage truck traffic—and the associated air pollution—is not evenly spread across the Seattle region but instead concentrated in specific communities like the Georgetown and South Park neighborhoods, which are home to predominantly lower-income residents and residents of color. Residents here have significantly higher rates of childhood asthma hospitalizations and reduced life expectancy, with lifespans up to 13 years shorter compared with wealthier North Seattle neighborhoods as of 2013.[10] These health outcomes reflect long-term exposure to elevated levels of air pollution from multiple sources, including diesel emissions from drayage trucks.

1 "Health Effects from Diesel Pollution," Washington State Department of Ecology, accessed August 6, 2025, https://ecology.wa.gov/air-climate/air-quality/vehicle-emissions/diesel-emissions/health-impacts.

2 "Duwamish Valley," University of Washington Interdisciplinary Center for Exposures, Diseases, Genomics and Environment, accessed September 8, 2025, https://edge.deohs.washington.edu/duwamish-valley.

3 Puget Sound Clean Air Agency, *2023 Air Quality Data Summary*, 2024, https://pscleanair.gov/DocumentCenter/View/5649/Air-Quality-Data-Summary-2023?bidId=; "Community Based Action on Heavy Duty Trucks in the Duwamish Valley," Duwamish River Community Coalition, accessed August 13, 2025, https://www.drcc.org/action-on-trucks.

4 Linn Gould and BJ Cumming, *Duwamish Valley Cumulative Health Impacts Analysis: Seattle, Washington* (Just Health Action and Duwamish River Cleanup Coalition/Technical Advisory Group, 2013), https://static1.squarespace.com/static/5d744c68218c867c14aa5531/t/5e0edc05d2e16f330fa0071d/1578032180988/CHIA_low_res+report.pdf.

5 Francisco Posada et al., *In-Use NOx Emissions and Compliance Evaluation for Modern Heavy-Duty Vehicles in Europe and the United States* (International Council on Clean Transportation, 2020), https://theicct.org/publication/in-use-nox-emissions-and-compliance-evaluation-for-modern-heavy-duty-vehicles-in-europe-and-the-united-states/.

6 Tushar Khurana, "A Duwamish Valley Truck Electrification Program Looks to Reduce Air Pollution," *South Seattle Emerald*, February 21, 2022, https://southseattleemerald.org/feature/2022/02/22/a-duwamish-valley-truck-electrification-program-looks-to-reduce-air-pollution.

7 Yoann Bernard et al., *Development and Application of a United States Real-World Vehicle Emissions Database* (TRUE Initiative, 2020), https://trueinitiative.org/research/development-and-application-of-a-us-real-world-vehicle-emissions-database/.

8 Port of Seattle, *2024 Annual Comprehensive Financial Report*, 2025, https://www.portseattle.org/sites/default/files/2025-07/Port%20of%20Seattle_2024%20Annual%20Financial%20Report.pdf.

9 Jamie Housen, "City of Seattle Announces New Pilot Program to Incentivize Heavy Duty Truck Electrification," Office of the Mayor, August 16, 2023, https://harrell.seattle.gov/2023/08/16/city-of-seattle-announces-new-pilot-program-to-incentivize-heavy-duty-truck-electrification/.

10 Gould and Cumming, *Duwamish Valley Cumulative Health*.

AIR POLLUTION AND HEALTH

Diesel truck emissions pose serious public health risks, particularly for children and other vulnerable populations living near freight operations. Despite modern emissions control technology, drayage operations create concentrated pollution hotspots in nearby residential areas due to low-speed driving and frequent idling—precisely the conditions that elevate real-world emissions.

Drayage truck tailpipe emissions include two main pollutants that pose a significant risk to public health: NO_X and $PM_{2.5}$.[11] As illustrated in Figure 1, NO_X contributes to the formation of ambient nitrogen dioxide (NO_2), ozone (O_3), and secondary $PM_{2.5}$ through atmospheric chemical reactions.[12] All three contribute to all-cause mortality and respiratory mortality from diseases like chronic obstructive pulmonary disease.[13] Additionally, NO_2 is associated with increased incidence of childhood asthma, and $PM_{2.5}$ is associated with increased rates of cardiovascular mortality and lung cancer.

While the effects of exposure to ambient O_3 and $PM_{2.5}$ are more widely understood and modeled, there is a growing body of evidence showing the adverse health impacts of NO_2 exposure, such as a link between NO_2 exposure and all-cause mortality, or premature death.[14] A study in 2023 estimated that 170,000 annual premature deaths are attributable to NO_2 exposure in the United States, exceeding estimates of premature deaths attributable to $PM_{2.5}$, highlighting the importance of studying NO_X emissions and pollution.[15]

Substantial health impacts have been found to be associated with exposure to NO_2 at levels well below current federal standards.[16] In 2021, the World Health Organization set a recommended air quality guideline level of 10 μg/m^3 of NO_2 as an annual average.[17] In contrast, the National Ambient Air

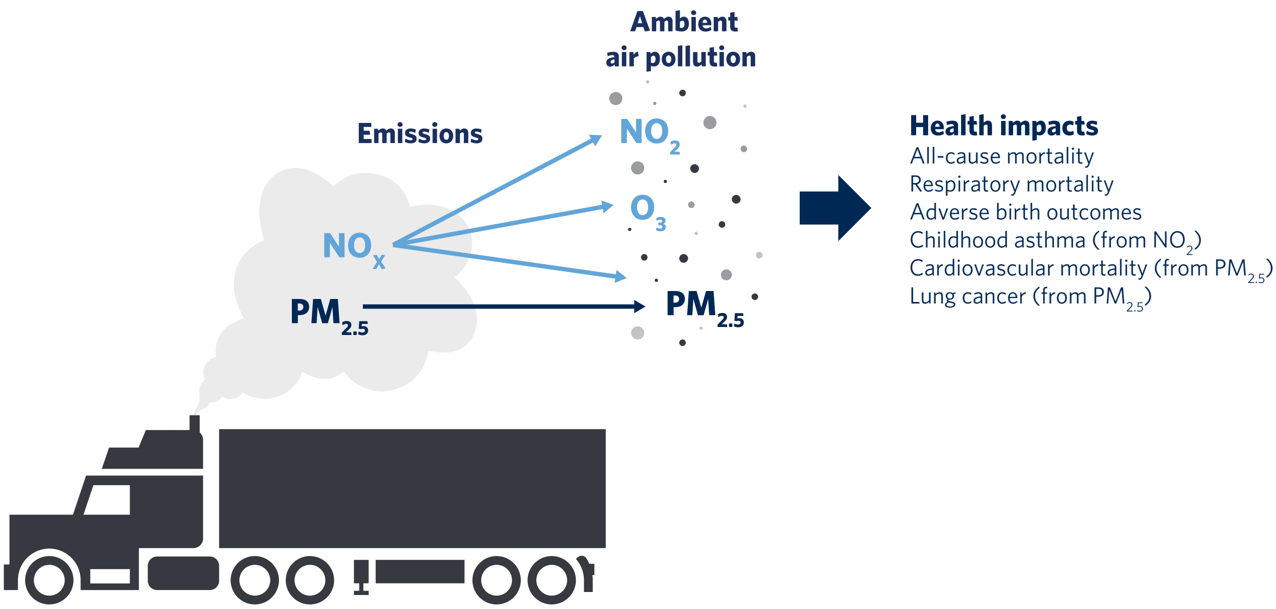


Figure 1. Air pollution and public health impact of drayage truck emissions

11 HEI Panel on the Health Effects of Long-Term Exposure to Traffic-Related Air Pollution, *Special Report 23: Systematic Review and Meta-Analysis of Selected Health Effects of Long-Term Exposure to Traffic-Related Air Pollution*, 2022, https://www.healtheffects.org/system/files/hei-special-report-23-executive-summary_1.pdf.

12 Diesel trucks also emit other pollutants, such as carbon monoxide, volatile organic carbons, and sulfur oxides. We focus on NO_X and $PM_{2.5}$ due to their substantial adverse health impacts.

13 World Health Organization, *WHO Global Air Quality Guidelines*, 2021, https://iris.who.int/bitstream/handle/10665/345329/9789240034228-eng.pdf.

14 HEI Panel on the Health Effects of Long-Term Exposure to Traffic-Related Air Pollution, *Special Report 23*.

15 Sara F Camilleri et al., "All-Cause NO_2-Attributable Mortality Burden and Associated Racial and Ethnic Disparities in the United States," *Environmental Science & Technology Letters* 10, no. 12 (2023): 1159–1164, https://doi.org/10.1021/acs.estlett.3c00500.

16 Camilleri et al., "All-Cause."

17 World Health Organization, *WHO Global Air Quality Guidelines*.

Quality Standards in the United States for annual average NO_2 concentration is set at approximately 100 μg/m^3, a threshold that no areas in the United States exceed.[18] As a result, the current national air quality regulations do not incentivize or require efforts to reduce NO_2 pollution.

Modern diesel trucks of model year (MY) 2007 and newer emit much lower quantities of $PM_{2.5}$ compared with older diesel trucks due to the near-universal use of diesel particulate filters (DPFs) to meet U.S. Environmental Protection Agency (EPA) emission standards. DPFs are highly effective, reducing tailpipe $PM_{2.5}$ by more than 95% compared with MY 2006 and older trucks not equipped with the filters.[19] Thus, for newer trucks, most of the associated health impacts are due to NO_X emissions. A TRUE study on diesel trucks in New York City found that for MY 2010 and newer trucks, 69%–87% of the health impacts from exposure to $PM_{2.5}$ ambient air pollution were due to NO_X tailpipe emissions.[20] Thus, while there has been progress in addressing the adverse effects of $PM_{2.5}$, NO_X emissions from diesel engines remain a more persistent challenge.

Reducing NO_2 pollution is also important from an environmental justice standpoint. Marginalized communities—particularly lower-income communities and communities of color—are exposed to disproportionate levels of harmful air pollutants due to legacies of discriminatory practices like redlining, which led industrial facilities and high-traffic roadways to be sited in or near these communities.[21] NO_2 air pollution is of particular concern because of its relatively short lifespan, meaning that ambient NO_2 is highly concentrated within 200–500 m of the emission site, often around high-traffic roadways or areas like ports.[22]

South Seattle, which includes the Duwamish Valley where the Port of Seattle's terminals are located, is an area with high population density as well as concentrated transportation and industrial activity. The region was identified by the State of Washington's Department of Ecology as an overburdened community highly impacted by air pollution.[23] A 2013 study found that levels of NO_X air pollution in Georgetown and South Park were 22%–104% higher than levels measured at comparison sites in neighborhoods of Queen Anne and Beacon Hill.[24]

Since 2013, there have been improvements in air quality in the Duwamish Valley, likely in part due to the transition to newer, cleaner diesel trucks. One indicator of this improvement is the decline in black carbon (BC) pollution, a component of $PM_{2.5}$ that is primarily from diesel engines.[25] Ambient air quality measurements in the Duwamish Valley show that BC levels declined by approximately 50% from 2010 to 2023.[26] There have been more modest declines in other pollutants, including NO_2, in various measurement locations across Seattle. Although substantial progress has been made in improving air quality, diesel drayage trucks remain a contributor to air pollution and adverse health impacts.

POLICY BACKGROUND

In response to the environmental and health concerns outlined above, policymakers have made efforts to reduce air pollution in Seattle, particularly around the port area. These efforts have been driven by a combination of local, state, and federal regulations aimed at cutting emissions from HDVs. This includes port drayage trucks, which are considered particularly well-suited for electrification among HDV segments due to their comparatively shorter travel

18 The conversion is based on an ambient temperature of 25 °C and ambient pressure of 1 atm. See US Environmental Protection Agency, "Review of the Primary National Ambient Air Quality Standards for Oxides of Nitrogen," *Federal Register* 83, no. 75 (April 18, 2018): 17145–17150, https://www.federalregister.gov/documents/2018/04/18/2018-07741/review-of-the-primary-national-ambient-air-quality-standards-for-oxides-of-nitrogen.

19 Jorn Dinh Herner et al., "Effect of Advanced Aftertreatment for PM and NO_X Control on Heavy-Duty Diesel Truck Emissions," *Environmental Science & Technology* 43, no. 15 (2009): 5928–5933, https://doi.org/10.1021/es9008294.

20 Michelle Meyer and Tim Dallmann, *Air Quality and Health Impacts of Diesel Truck Emissions in New York City and Policy Implications* (TRUE Initiative, 2022), https://www.trueinitiative.org/publications/reports/air-quality-and-health-impacts-of-diesel-truck-emissions-in-new-york-city-and-policy-implications.

21 Kaya Bramble et al., "Exposure Disparities by Income, Race and Ethnicity, and Historic Redlining Grade in the Greater Seattle Area for Ultrafine Particles and Other Air Pollutants," *Environmental Health Perspectives* 131, no. 7 (2023): 077004, https://pubmed.ncbi.nlm.nih.gov/37404015/; PolicyLink, *Advancing Racial Equity as Part of the 2024 Update to the Seattle 2035 Comprehensive Plan and Urban Village Strategy*, 2021, https://www.seattle.gov/a/127266.

