August 9, 2021

Via Electronic Filing

Elena Guilfoil
Department of Ecology
Air Quality Program
P.O. Box 47600
Olympia, WA 98504-7600

RE: NRDC comments on the draft rule for Chapter 173-423 WAC regarding the Clean Vehicles Program

Dear Ms. Guilfoil:

The Natural Resources Defense Council ("NRDC") submits the following comments on Washington's Department of Ecology's ("Ecology") proposed Clean Vehicles Program in support of the Duwamish Valley Community, including the Duwamish River Clean Up Coalition ("DRCC"). These comments incorporate and uplift the arguments made by DRCC in support of the rulemaking and underscore the importance of Washington's proposal for environmental justice ("EJ") communities. Moving forward, we strongly encourage that Ecology consult with and seek leadership from EJ leaders, including DRCC, as it adopts subsequent regulations.

Following DRCC's letter on medium- and heavy-duty vehicles are NRDC-only comments focusing on the Zero Emission Vehicles portion of the program. Also included as an appendix is a report by MJ Bradley & Associates. The analysis examines the impact to Washington State from three scenarios:

1. Adopting the Advanced Clean Truck Rule;

2. Adopting the Advanced Clean Truck Rule and Heavy-Duty Omnibus Rule; and

3. Adopting an aggressive clean grid and zero-emission vehicle deployment strategy.

EARTHJUSTICE

August 9, 2021

Elena Guilfoil
Department of Ecology
Air Quality Program
P.O. Box 47600
Olympia, WA 98504-7600

RE: Comment Letter Regarding Proposed Rulemaking to change Chapter 173-423 WAC – Low Emission Vehicles

Dear Elena Guilfoil:

This comment letter is submitted on behalf of the Duwamish River Cleanup Coalition/Technical Advisory Group (DRCC).

The Duwamish Valley is a "near port" and Environmental Justice community along the Duwamish River in Seattle. Heavy duty truck traffic is a serious health threat and community concern as it disproportionately impacts Black, Indigenous, immigrant, and refugee families. We recommend that the Department of Ecology ("Ecology") adopt the emissions standards described in its notice of proposed rulemaking. In addition, we further recommend that Ecology adopt emission standards for heavy-duty vehicles that are already law in California, which would reduce emissions of criteria air pollutants. Pursuant to RCW 70A.30.010, Ecology must adopt these regulations because they are motor vehicle emission standards adopted by the State of California.

DRCC is a nonprofit (501(c)3) that seeks to amplify the will and lift the voices of the Duwamish Valley community members, specifically those most harmed by the combined impacts of climate change, health disparities, and environmental and economic inequities. DRCC's mission is to elevate the voices of those impacted by the Duwamish River pollution and other environmental injustices to advocate for a clean, healthy, and equitable environment for people and wildlife.

In addition, DRCC promotes place-keeping, prioritizes community capacity and resilience. According to EPA's environmental justice mapping tool, 71% of the population in the six Census Block Groups encompassing Georgetown and South Park is nonwhite.[1] By committing to frequent and authentic community engagement and power-building, DRCC hears the concerns of the community to ultimately focus programming and take action. For decades, our community has raised issues with the noise disturbance, smell, public safety and visible combustion pollution of heavy-duty dirty diesel trucks which continue to travel back and forth, through the Duwamish Valley (DV) neighborhoods. Improving vehicle emissions standards is

[1] https://ejscreen.epa.gov/mapper/

critically important to protecting the health and welfare of residents living and working in the Duwamish Valley, and we applaud Ecology's proposal to strengthen these standards. We urge Ecology to promulgate rulemaking that will further reduce diesel exhaust emissions in the Duwamish Valley, as described below.

I. SUMMARY OF OUR RECOMMENDATIONS:

We strongly recommend the Department of Ecology adopt the emissions standards described in its notice of proposed rulemaking, and we further recommend that Ecology promulgate rulemaking to require fleet reporting, and to reduce emissions of criteria air pollutants from mobile sources that are already law in California:

1. **Ecology should adopt the (one time) <u>Fleet Reporting Requirement</u>**, which is part of the Advanced Clean Truck rule. The fleet reporting requirement is critical to achieving the emission standards for truck fleets described in the Advanced Clean Truck rule. The reporting requirement would create an inventory of existing truck fleets, and would document where fleets in Washington primarily operate. A fleet reporting requirement would document the disproportionate impact of truck emissions on the Duwamish Valley, an environmental justice issue. Further, Ecology can use the information obtained through fleet reporting to help finance cleaner trucks, especially for truck drivers who can't afford to comply with existing and future air emission standards. These trucks are among the oldest and dirtiest vehicles on the road and are excellent for zero-emission technology given their short-haul, idling, and stop-and-go operations. Research shows that a pathway to a near-100% electrified transportation future in 2050 would save communities of color in Seattle and the surrounding areas up to $138 million annually by that year. As soon as 2025, these health benefits could amount to $8 million as a result of fewer asthma attacks, hospital admits, lost workdays, and more.