22 Ying Zhou and Jonathan I. Levy, "Factors Influencing the Spatial Extent of Mobile Source Air Pollution Impacts: A Meta-Analysis," *BMC Public Health* 7, no. 1 (2007): 89, https://doi.org/10.1186/1471-2458-7-89.

23 "Overburdened Communities Highly Impacted by Air Pollution," Department of Ecology Air Quality Program, March 1, 2023, https://gis.ecology.wa.gov/portal/apps/storymaps/stories/c10bdbfc69984a9d85346be1a23f6338.

24 Jill K Schulte et al., *Diesel Exhaust Exposure in the Duwamish Study* (University of Washington School of Public Health, Department of Environmental Health Sciences, September 1, 2013), http://dl.pscleanair.org/DEEDS/DEEDS_Tech_Report.pdf.

25 "Black Carbon," Climate & Clean Air Coalition, accessed July 22, 2025, https://www.ccacoalition.org/short-lived-climate-pollutants/black-carbon.

26 Puget Sound Clean Air Agency, *2023 Air Quality Data Summary*.

distances (typically under 300 km per day), predictable routes, and return-to-depot operations that facilitate overnight charging.[27]

LOCAL POLICIES

Local policymakers have developed plans to reduce freight emissions and invest funding in zero-emission trucks. The City of Seattle has set a target that, by 2030, 30% of goods deliveries will be carried out by zero-emission vehicles.[28] Additionally, the city recently announced $1.5 million in purchase incentives that will fund 12 electric drayage trucks.[29]

The Northwest Seaport Alliance (NWSA), an operating partnership of the Ports of Seattle and Tacoma that oversees cargo operations including drayage trucking, has prioritized drayage truck emission reductions through both near-term engine standards and long-term zero-emission transition goals.[30] The NWSA has also partnered with Zeem Solutions through a $6.2 million program to fund 19 electric drayage trucks and charging infrastructure deployment.[31] Together with the Port of Seattle, the NWSA committed to the Northwest Ports Clean Air Strategy, which aims to phase out emissions from port-related activity by 2050.[32] The NWSA's Clean Air Implementation Plan includes shorter-term strategies to reduce drayage truck emissions, such as requiring newer, cleaner diesel trucks, as well as long-term plans for transitioning to zero-emission vehicles. As part of this plan, the NWSA established a requirement in 2019 that all trucks serving their international container terminals have engines of MY 2007 or later, or equivalent emission control systems.[33] This requirement, supported by a rebate program that facilitated replacing over 300 older diesel trucks, has helped to reduce diesel PM emissions by 89% compared with 2005 levels.[34]

The NWSA also established the Puget Sound Zero-Emission Truck Collaborative, a multi-stakeholder group involving government agencies, local community organizations, truck drivers, and other industry representatives to develop a roadmap for transitioning to zero-emissions drayage services no later than 2050.[35] Additionally, the Clean Air Program—a multi-stakeholder group led by the Duwamish River Community Coalition—gathers many of the same organizations and agencies to focus on the environmental justice aspects of air pollution in the Duwamish Valley.[36] One key strategy of the program is to reduce vehicle emissions in the area, of which drayage trucks are a major contributor.

In addition, the Port of Seattle, NWSA, and Seattle City Light (SCL), the city's electric utility, have developed the Seattle Waterfront Clean Energy Strategy, which aims to proactively plan and implement infrastructure to support growing electrical demand at the port.[37] Together, these agencies play an important role in upgrading grid capacity and deploying the charging infrastructure required for drayage truck electrification.[38]

27 "An Overview and Assessment of Drayage Charging Site Models," Electrification Coalition, May 13, 2025, https://electrificationcoalition.org/resource/an-overview-and-assessment-of-drayage-charging-site-models/.

28 City of Seattle, *Seattle's Clean Transportation Electrification Blueprint*, March 2021, https://www.seattle.gov/environment/climate-change/transportation-emissions/transportation-electrification-blueprint.

29 David Benedict, *City of Seattle Announces $1.5 Million in Funding to Help Bring New Electric Drayage Trucks to Seattle*, press release, October 16, 2025, https://greenspace.seattle.gov/2025/10/city-of-seattle-announces-1-5-million-in-funding-to-help-bring-new-electric-drayage-trucks-to-seattle/.

30 Northwest Seaport Alliance, Northwest Seaport Alliance, *Northwest Ports Clean Air Strategy 2021–2025 Implementation Plan*, November 2021, https://s3.us-west-2.amazonaws.com/nwseaportalliance.com.if-us-west-2-or/2021-12/2021_12_NWSA_NWPCAS_Implementation_Plan_Stylized-LT-91CL273.pdf.

31 Northwest Seaport Alliance, *The Northwest Seaport Alliance Announces Inaugural Incentive Program for Zero Emission Drayage*, July 9, 2025, https://www.nwseaportalliance.com/newsroom/northwest-seaport-alliance-announces-inaugural-incentive-program-zero-emission-drayage-0.

32 Northwest Seaport Alliance, *Northwest Ports Clean Air Strategy*.

33 "Clean Truck Program," Northwest Seaport Alliance, accessed July 22, 2025, https://www.nwseaportalliance.com/environment/clean-air/clean-truck-program.

34 Jason Jordan and Janice Gedlund, "Interlocal Agreement with Puget Sound Clean Air Agency to supply $275,000 matching funds for USEPA DERA grate for Drayage Truck Replacement," memorandum to Northwest Seaport Alliance, November 23, 2016, https://meetings.portseattle.org/portmeetings/attachments/2016/5J%20Memo.pdf; "Clean Truck Program," Northwest Seaport Alliance.

35 Puget Sound Zero-Emission Truck Collaborative, *Decarbonizing Drayage Roadmap: Executive Summary*, April 2025, https://www.rossstrategic.net/Zero-Emission-Truck-Collaborative/docs/Puget%20Sound%20ZE%20Truck%20Collaborative%20Roadmap_Executive%20Summary.pdf.

36 "The Duwamish Valley Clean Air Program," Duwamish River Community Coalition, accessed August 13, 2025, https://www.drcc.org/clean-air-program.

37 Port of Seattle, The Northwest Seaport Alliance, and Seattle City Light, *Seattle Waterfront Clean Energy Strategy*, 2025, https://www.portseattle.org/sites/default/files/2025-04/Seattle%20Waterfront%20Clean%20Energy%20Strategy%20-%20FINAL.pdf.

38 Jenn Strang, "City Light Commissions Study to Explore Impacts of Medium- and Heavy-Duty Electrification," *Seattle City Light Powerlines*, May 23, 2024, https://powerlines.seattle.gov/2024/05/23/city-light-commissions-study-to-explore-impacts-of-medium-and-heavy-duty-electrification/; Hamilton Steimer et al., *Powering Seattle Fleets: A Charging Infrastructure Strategy for Battery Electric Medium- and Heavy-Duty Vehicles* (International Council on Clean Transportation, 2024), https://theicct.org/publication/powering-seattle-fleets-charging-infrastructure-strategy-for-battery-electric-medium-and-heavy-duty-vehicles-may24/.

STATE POLICIES

At the state level, Washington has several policies and plans aiming to accelerate the production and adoption of zero-emission trucks. Washington adopted California's Advanced Clean Trucks (ACT) rule, which requires an increasing share of zero-emission HDV sales over time to accelerate the production of battery electric vehicles (BEVs).[39] However, in May 2025, the federal government revoked California's ability to implement the ACT rule, subsequently blocking Washington and nine other states from implementing it.[40] Although Washington joined California and the remaining nine states in bringing legal action against the federal government, the future of the rule remains uncertain.

Despite regulatory uncertainty, Washington State has committed substantial funding to supporting the transition to zero-emission medium- and heavy-duty vehicles, with explicit focus on reducing pollution in overburdened communities, including the Duwamish Valley. Washington's Climate Commitment Act (CCA), a cap-and-invest program that has raised several billion dollars in revenue so far, allocates funding to projects such as drayage truck electrification and building charging infrastructure.[41] Accordingly, $126 million of this funding will support the Washington State Zero-Emission Incentive Program through 2027, providing point-of-sale discounts on zero-emission medium- and heavy-duty vehicles.[42] The CCA specifically aims to reduce air pollution in 16 identified overburdened communities, including South King County (Duwamish Valley Area) where the Port of Seattle is located.[43]

FEDERAL POLICIES

At the federal level, the most recent EPA pollutant standards for HDVs, which apply starting in 2027, require 80% lower NO_X levels than the current standards.[44] However, the pace of emission reductions depends on how quickly newer, cleaner trucks replace older vehicles. This means that while federal standards establish an important regulatory floor for future emissions, they do not address the current fleet composition or provide mechanisms for accelerating retirement of older, higher-emitting trucks.

DATA OVERVIEW AND STUDY METHODOLOGY

For this report, we modeled NO_X and $PM_{2.5}$ tailpipe emissions from diesel-powered drayage trucks serving port terminals in Seattle and assessed associated health impacts. The study had two main objectives: (1) establishing a baseline spatial emissions inventory of drayage truck emissions, and (2) analyzing results alongside demographic information and health outcomes to assess environmental justice implications. Figure 2 summarizes the datasets used and the analysis steps.

39 Steimer et al., *Powering Seattle Fleets*.

40 "California Sues Trump for Blocking Clean-Air Rules for Cars, Trucks—and Vows to Set New Mandates," *CalMatters*, June 12, 2025, https://calmatters.org/environment/2025/06/california-sues-trump-blocking-clean-air-rules-cars/.

41 Washington State Department of Ecology, *Distribution of Funds from CCA Accounts Fiscal Year 2024*, November 2024, https://apps.ecology.wa.gov/publications/documents/2414076.pdf.

42 Washington State Department of Ecology, "Ecology Proposes New Updates to Help Industry Transition to Clean Semi-Trucks," press release, May 15, 2025, https://ecology.wa.gov/about-us/who-we-are/news/2025/ecology-proposes-new-updates-to-help-industry-transition-to-clean-semi-trucks; "The Washington Zero-Emission Incentive Program," CALSTART, accessed August 13, 2025, https://calstart.org/wazip/.

43 "Improving Air Quality in Overburdened Communities," Washington State Department of Ecology, accessed August 13, 2025, https://ecology.wa.gov/air-climate/climate-commitment-act/overburdened-communities.

44 U.S. Environmental Protection Agency, "Final EPA Standards for Heavy-Duty Vehicles to Slash Dangerous Pollution and Take Key Step toward Accelerating Zero-Emissions Future," press release, December 20, 2022, https://www.epa.gov/newsreleases/final-epa-standards-heavy-duty-vehicles-slash-dangerous-pollution-and-take-key-step.

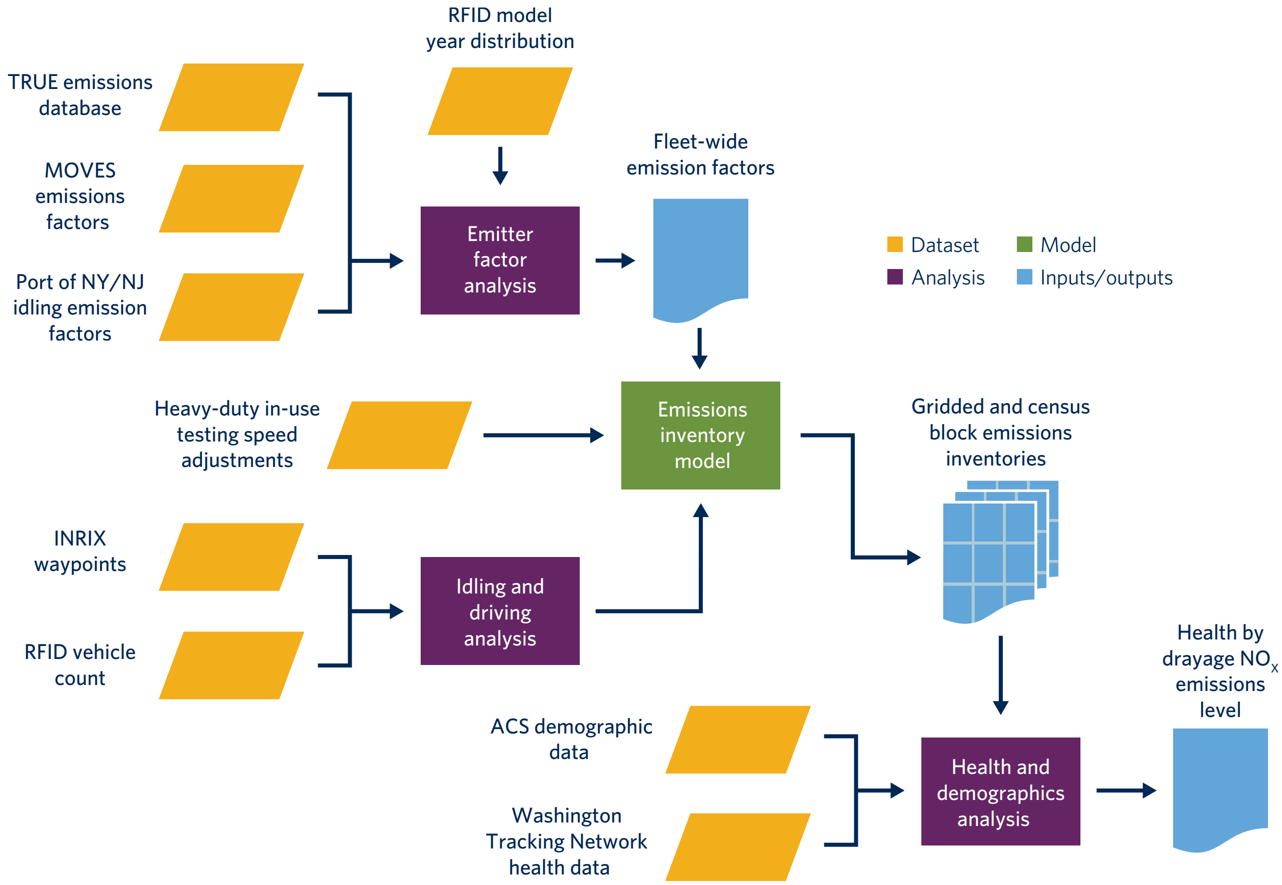


Figure 2. Overview of modeling steps and data sources

Our methodology combines real-world emissions data with traffic patterns to create a high-resolution spatial inventory. First, we calculated driving and idling NO_X and $PM_{2.5}$ emission factors for the fleet of drayage trucks. NO_X driving emission factors were primarily derived from the TRUE U.S. database, which contains 20,167 HDV Class 8 observations collected between 2015 and 2023 via the Colorado Department of Public Health & Environment's remote sensing program.[45] Driving emission factors for $PM_{2.5}$ were taken from EPA's motor vehicle emission simulator, MOVES4.[46] Short-term idling emissions were derived from a 2022 Port Authority of New York and New Jersey emissions inventory report and were adjusted to reflect the model year distribution of the Seattle truck fleet. Additional details on the emission factors are available in Appendix A.

To calculate fleet-wide emission factors, we combined emission factors with the model year distribution. The model year distribution was calculated from the Radio Frequency Identification (RFID) data from all drayage truck entries into Seattle's international container terminals between 2021 and 2022, shared by the Northwest Seaport Alliance. Based on the RFID data, we focused on EPA Class 8 HDVs, which account for 99.7% of the port's truck trips.

We then mapped emissions across Seattle by combining emission factors and speed adjustments with real-world vehicle activity data to develop a spatial emissions inventory. Vehicle activity data from INRIX were sourced from connected vehicles in the form of waypoints, or coordinates with timestamps.[47] We included trips that involved any waypoints within the international container terminals as

45 Yoann Bernard et al., *Development and Application*.

46 "MOVES Versions in Limited Current Use," U.S. Environmental Protection Agency, accessed August 13, 2025, https://www.epa.gov/moves/moves-versions-limited-current-use.

47 Mark Braibanti, "Providing Transportation Intelligence While Respecting Data Privacy," *INRIX*, April 9, 2025, https://inrix.com/blog/inrixs-approach-to-data-privacy/.

well as activity in the domestic container terminal (Figure 3).[48] We added supplemental idling data from the Duwamish Valley to reflect stationary idling from drayage trucks outside of the port terminals, as outlined in Appendix A. Distance traveled was calculated by taking the distance between consecutive waypoints. Idling time was calculated by adding up the duration of any waypoints that moved less than 200 m over the span of at least 3 minutes.[49]

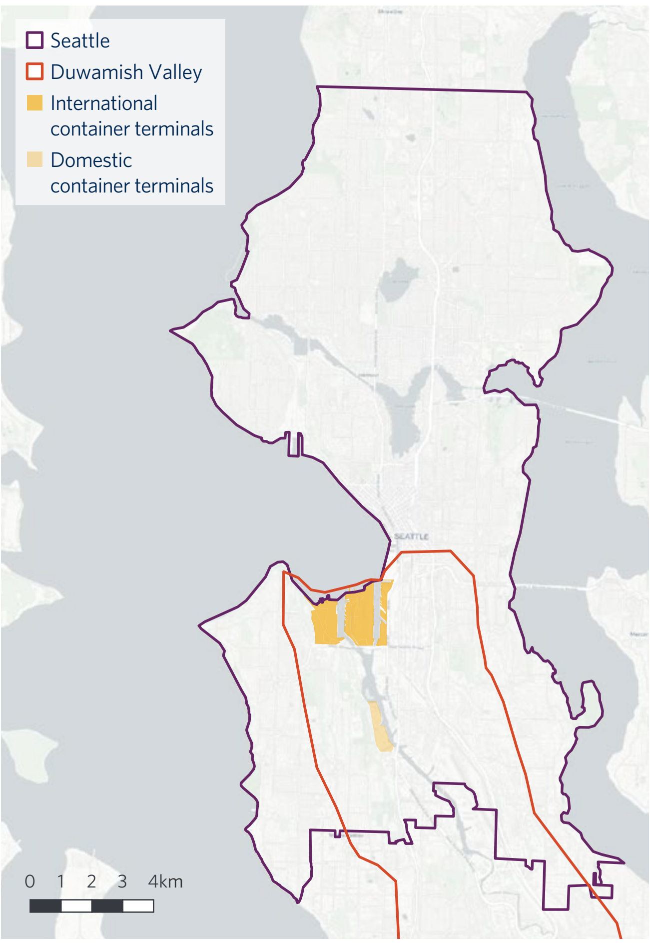


Figure 3. Map of Seattle and port terminals

Finally, we created spatial emissions inventories of NO_x and $PM_{2.5}$ emissions after scaling the activity data to represent total annual drayage truck activity within Seattle. To calculate driving emissions, we multiplied the distance traveled by the emission factor for the applicable speed bin. Idling emissions were calculated by multiplying the idling time by the idling emission factor. We then analyzed the spatial inventories of drayage truck emissions against various demographic and health data.

RESULTS

Our spatial analysis reveals how drayage truck emissions are distributed across Seattle and which communities experience disproportionate levels of harmful pollutants. Key findings include:

1. MY 2007+ requirements were effective for $PM_{2.5}$ control but NO_x emissions remain substantial
2. Trucks of MY 2010 and older (22% of the fleet) produced 48% of NO_x emissions
3. Emissions were concentrated in the Duwamish Valley; idling accounted for 45%–55% of NO_x emissions in Georgetown and South Park
4. Based on an analysis at the census block level, people of color experienced 33% higher levels of NO_x emissions from idling than non-Latino White residents
5. Areas with the highest idling emissions showed 50% higher overall premature mortality rates than areas with no idling emissions

REAL-WORLD EMISSIONS ANALYSIS

Our analysis of the truck fleet found that relatively newer model trucks typically operated out of the international port terminals, demonstrating the effectiveness of the NWSA's Clean Truck Program, which requires that all drayage trucks entering international terminals have MY 2007 engines or equivalent emissions controls. Only 3.5% of trips in our dataset involved pre-2007 trucks, and these trucks may have been retrofitted to meet the emission control requirements (Figure 4).

48 The Northwest Seaport Alliance, *Facilities Guide: Seattle & Tacoma Harbors, USA*, August 13, 2025, https://s3.us-west-2.amazonaws.com/nwseaportalliance.com.if-us-west-2-or/2024-09/Facilities%20Guide%2020240923.pdf.

49 These criteria were selected to account for GPS drift, the effect of fluctuating GPS location while stationary due to measurement issues.

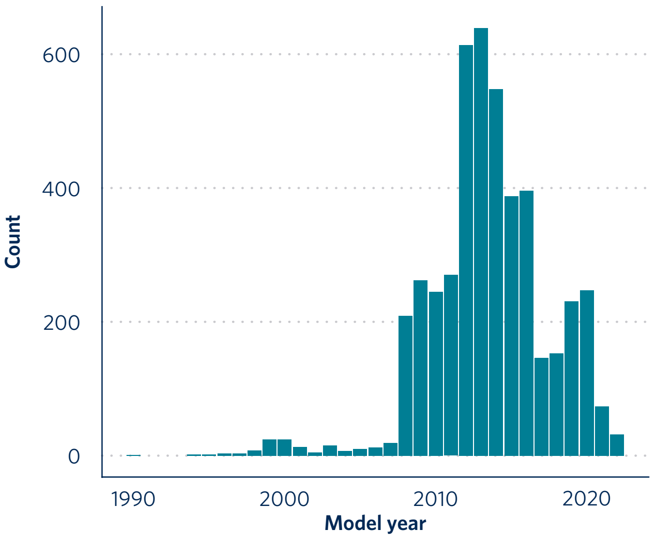


Figure 4. Model year distribution of trucks operating in the Port of Seattle

This policy's effectiveness was evident in the low estimated $PM_{2.5}$ emissions from the fleet, which amounted to 0.048 metric tons in 2022 (Table 1). This represents just a small fraction of total $PM_{2.5}$ emissions associated with port activity. By comparison, a 2023 International Council on Clean Transportation (ICCT) study estimated that ocean-going vessels at berth at the Port of Seattle produced 8 tons of $PM_{2.5}$ emissions in 2019.[50]

Table 1. Modeled NO_x and $PM_{2.5}$ emissions from drayage trucks in Seattle in 2022

Operation	NO_x emissions (t/year)	$PM_{2.5}$ emissions (t/year)
Driving	21	0.039
Idling	9.9	0.009
Total (driving + idling)	**31**	**0.048**

These $PM_{2.5}$ emission estimates may, however, be conservative due to data limitations and methodological constraints. The RFID data only cover international terminals, where retrofits are required; older, higher-emitting vehicles may be operating in other areas of the port. Additionally, this modeling used MOVES emission factors for $PM_{2.5}$, which may underestimate real-world emissions. A 2018 study focused on the Port of Oakland, which also requires DPFs on trucks operating in the port, found a substantial increase in BC—a component of $PM_{2.5}$ emissions—as vehicles aged; according to the study, high-emitting MY 2007–2009 trucks comprised 7% of the fleet but emitted 65% of total BC emissions.[51] Thus, there are likely additional BC and $PM_{2.5}$ emission reductions to be achieved through targeted replacement of the remaining older vehicles.

In contrast to $PM_{2.5}$, we found substantial NO_X emissions from drayage trucks: 31 tons per year (see Table 1). While ocean-going vessels at berth emit far more NO_X—384 tons according to the 2023 ICCT study—drayage trucks operate through residential neighborhoods, which amplifies the associated health impact.[52]

Older trucks were found to contribute a disproportionate share of total emissions, despite fleet modernization efforts. Although MY 2010 and older vehicles comprised just 22% of the fleet, they contributed nearly half of total NO_X emissions (Figure 5). These results demonstrate the potential policy benefit of continuing to strengthen the model year requirement to reduce real-world NO_X emissions.

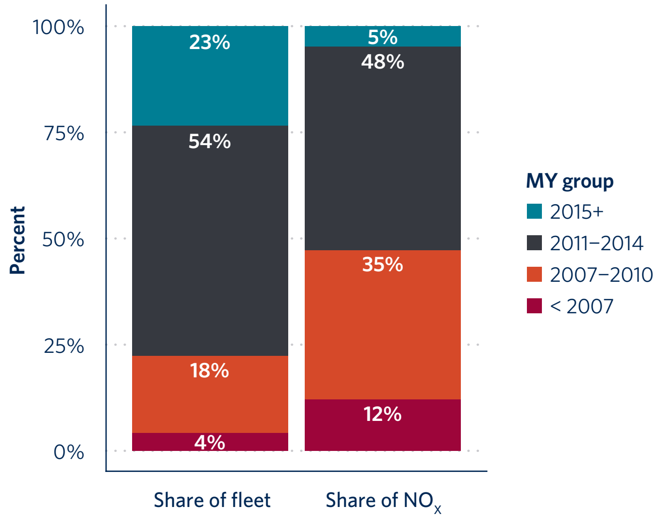


Figure 5. Drayage truck fleet by model year and NO_X emissions shares

Our analysis found that NO_X emissions were heavily concentrated within the Duwamish Valley, with the highest

50 Zhihang Meng and Bryan Comer, *Electrifying Ports to Reduce Diesel Pollution from Ships and Trucks and Benefit Public Health: Case Studies of the Port of Seattle and the Port of New York and New Jersey* (International Council on Clean Transportation, 2023), https://theicct.org/publication/marine-ports-electrification-feb23/.

51 Chelsea Preble et al., "In-Use Performance and Durability of Particle Filters on Heavy-Duty Diesel Trucks," *Environmental Science & Technology* 52, no. 20 (2018): 11913–11921, https://doi.org/10.1021/acs.est.8b02977.

52 Meng and Comer, *Electrifying Ports.*

levels at port terminals and along several major truck routes. Figure 6 shows the spatial NO_x emissions inventory of the diesel drayage trucks at a 200 m x 200 m resolution, with the left panel showing total emissions and the right panel showing idling emissions only. We focus here on NO_x emissions due to the finding that drayage trucks contributed a much larger share of total port-related NO_x emissions compared with $PM_{2.5}$.

Idling accounted for an exceptionally high share of drayage truck emissions in Georgetown and South Park—the two neighborhoods previously identified as hotspots for drayage truck idling.[53] In South Park, 55% of total modeled drayage truck NO_x emissions came from idling activity; in Georgetown, idling accounted for 45% of NO_x emissions (see Figure 7). These shares are well above the city-average share of 32%, indicating that idling is a major source of drayage truck emissions in these neighborhoods.

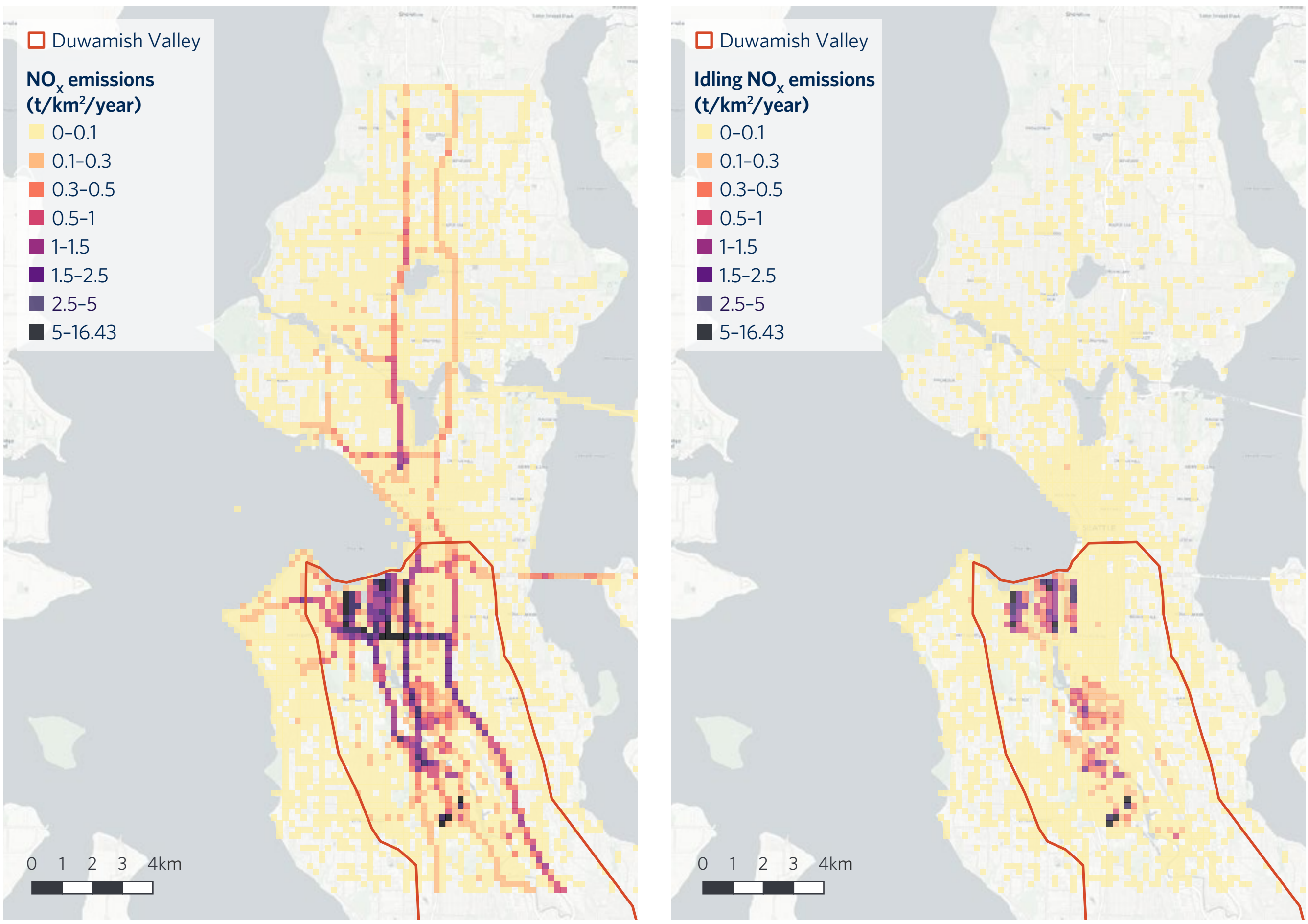


Figure 6. Spatial NO_x emissions inventory from diesel trucks attributable to driving and idling operation (left) and idling operation only (right)

53 Duwamish River Community Coalition, "Community Based Action."

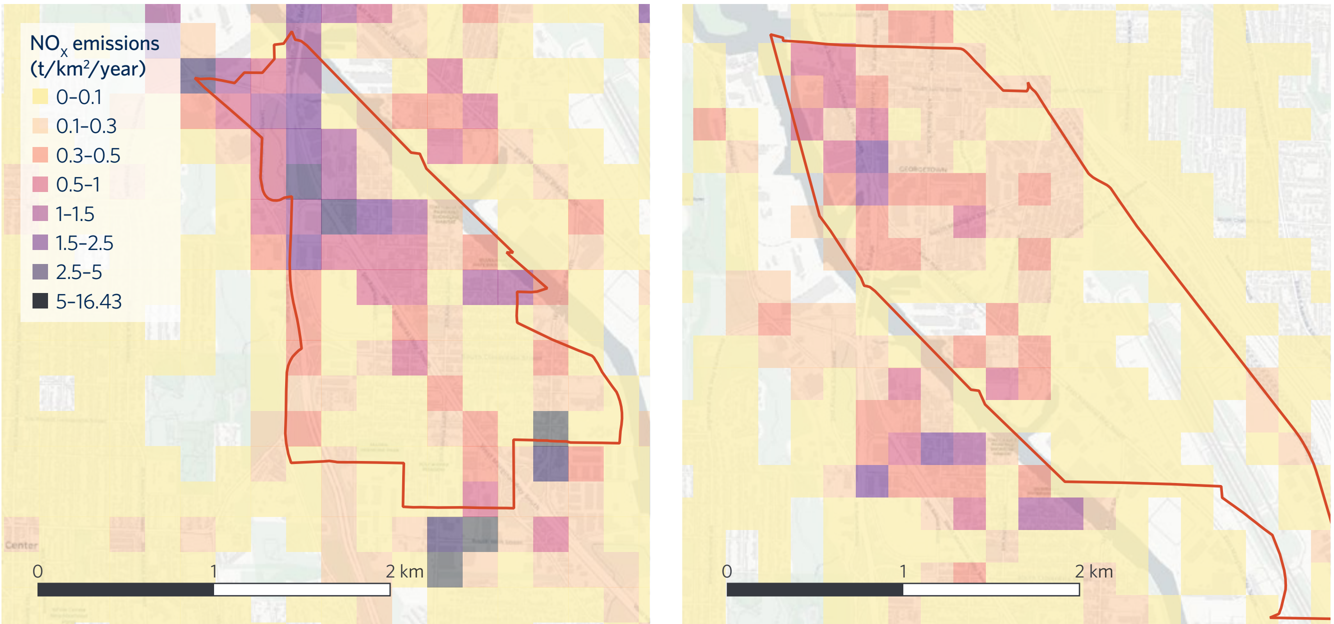


Figure 7. Idling NO_x emissions inventory in South Park (left) and Georgetown (right)

ENVIRONMENTAL JUSTICE ANALYSIS

Using the spatial emissions inventory, we analyzed the connection between drayage truck emission levels and various demographic and health indicators. This analysis did not model ambient concentrations of air pollution or the associated health effects. However, given that NO_2 air pollution tends to be highly concentrated around the NO_x emissions source, we used the total NO_x emissions by census block as a proxy for NO_2 exposure.[54] We then analyzed this metric by racial/ethnic demographics, socioeconomic indicators, and health indicators from census data and the Washington Tracking Network to evaluate equity and environmental justice impacts.[55] The health indicators selected are those linked to NO_2 exposure: premature death, cardiovascular disease-related premature mortality, life expectancy, rates of disability, and asthma-related emergency room visits.

In line with other environmental justice assessment tools, we categorized each census block by NO_x emissions levels (none, low, medium, high) based on the density of emissions per census block.[56] These cutoffs were set based on percentiles to analyze relative exposure patterns. Figure 8 shows the NO_x emissions level by census block for total NO_x emissions and idling NO_x emissions only. The areas with the highest NO_x emissions levels are generally in the Duwamish Valley. Additional detail on the cutoffs for each NO_x emissions level is available in Appendix B.

54 Census blocks are the smallest geographic area for which demographics are reported, typically one block in urban areas. There are 11,512 census blocks in Seattle. City of Seattle, *Geographic Files and Maps,* accessed January 5, 2026, https://www.seattle.gov/opcd/population-and-demographics/geographic-files-and-maps.

55 See Appendix A for full list of sources. Washington State Department of Health, *Washington Tracking Network (WTN) Database*, accessed February 19, 2025, https://fortress.wa.gov/doh/wtn/WTNPortal/.

56 EPA, EJScreen Technical Documentation for Version 2.3, 2024, https://www.epa.gov/system/files/documents/2024-07/ejscreen-tech-doc-version-2-3.pdf. Washington State Department of Health, "Washington Environmental Health Disparities Map," accessed August 13, 2025, https://fortress.wa.gov/doh/wtnibl/WTNIBL/.

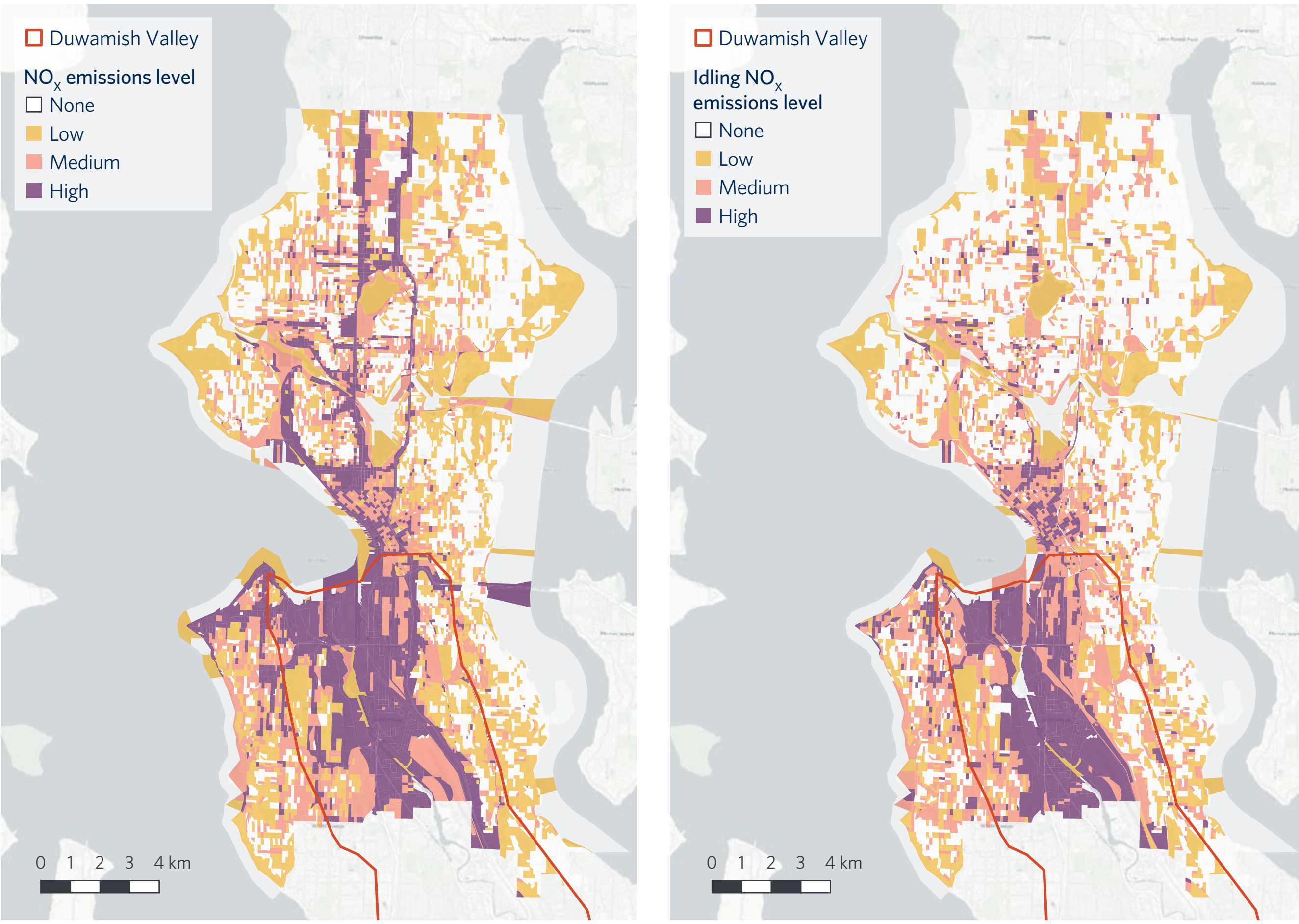


Figure 8. Total NO_x emissions level (left) and idling NO_x emissions level (right) at the census block level

We quantified drayage truck NO_x emissions by summing the total emissions in each census block and dividing by area. Then, we calculated population-weighted average values for various racial/ethnic groups across all census blocks. While this average value for idling NO_x emissions was 33% higher for people of color compared to non-Latino White residents,[57] the disparity for total NO_x emissions (including driving and idling) was 20% (Figure 9). This difference suggests that idling emissions are a key contributor to inequities associated with drayage truck pollution.

57 In this analysis, the term "people of color" refers to Latino people of any race and non-Latino, non-White people.

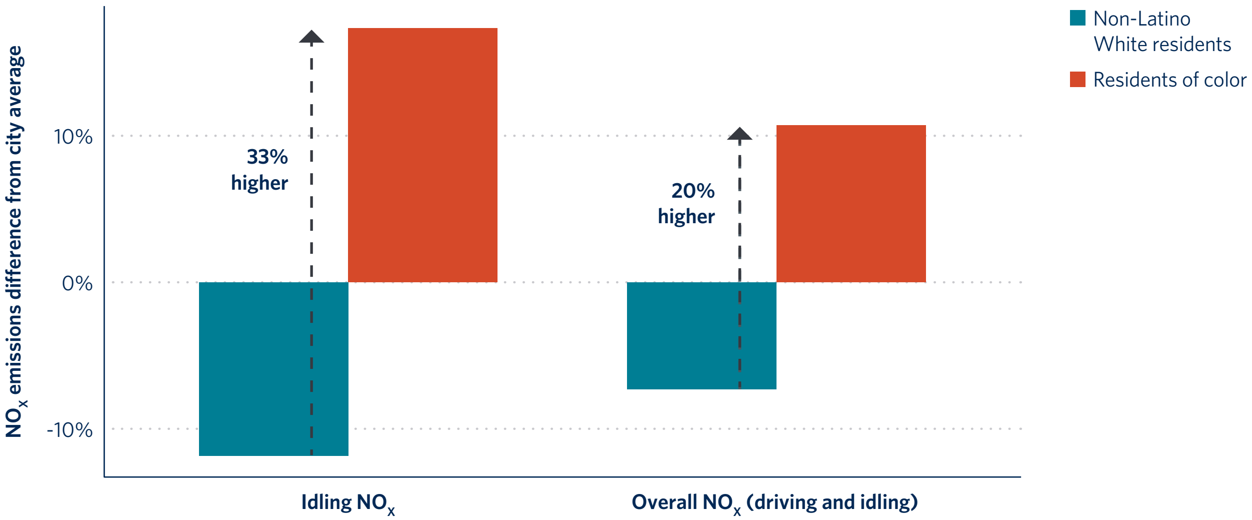


Figure 9. NO_x emissions disparities between non-Latino White residents and residents of color

There were substantial demographic disparities between the communities with the highest and lowest drayage NO_x emissions. In census blocks where drayage NO_x emission levels are highest, Native American residents represented a disproportionately high share of the population, approximately 34% higher than the city average. Latino and Asian residents were also overrepresented—by nearly 20%—in census blocks with high levels of drayage NO_x emissions. Meanwhile, in census blocks with no drayage NO_x emissions, non-Latino White residents made up a disproportionately high share of the population (see Figure 10). These results corroborate the findings of other studies indicating racial/ethnic disparities in exposure to truck pollution.[58]

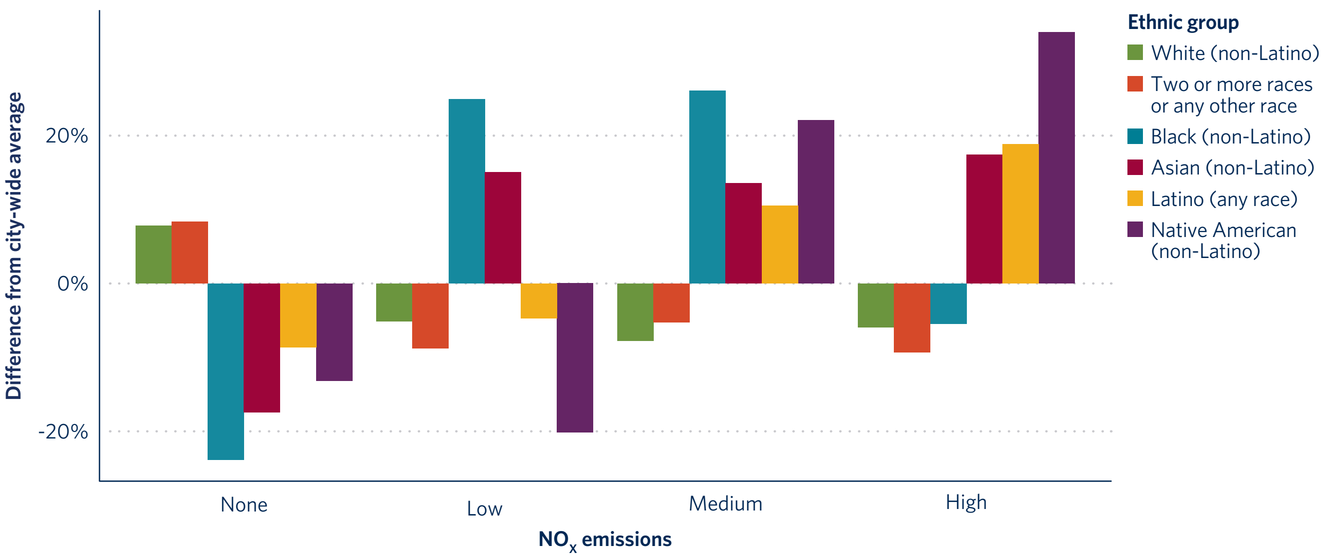
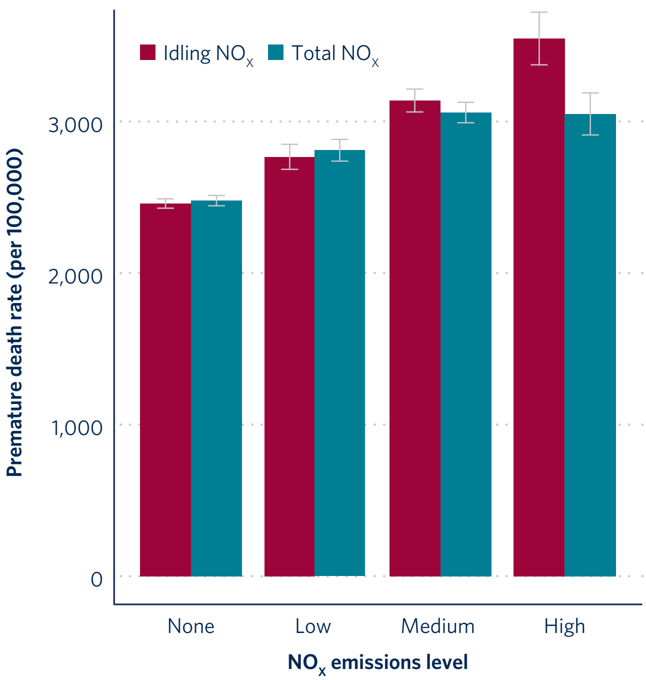


Figure 10. Demographic disparities in NO_x emission level compared with city average

58 Camilleri et al., "All-Cause."

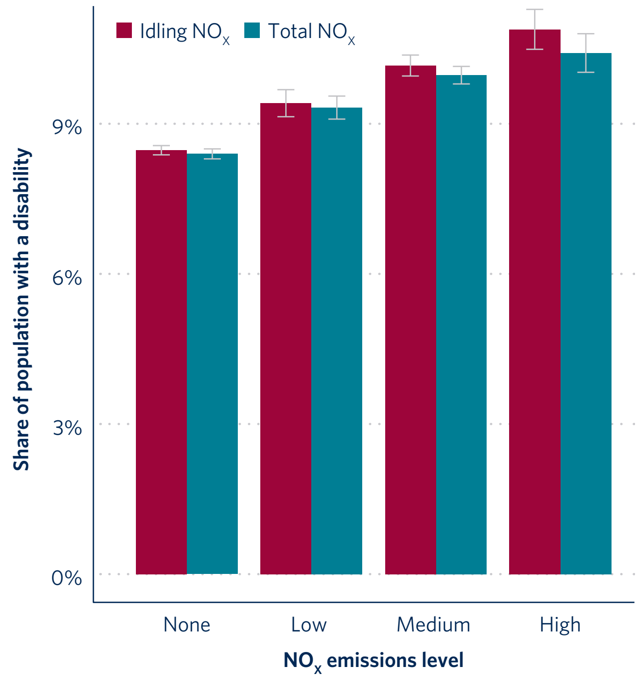
Although we cannot infer direct causation from these results, areas with high drayage truck emissions experience significantly worse health outcomes. Due to limitations in modeling capabilities, we cannot effectively quantify the health impact of these emissions. Instead, we show the correlation between the level of drayage truck emissions and various health and social indicators. This analysis aims to provide evidence to support an equity-centered approach to addressing health disparities.

Our analysis shows that areas with high idling NO_x levels have rates of premature death that are over 50% higher than areas with no idling emissions (see Figure 11). The disparity is smaller but still substantial for total NO_x emissions: the premature death rate is 23% higher for areas with high total NO_x levels compared with areas with no NO_x emissions. Similarly, Figure 12 shows that the share of the population living with a disability is highest in areas with high NO_x emission levels.



Note: Error bars show the 95% confidence interval

Figure 11. Premature mortality rate by NO_x emissions level



Note: Error bars show the 95% confidence interval

Figure 12. Share of population with a disability by NO_x emissions level

While these findings do not establish that drayage trucks directly cause health inequities, they indicate that emissions from drayage trucks may be one contributor to worse health outcomes. Moreover, this finding highlights the importance of reducing drayage truck emissions to ease health burdens and address health disparities. Comprehensive results including other health and socioeconomic indicators—including cardiovascular disease-related premature death, average life expectancy, asthma-related emergency room visits, and income—are available in Appendix B.

POLICY IMPLICATIONS

This study found that drayage truck $PM_{2.5}$ emissions have decreased substantially but NO_X emissions remain a concern for air quality and environmental justice. In this section, we highlight policies, programs, and actions that can address this issue through two main strategies: transitioning to zero-emission drayage trucks and implementing place-based emission reductions in overburdened areas.

ZERO-EMISSION DRAYAGE TRUCKS

Our finding that NO_X emissions remain substantial despite a relatively modern drayage truck fleet points to the limitations of diesel technology for addressing air quality and health disparities. By eliminating both NO_X and $PM_{2.5}$ tailpipe emissions, zero-emission trucks offer the most complete solution. While zero-emission trucks can be battery electric or hydrogen fuel-cell electric, hydrogen may be less suitable for short-distance travel given substantial barriers like high upfront costs and limited low-carbon hydrogen sources.[59]

Alternative fuels have been proposed as an intermediate step in the transition to zero-emission drayage vehicles.[60] However, recent testing showed that renewable diesel provided NO_X reductions only in pre-2010 MY trucks not equipped with selective catalytic reduction (SCR) systems; meanwhile, newer trucks equipped with SCR systems showed inconsistent results, with some tests even finding higher NO_X levels.[61] A 2022 memo prepared for the New York State Energy Research and Development Authority found that no low-carbon fuel showed significant NO_X reductions relative to their fossil fuel counterparts.[62] Thus, while alternative fuels can be useful for meeting climate goals, battery electric trucks remain the most effective technology for reducing drayage NO_X air pollution and the associated health impacts.

Despite the air quality advantages of electric HDVs, sales of these vehicles have been relatively slow in the United States, largely due to high upfront costs: used diesel trucks typically cost $30,000–$90,000, while new battery electric trucks cost $400,000–$600,000—a difference that is particularly challenging for independent owner-operators who tend to purchase used vehicles.[63] In 2024, approximately 2,800 zero-emission medium- and heavy-duty vehicles were sold in the United States, compared with 14,000 in Europe and over 230,000 in China.[64] Recent changes in federal legislation and funding freezes have only increased barriers to uptake.[65]

Nevertheless, momentum is growing: California's Ports of Los Angeles and Long Beach currently have 546 zero-emission trucks in operation, demonstrating that large-scale drayage electrification is achievable.[66] Despite delays in receiving a $250 million federal grant for truck electrification, these ports remain committed to zero-emission trucks and charging infrastructure.[67] These examples suggest that dedicated resources and coordinated strategies between government, industry, and community groups at the state, regional, and local levels can drive progress. The following sections explore specific policy approaches that could accelerate zero-emission HDV adoption.

59 Chris Busch et al., *Delivering Affordability: The Emerging Cost Advantages of Battery Electric Heavy-Duty Trucks And U.S. Policy Strategies To Unlock Their Full Potential* (Energy Innovation, 2025), https://energyinnovation.org/report/delivering-affordability-the-emerging-cost-advantages-of-battery-electric-heavy-duty-trucks-and-u-s-policy-strategies-to-unlock-their-full-potential/.

60 Puget Sound Zero-Emission Truck Collaborative, *Decarbonizing Drayage Roadmap* (2025), https://www.rossstrategic.net/Zero-Emission-Truck-Collaborative/docs/Puget%20Sound%20ZE%20Truck%20Collaborative%20Roadmap.pdf.

61 Kenneth J. Kelly and Adam C. Ragatz, *Economy and Emissions Impacts from Solazyme Fuel in UPS Delivery Vehicles*, NREL/TP-5400-68896, 2018, https://doi.org/10.2172/1464922; David Cooley et al., "Effect of Low-Carbon Fuels and Energy Technologies on Co-Pollutant Emissions," Memorandum to Hillel Hammer (NYSERDA), January 26, 2021, https://www.nyserda.ny.gov/-/media/Project/Nyserda/Files/EDPPP/Energy-Prices/Energy-Statistics/Co-Pollutant-Impacts-of-Low-Carbon-Fuels-and-Technologies.pdf.

62 Cooley et al., "Effect of Low-Carbon Fuels."

63 Puget Sound Zero-Emission Truck Collaborative, *Decarbonizing Drayage Roadmap*.

64 Ilma Fadhil and Yihao Xie, *Zero-Emission Bus and Truck Market in the United States (January–December 2024)* (International Council on Clean Transportation, 2025), https://theicct.org/publication/r2z-zero-emission-bus-and-truck-market-us-2024-jun25/; Eamonn Mulholland, *European Heavy-Duty Vehicle Market Development Quarterly (January–December 2024)* (International Council on Clean Transportation, 2025), https://theicct.org/publication/r2z-eu-hdv-market-development-quarterly-jan-dec-2024-feb25/; Shiyue Mao and Felipe Rodríguez, *Zero-Emission Medium- and Heavy-Duty Vehicle Market in China, 2024* (International Council on Clean Transportation, 2025), https://theicct.org/publication/ze-mhdv-market-china-2024-mar25/.

65 Brian Edwards, "EPA Moves to Seize $20B in Clean Energy Grants, Including $1.5B for Native Communities," *Tribal Business News*, February 14, 2025, https://tribalbusinessnews.com/sections/energy/15019-epa-moves-to-seize-20b-in-clean-energy-grants-including-1-5b-for-native-communities; James C. McGrath and Sam Rowley, "Trump Rescinds California's Emission Waivers: What It Means for the Future of EV Mandates," Seyfarth, accessed September 22, 2025, https://www.seyfarth.com/news-insights/trump-rescinds-californias-emission-waivers-what-it-means-for-the-future-of-ev-mandates.html.

66 "Port of Los Angeles Adopts Near-Term Clean Truck Spending Plan," The Port of Los Angeles, May 22, 2025, https://www.portoflosangeles.org/references/2025-news-releases/news_052225_ctf.

67 David Ferris, "Trump Stalls $1B Push to Electrify Trucking at Port of LA," *E&E News by POLITICO*, March 7, 2025, https://www.eenews.net/articles/trump-stalls-1b-push-to-electrify-trucking-at-port-of-la/; The Port of Los Angeles, "Near-Term Clean Truck Spending Plan."

SAFEGUARD AND ADAPT POLICIES SETTING TARGETS FOR ZERO-EMISSION TRUCK SALES

The uncertain fate of the ACT rule presents both challenges and opportunities for state-level action. Policymakers might draw on California's emerging alternative approaches to meeting zero-emission vehicle goals,[68] such as manufacturer incentive programs that apply charges or incentives depending on the carbon emission levels of each truck sold.[69] Such revenue-neutral policies incentivize manufacturers to produce cleaner trucks without requiring federal waiver approval or new funding sources. To complement these supply-side policies, purchaser-focused incentives for zero-emission trucks can support uptake, particularly among the independent owner-operators and small fleets that dominate drayage. Washington's CCA provides a crucial foundation, highlighting the importance of sustaining the program beyond the currently budgeted time frame, which ends in 2027.

Finally, the persistence of NO_X emissions underscores that ensuring funds go toward vehicles with zero emissions and not combustion engines powered by alternative fuels is important for achieving air quality improvements.

DEVELOP AND SUSTAIN REBATE PROGRAMS AND ALTERNATIVE FINANCING MODELS

An ICCT analysis of total cost of ownership suggested that battery electric short-haul tractor trucks will reach parity with their diesel counterparts as soon as 2027.[70] However, upfront costs remain a barrier for many truck and fleet owners with limited capital.

Two complementary approaches could help address this challenge: point-of-sale rebates and alternative financing models. Washington's emerging Zero-Emission Incentive Program and NWSA's recently launched drayage program will implement both approaches and provide useful information on effective program design.

Point-of-sale rebate programs balance improving access for small fleet owners and owner-operators while increasing the volume of zero-emission trucks. Although larger rebates improve the purchase feasibility for a larger number of truck and fleet owners, without careful structuring, subsidies risk enabling manufacturers to increase or maintain high prices rather than passing savings on to purchasers. Conversely, although lower rebate amounts targeting a larger number of trucks can help accelerate the creation of a secondary market, they may not align with equity goals.

Several design elements could address these challenges. For instance, programs can stipulate pricing transparency—such as by requiring list prices for eligible vehicles—and collect purchase data like battery size and vehicle information number. Further, programs might consider price ceilings or other mechanisms to place downward pressure on prices while helping to increase adoption.[71] To balance volume and access, Washington's Zero-Emission Incentive Program will use a tier structure, providing higher rebates to small businesses.[72] Used zero-emission trucks are also eligible under this program, a measure that can substantially lower upfront costs.

Alternative financing models can also mitigate the upfront investment barrier. The Puget Sound Zero-Emission Truck Collaborative's Decarbonizing Drayage Roadmap outlines leasing and trucking-as-a-service as options that spread costs over time while transferring technology and resale value risks from operators to service providers.[73] The NWSA's program for zero-emission trucks and charging deployment uses a dual approach: it offers operators either point-of-sale vouchers equivalent to an 80% cost reduction or leasing arrangements that include charging, parking, and maintenance for a monthly fee.[74] This structure will provide helpful data on which model appeals to different fleet sizes and how actual costs compare between the two models.

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68 State of California Executive Department, *Executive Order N-27-25*, 2025, https://www.gov.ca.gov/wp-content/uploads/2025/06/CRA-Response-EO-N-27-25_-ATTESTED.pdf.

69 Ray Minjares, "A Clean Commercial Vehicle Sales Incentive That Costs Nothing," *International Council on Clean Transportation Staff Blog*, July 8, 2025, https://theicct.org/a-clean-commercial-vehicle-sales-incentive-that-costs-nothing-jul25/.

70 Busch et al., *Delivering Affordability*.

71 Busch et al., *Delivering Affordability*.

72 Range Truck Group, "Washington's Zero-Emission Incentive Program (WAZIP) – What We Know So Far," October 4, 2025, https://www.rangetruck.com/resource/washingtons-zero-emission-incentive-program-wazip/.

73 Puget Sound Zero-Emission Truck Collaborative, *Decarbonizing Drayage Roadmap*; "Affordable Zero Emission Truck Leases," Forum Mobility, accessed August 13, 2025, https://forummobility.com/truck-leasing/.

74 "The Northwest Seaport Alliance Announces Inaugural Incentive Program for Zero Emission Drayage," Northwest Seaport Alliance, July 9, 2025, https://www.nwseaportalliance.com/newsroom/northwest-seaport-alliance-announces-inaugural-incentive-program-zero-emission-drayage-0; Bellamy Pailthorp, "Zero-Emissions Drayage Trucks Coming to Seattle and Tacoma," KNKX Public Radio, July 17, 2025, https://www.knkx.org/environment/2025-07-17/zero-emissions-drayage-trucks-coming-to-seatac-ports-transportation-emissions.

BUILD A COORDINATED INFRASTRUCTURE AND UTILITY STRATEGY

Charging infrastructure availability is also vital for zero-emission vehicle adoption, requiring coordination across utilities, port authorities, and private fleet operators. An ICCT study commissioned by SCL found that by 2030, overnight private depot chargers could support most short-haul tractor truck charging needs, and overnight public chargers could fill in most of the rest.[75] A study of real-world drayage truck routes in the Seattle-Tacoma area further supported this point, finding that 63% of truck routes were less than 40 miles.[76]

Coordination to address common bottlenecks is important for implementing depot charging. For example, a depot owner looking to build charging infrastructure must work with SCL to ensure that grid upgrades are identified and implemented. A coordinated strategy can involve joint planning forums and a streamlined process for completing new service connections.

Public charging infrastructure can be located strategically to reduce pollution and facilitate battery electric truck adoption in Seattle and Washington. Instead of waiting for demand to increase, utilities can proactively build distribution grid upgrades in zones where charging demand is expected to increase to allow for easier deployment of charging infrastructure.[77] An RFI report recommended distributing charging infrastructure away from port areas that already face high levels of congestion, avoiding areas that may experience grid bottlenecks, and prioritizing areas of the city that already have grid capacity.[78] Finally, collaboration amongst utilities and agencies beyond the SCL service area can help alleviate congestion; utility and infrastructure planning can involve community members who understand the neighborhood and truck drivers who understand operational constraints.

75 Steimer et al., *Powering Seattle Fleets.*

76 Anish Sinha, *Preparing for Electric Drayage Trucks: Analysis of Real-World Operations in the Seattle-Tacoma Port Region* (International Council on Clean Transportation, 2025), https://theicct.org/publication/drayage-trucks-rw-operations-seattle-tacoma-port-region-jul25/.

77 Steimer et al., *Powering Seattle Fleets.*

78 Nocona Sanders et al., *The Case for Placing Drayage Truck Chargers Away from Ports* (Rocky Mountain Institute, March 28, 2024), https://rmi.org/the-case-for-placing-drayage-truck-chargers-away-from-ports/.

LOCALIZED EMISSION REDUCTION SOLUTIONS

While fleet-wide electrification will ultimately provide the most substantial overall emission reductions, targeted near-term interventions can provide more immediate health benefits to communities experiencing the highest levels of NO_X emissions. Our finding that idling contributes as much as 55% of total NO_X emissions in some neighborhoods suggests that there are opportunities for targeted, localized solutions to address emissions hotspots. Research comparing various strategies shows that targeting emission reductions in the most overburdened areas is the best method for reducing exposure disparities.[79] The following policies reflect strategies to reduce emissions in overburdened neighborhoods.

IMPLEMENT A DRAYAGE TRUCK REGISTRY AND LOCATION-BASED PROGRESS TRACKING

Current information gaps limit the ability to assess whether emission reductions are occurring equitably across neighborhoods. A drayage truck registry shared by the NWSA could address these gaps while respecting proprietary concerns. For instance, the registry could track the number of zero-emission trucks and the model year distribution of diesel trucks servicing each port terminal. Data on vehicle counts, general route patterns, and approximate service areas could clarify the effectiveness of fleet modernization efforts in reducing pollution in overburdened areas.

Transparent data sharing is important for building trust with local communities monitoring progress in reducing air pollution in the Duwamish Valley. While it may be challenging to gather data on the exact location of truck idling and operation, data aggregated at a neighborhood level or by port terminal can provide useful information. The Clean Air Program's multiple stakeholders can co-create a list of metrics to track progress over time, negotiating what data serve community interests without compromising privacy. Zero-emission truck incentive programs could also be paired with reporting requirements to gather general information on where these trucks operate and park.

79 Yuzhou Wang et al., "Location-Specific Strategies for Eliminating US National Racial-Ethnic $PM_{2.5}$ Exposure Inequality," *Proceedings of the National Academy of Sciences of the United States of America* 119, no. 44 (2022): e2205548119, https://doi.org/10.1073/pnas.2205548119.

The planned 2026 extension of the MY 2007+ requirement to Terminal 115, located next to the neighborhoods of Georgetown and South Park, also offers an opportunity to enhance data collection.[80] Comparisons of the volume and model years of trucks servicing Terminal 115 versus the international terminals can provide useful location-specific data. Additionally, MY 2016 and later trucks are 23% of the drayage fleet and contribute only 5% of total NO_x emissions, showing the potential to reduce NO_x emissions by shifting to newer vehicles. The port could leverage these data to implement a fixed-age requirement that gradually removes vehicles with high real-world NO_x emissions.

COLLABORATE TO DEVELOP METHODS TO REDUCE IDLING EMISSIONS IN OVERBURDENED AREAS

Before designing interventions, understanding why idling occurs is essential, and truck drivers hold crucial knowledge about operational realities. Drivers have reported that heavy traffic when entering terminals, delays in port efficiency, and unpredictable wait times are among the issues causing idling.[81] Gathering additional information from truck drivers and neighborhood and community groups can help identify the best approaches for reducing idling. NWSA could then use this insight to improve reliability and reduce wait times.

Targeted outreach to truck drivers on the effects of idling can be a helpful step, highlighting the cost of fuel consumption associated with idling and the health effects to surrounding community and drivers themselves. Another mechanism is legislation restricting idling over a certain time. Twenty states have enacted anti-idling legislation, but Washington currently has no state-, county-, or city-level restrictions.[82] To ensure effective enforcement, Seattle may consider implementing a program like New York City's Citizen Air Complaint Program, which allows anyone to submit a complaint of idling with documentation.[83]

Finally, several technologies exist for electrifying temperature control and other power needs, including electric auxiliary power units, battery air conditioning, and truck stop electrification.[84] However, these technologies require upfront investment and, in some cases, additional infrastructure. Rebates could be used to mitigate this concern, as was done in British Columbia's incentive program.[85] These solutions can be designed to target emission reductions in overburdened neighborhoods within the Duwamish Valley.

80 Northwest Seaport Alliance, *Clean Air Strategy*.

81 Sinha, *Preparing for Electric Drayage Trucks*; Pailthorp, "Zero-Emissions Drayage Trucks."

82 American Transportation Research Institute, *Compendium of Idling Regulations*, June 2025, https://truckingresearch.org/wp-content/uploads/2025/06/2025-ATRI-Cab-Card.pdf.

83 New York City Department of Environmental Protection, "Citizens Air Complaint Program," accessed November 6, 2025, https://www.nyc.gov/site/dep/environment/idling-citizens-air-complaint-program.page.

84 "Learn about Idling Reduction Technologies (IRTs) for Trucks and School Buses," U.S. Environmental Protection Agency, March 28, 2016, https://www.epa.gov/verified-diesel-tech/learn-about-idling-reduction-technologies-irts-trucks-and-school-buses.

85 BC Trucking Association, "Program Guide Year 6: CleanBC Heavy-Duty Vehicle Efficiency Program," September 1, 2024, https://bctrucking.com/wp-content/uploads/2025/03/CleanBC-Heavy-duty-Vehicle-Program-Guide-Year-6.pdf.

CONCLUSIONS

The spatial inventory of drayage truck emissions presented in this report provides evidence to support policies for reducing emission hotspots and addressing health impacts in the communities that bear the greatest burden. By mapping emissions at high resolution and analyzing these findings alongside demographic and health data, we identified strategies to reduce overall emissions and targeted interventions for overburdened neighborhoods—two complementary approaches that together could advance air quality and environmental justice goals.

The findings reveal both progress and persistent challenges. The analysis showed that the port policy requiring MY 2007 and newer engines has been effective in reducing $PM_{2.5}$. However, NO_X emissions remain substantial. A disproportionate share of NO_X emissions came from vehicles of MY 2010 and older, indicating potential for further progress.

The analysis of emissions at a census block level found evidence of a racial/ethnic disparity in neighborhood levels of drayage truck NO_X emissions. People of color faced 33% higher levels of NO_X emissions from idling in their neighborhood than non-Latino White residents. Areas with the highest idling emissions had rates of overall premature mortality that were 50% greater than areas with no idling emissions, underscoring the public health urgency of addressing these disparities.

Transitioning to zero-emission trucks remains the most important strategy for reducing emissions. State-level legislation and funding aimed at increasing the share of zero-emission truck sales are important policy tools to pursue amid a challenging federal policy landscape.

Additionally, targeted policy measures to reduce drayage truck emissions in overburdened neighborhoods can help reduce health disparities. Sharing data on truck counts disaggregated by location can support progress toward reducing air pollution hotpots. This study highlights the need for further efforts to understand drayage truck idling and implement effective solutions.

APPENDIX A

DETAILED METHODOLOGY

Driving emission factors by vehicle model year (MY) for Class 8 heavy-duty vehicles are displayed in Figure A1. NO_X emission factors by MY were derived from the TRUE U.S. database, with a minimum of 50 measurements per MY. Pre-MY 1998 emission factors were from the U.S. Environmental Protection Agency's motor vehicle emission simulator, MOVES4, due to insufficient sample sizes.[86] A speed adjustment was applied to account for higher real-world NO_X emissions at low-speed operation.[87] Most of the remote sensing measurements were taken at speeds of 25–50 mph. Multipliers were calculated using heavy-duty in-use testing combination unit truck data by dividing the average NO_X emissions for a given speed bin by average NO_X emissions for 25–50 mph (Table A1). $PM_{2.5}$ emission factors were entirely derived from MOVES4. Finally, we also used MOVES4 fuel economy data to convert emission factors from fuel-specific units (g/kg fuel) to distance-specific units (grams/mile).

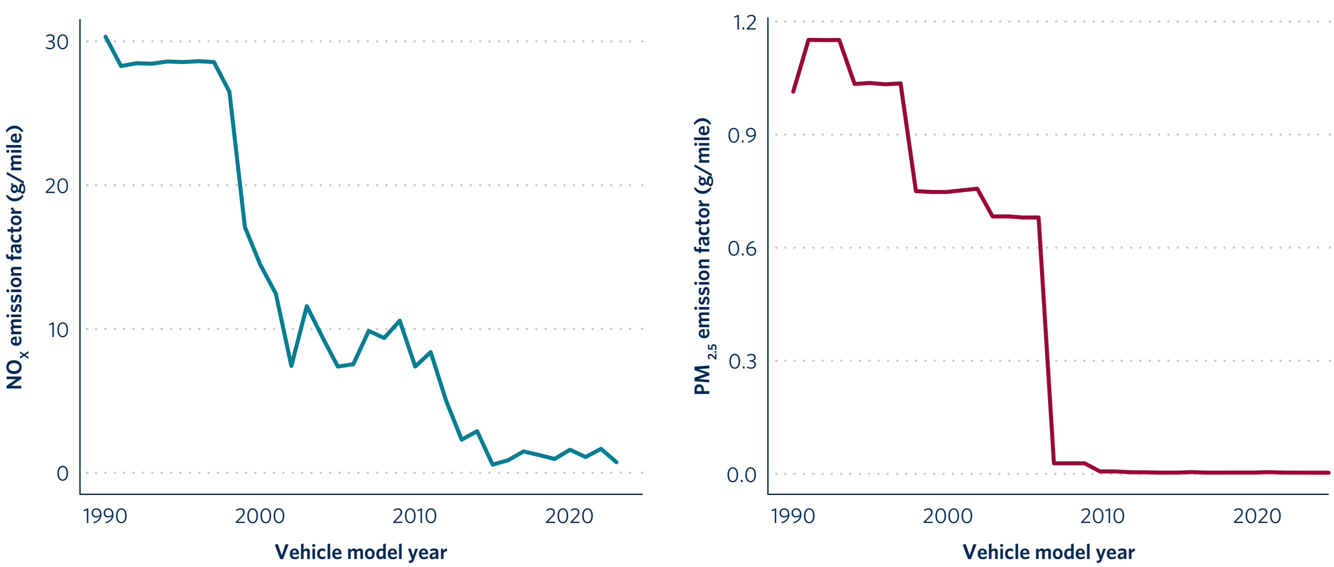


Figure A1. Heavy-duty vehicle emission factors by model year

86 U.S. Environmental Protection Agency, "MOVES versions in limited current use."

87 Huzeifa Badshah et al., *Current state of NO_X emissions.*

Table A1. NO_X emission factor multipliers by speed bin for combination-unit trucks

Speed (mph)	NO_X emission factor multiplier
1–10	2.33
10–20	1.76
20–30	1.37
30–40	1.16
40–60	0.49
60–80	0.27

Due to the port's requirement of MY 2007 engine or equivalent emission control systems, or a diesel particulate filter (DPF), we adjusted the pre-MY 2007 $PM_{2.5}$ emission factors. We assumed that all pre-MY 2007 trucks are equipped with DPFs and emit $PM_{2.5}$ at levels comparable to MY 2007–2009 trucks. Based on this adjustment, the calculated fleet average $PM_{2.5}$ emission factor is 8 mg/mile. This is a conservative assumption that may result in an underestimate of $PM_{2.5}$ emissions, as some of these trucks may not be equipped with DPFs. The emission factor used in this analysis, 8 mg/mile, is much lower than the unadjusted 37 mg/mile calculated for vehicles without DPFs. Despite making up a small share of the drayage truck fleet (3.5%), the pre-MY 2007 trucks and their DPF status have a large influence on the average $PM_{2.5}$ emission factor, resulting in some uncertainty about the real-world emission factor.

Idling emission factors were calculated from a combination of two sources. Given our definition of idling as a vehicle stationary for 3 minutes or longer, we used short-term idling emission factors. One source basis for the emission factors were the drayage truck fleet-average idling factors, published by the Port Authority of New York and New Jersey (PANY/NJ). This source, however, accounts for a higher share of pre-MY 2007 trucks compared with Seattle. Thus, we also relied on emission factors from MOVES4, whose emission factors are disaggregated by model year.

The MOVES4 idling emission factors were weighted by the model year distribution of the Seattle drayage truck fleet to derive a fleet-average emission factor. MOVES4 emission factors, originally in units of g/MJ, were multiplied by 43 MJ/kg fuel and 2.5 kg fuel/hr to calculate the emission factor in units of g/hr.[88] The MOVES4 emission factors are only available for extended idling. To estimate the short-term idling emission factors, we applied an adjustment factor, the ratio of short-term versus extended idling emission factors from PANY/NJ (0.81 for NO_X and 1.2 for $PM_{2.5}$). The resulting emission factors are shown in Table A2. The NO_X emission factor is relatively similar to the PANY/NJ value, while the $PM_{2.5}$ emission factor is substantially lower, due to the lower share of pre-2007 MY vehicles and assumption that all trucks are equipped with DPFs.

Table A2. Short-term idling emission factor comparison

	PM (g/hr)	NO_X (g/hr)
PANY/NJ inventory	2.5	55
Seattle analysis	0.03 (0.11 [a])	44

[a] This value represents the idling emission factor calculated assuming no pre-2007 MY trucks are equipped with DPFs. This value is not used in modeling and is provided for reference only.

Vehicle activity was derived from INRIX data, which captured port activity from a subset of drayage truck providers over 4 weeks in 2021–2022. The data were scaled up to estimate all annual drayage truck activity associated with the main port terminals. Comparing INRIX truck trips with total port trips from the RFID data, we estimate that these data capture approximately 19% of total drayage truck activity associated with the main port terminals. Driving distances were scaled up according to this estimate. Additionally, both driving distances and idling time were scaled up by a factor of 13 to represent activity across all 52 weeks in the year.

In addition to truck activity that started, originated, and passed through the ports, we also considered idling activity within the Duwamish Valley. This idling data were scaled down slightly to reflect that there may be non-drayage trucks captured in the dataset. To approximate the share of Class 8 trucks in Seattle that are drayage trucks, we compared the fleet sizes with other sources. The fleet of drayage trucks operating in Seattle was approximately 4,000 trucks as of 2023.[89] Other Class 8 trucks in the dataset are likely

88 "Higher Calorific Values of Common Fuels: Reference & Data," The Engineering Toolbox, accessed November 13, 2025, https://www.engineeringtoolbox.com/fuels-higher-calorific-values-d_169.html; The Port Authority of New York and New Jersey, *2022 Multi-Facility Emissions Inventory* (December 2023), https://www.panynj.gov/content/dam/port/our-port/air-emissions-inventory-reports/PANYNJ-2022-Multi-Facility-EI-Report.pdf; "Combustion of Fuels – Carbon Dioxide Emission," The Engineering Toolbox, accessed November 13, 2025, https://www.engineeringtoolbox.com/co2-emission-fuels-d_1085.html.

89 Housen, "Seattle Announces New Pilot Program."

combination-unit long-haul trucks. A 2024 ICCT analysis found that there are approximately 2,400 long-haul trucks in the Seattle City Light territory.[90] Comparing the geographic areas of the City of Seattle with the Seattle City Light territory, we estimate that 64% of these trucks operate within the City of Seattle.[91] Further, based on 2020 National Emissions Inventory data, approximately 80% of long-haul trucks in King County are combination-unit trucks, which we use as a proxy for Class 8 weight rating.[92] From this, we estimated there are 1,200 Class 8 long-haul trucks in Seattle, meaning 4,000 out of 5,200 Class 8 trucks (75%) in Seattle are drayage trucks. Based on the assumption that 75% of idling activity is from drayage trucks, we scaled idling times down by 0.75 to model only drayage truck idling activity.

After calculating the driving and idling emissions associated with each waypoint, we created spatial emissions inventories for two geometries: a 200 m x 200 m grid and census blocks. The grid is used to visualize the spatial distribution, and the census block inventory is used for the environmental justice analysis.

Census blocks were selected as the finest resolution used for demographic analysis based on evidence that using high resolution NO_2 emissions data to model health impacts reveals substantial spatial variability at a 100 m x 100 m resolution.[93]

The environmental justice analysis relies on demographic and health data from the Washington Tracking Network. Table A3 shows the full list of demographics and health indicators considered in this analysis, along with the spatial resolution and time frame for each.[94]

Table A3. Summary of health and socioeconomic indicators

	Spatial resolution	Years
Race and ethnicity	Census block	2020
Rate of premature mortality	Census tract	2018–2022
Rate of premature mortality from cardiovascular disease	Census tract	2018–2022
Life expectancy	Census tract	2015–2019
Share of the population with a disability	Census tract	2015–2019
Share of the population earning below the poverty level	Census tract	2015–2019
Emergency department visits involving asthma	Zip code	2023

90 Steimer et al., *Powering Seattle Fleets*.

91 The area of the City of Seattle is approximately 84 mi^2 and the area of the Seattle City Light territory is approximately 131 mi^2. See Seattle City Light, *Fingertip Facts* (September 2025), https://www.seattle.gov/documents/Departments/CityLight/FingertipFacts.pdf; "2022 U.S. Gazetteer: Washington," United States Census Bureau, accessed November 8, 2025, https://www2.census.gov/geo/docs/maps-data/data/gazetteer/2022_Gazetteer/2022_gaz_place_53.txt.

92 "2020 National Emissions Inventory (NEI) Data," U.S. Environmental Protection Agency, accessed January 2021, https://www.epa.gov/air-emissions-inventories/2020-national-emissions-inventory-nei-data.

93 Veronica A. Southerland et al., "Assessing the Distribution of Air Pollution Health Risks within Cities: A Neighborhood-Scale Analysis Leveraging High-Resolution Data Sets in the Bay Area, California," *Environmental Health Perspectives* 129, no. 3 (2021): EHP7679, 037006, https://pmc.ncbi.nlm.nih.gov/articles/PMC8011332/.

94 Jonathan Schroeder et al., *IPUMS National Historical Geographic Information System: Version 20.0*, *Hispanic or Latino Origin by Race (2020)*, dataset, 2025, http://doi.org/10.18128/D050.V20.0; "All Cause Mortality," Washington Tracking Network, Washington Department of Health, accessed November 13, 2025, https://fortress.wa.gov/doh/wtn/WTNPortal/#!q0=8963; "Death from Cardiovascular Disease," Washington Tracking Network, Washington Department of Health, accessed November 13, 2025, https://fortress.wa.gov/doh/wtn/WTNPortal/#!q0=8926; "Life Expectancy at Birth," Washington Tracking Network, Washington State Department of Health, accessed November 13, 2025, https://fortress.wa.gov/doh/wtn/WTNPortal/#!q0=655; "Population with a Disability," Washington Tracking Network, Washington State Department of Health, accessed November 13, 2025, https://fortress.wa.gov/doh/wtn/WTNPortal/#!q0=623; "Poverty: Individuals Living below Poverty Level," Washington Tracking Network, Washington State Department of Health, accessed November 13, 2025, https://fortress.wa.gov/doh/wtn/WTNPortal/#!q0=133; "Emergency Department Visits Involving Asthma among King County Residents (2022)," King County Climate and Health Equity Initiative, accessed November 13, 2025, https://kingcounty.gov/en/dept/dph/about-king-county/about-public-health/data-reports/climate/asthma.

APPENDIX B

Full results

First, the NO_x emissions score was calculated for each census block by summing the NO_x emissions within the block and dividing by the area. A Box-Cox transformation was applied to better visualize the distribution due to the extreme right skew of the data, and values were then scaled from 0 to 100. Figures B1 and B2 show the distribution of the NO_x emissions score and the categorization for low, medium, and high emission levels. Census blocks with no emissions were categorized as none. The "low" category consists of all values below the 25th percentile of non-zero values, "medium" consists of all values between the 25th percentile and 75th percentile, and "high" consists of all values greater than the 75th percentile.

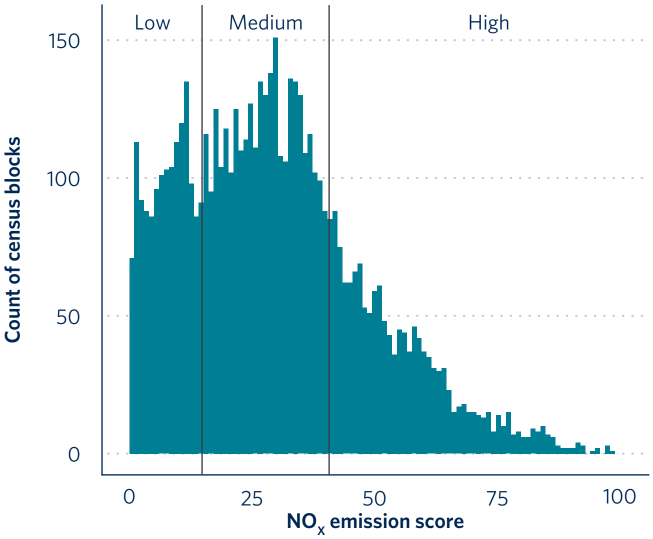
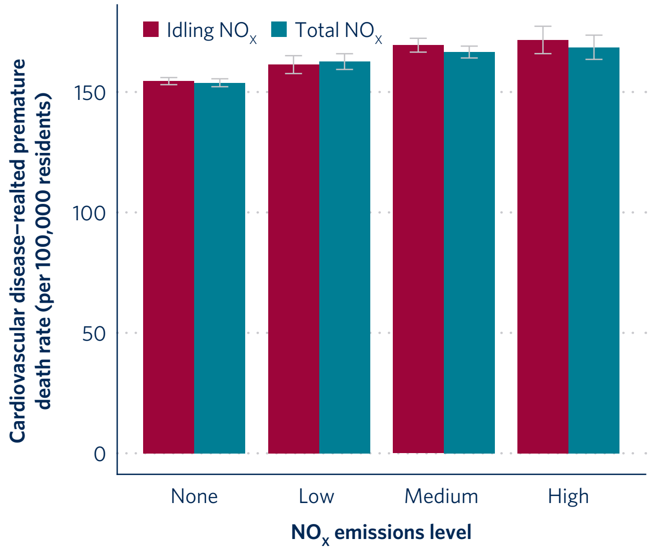


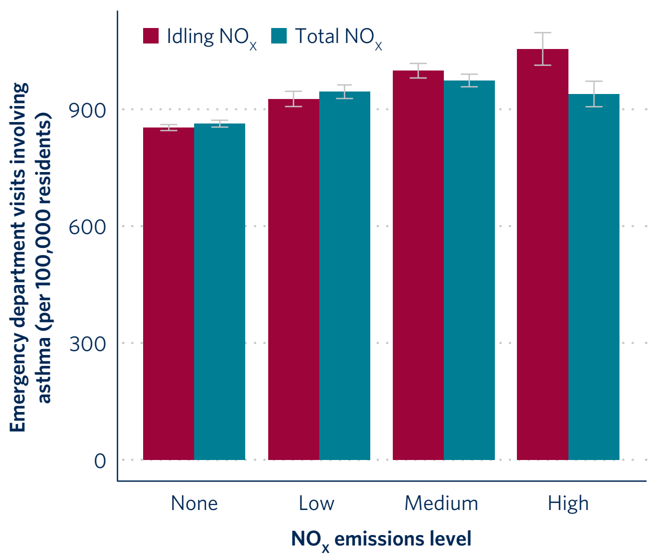
Figure B1. Designation of NO_x emission levels for total (driving plus idling) NO_x emissions

Figures B2–B5 show various health and social metrics by drayage NO_x emissions level. Figure B2 shows that cardiovascular disease-related premature mortality rates show less variation by NO_x emission levels compared with overall premature mortality (see Figure 11). Average emergency department visits involving asthma are somewhat elevated amongst areas with higher levels NO_x emissions (Figure B3). Figure B4, which shows the share of the population living below the poverty line, does not display clear trends by level of drayage NO_x emissions. Finally, average life expectancy is highest in areas with no drayage NO_x emissions, and areas with low, medium, and high emissions have average life expectancies that are around 1 year lower (Figure B5). Figure B6 shows more detail on the disparities in life expectancy. Importantly, the life expectancy in South Park, an area with a high level of drayage emissions, is 76 years, while many neighborhoods in North Seattle exceed 85 years.



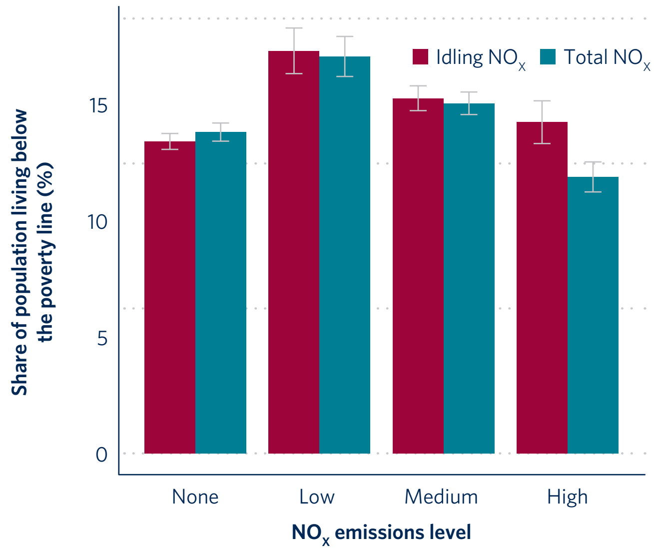
Note: Error bars show the 95% confidence interval

Figure B2. Average cardiovascular disease-related premature mortality rate by drayage truck NO_x emissions level



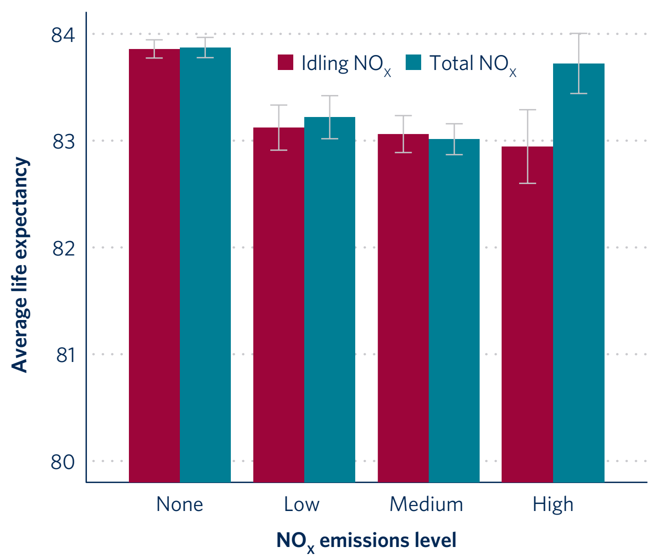
Note: Error bars show the 95% confidence interval

Figure B3. Average asthma-related emergency department visits by drayage truck NO_x emissions level



Note: Error bars show the 95% confidence interval

Figure B4. Share of population living below the poverty line by drayage truck NO_x emissions level



Note: Error bars show the 95% confidence interval

Figure B5. Average life expectancy by drayage truck NO_x emissions level

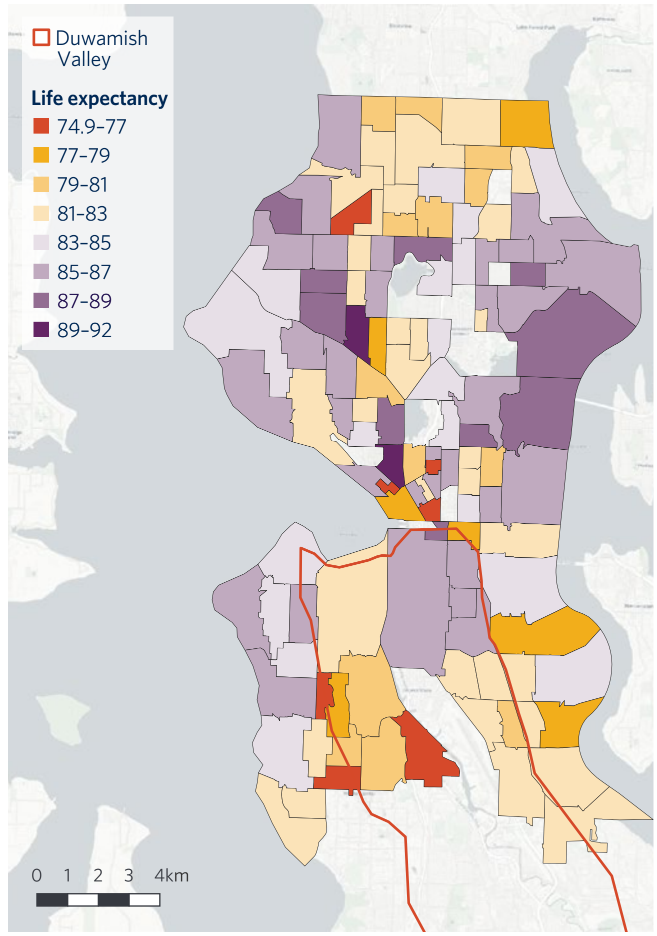


Figure B6. Average life expectancy by census tract

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