2. **We strongly support Ecology's recommendation to adopt the Heavy-Duty Omnibus rule that has already been approved by the California Air Resources Board. We encourage quick adoption of this rule by the end of the year**. Pollution emitted by heavy-duty trucks disproportionately harms the health of residents in the Duwamish Valley. The Duwamish Valley is a major trucking corridor for goods movement in the Seattle Area, emitting diesel, NOx and SOx pollution as drayage trucks transport goods to and from the Port of Seattle. Adopting the Heavy-Duty Omnibus Rule will reduce toxic diesel exhaust pollution now and in years to come.

3. **We recommend that Ecology adopt California Code of Regulations, Title 13, §§ 2025, 2027, and 2299.1, which regulate emissions from heavy-duty vehicles and ocean-going vessels to reduce emissions in port communities, including the Duwamish Valley.** California's emission standards for diesel-powered mobile sources including heavy-duty vehicles, and oceangoing vessels, have achieved steep cuts in diesel pollution. Residents in the Duwamish Valley are disproportionately impacted by diesel particulate matter, and residents experience serious health impacts. Strengthening

emission standards for heavy-duty vehicles and ocean-going vessels, would reduce diesel particulate matter and smog forming pollutants including nitrous oxide and sulfur oxides, which cause severe health impacts including cancer, cardiovascular disease, and respiratory disease.

II. CUMULATIVE HEALTH IMPACTS FACED BY THE DUWAMISH VALLEY COMMUNITY:

Air Pollution in the Duwamish Valley causes serious and severe health impacts. Air pollution from trucks moving goods, industry, traffic congestion, manufacturing facilities and highways close to residential and civic spaces is the worst in the city.[2] More so, exposure to particulate matter from vehicle exhaust in the Duwamish Valley has been linked to asthma, early mortality, birth defects, and a wide range of other illnesses, and is especially hazardous for children.[3] Air pollution emitted from trucks contributes to major health issues such as lung and heart disease, increased risk of cancer, asthma, more frequent hospital admissions, and even premature mortality.[4] These ramifications can also span across multiple generations[5]. In addition, these health impacts that disproportionately affect the Duwamish Valley community mimic the inequitable distribution of socioeconomic benefits (such as jobs opportunities and economic growth).[6] The Duwamish Valley Cumulative Health Impact Analysis found:

- Life Expectancy: Measured at the census-tract level, life expectancy in both South Park and Georgetown is 13 years lower than in Laurelhurst and Magnolia, two predominately white, upper-income neighborhoods in North Seattle.[7]
- Particulate matter exposure: Exposure to particulate matter from vehicle exhaust in the Duwamish Valley has been linked to asthma, early mortality, birth defects, and a wide range of other illnesses, and is especially hazardous for children. [8]

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[2] **Exhibit A**, L. Gould & B.J. Cummings, *Duwamish Valley Cumulative Health Impacts Analysis,* Just Health Action, DRCC (Mar. 2013), https://www.seattle.gov/Documents/Departments/Environment/EnvironmentalEquity/CHIA_low_res.pdf

[3] City of Seattle, *South Park Neighborhood Profile* (Feb. 2019), https://www.seattle.gov/Documents/Departments/OPCD/OngoingInitiatives/OutsideCitywide/OutsideCitywideSouthParkNeighborhoodProfile.pdf

[4] U.S. Envt'l Prot. Agency, *Research on Near Roadway and Other Near Source Air Pollution*, www.epa.gov/air-research/research-near-roadway-and-other-near-source-air-pollution.

[5] U.S. Envt'l Prot. Agency, *Environmental Justice Primer for Ports: Impacts of Port Operations and Goods Movement*, www.epa.gov/community-port-collaboration/environmental-justice-primer-ports-impacts-port-operations-and-goods.

[6] *Id.*

[7] **Exhibit A**, Gould et al., *supra* note 2.

[8] City of Seattle, *supra* note 3.

- Asthma: Air pollution causes asthma and the childhood asthma hospitalization rates in the Duwamish Valley are some of the highest in the City of Seattle.[9]
- Heart disease death rates: Air pollution increases heart disease problems. Heart disease death rates measured at the census tract level are almost 2.5 times higher than wealthier parts of Seattle.[10]
- Proximity to environmental hazards: The community is living in close proximity to multiple contaminated waste sites including proximity to the Duwamish River Superfund site (one of the most toxic hazardous waste sites in the nation). [11]
- Tree canopy coverage: Tree canopy helps alleviate air pollution. South Park and Georgetown have some of the lowest tree canopy coverage in Seattle. Approximately 140 square feet of accessible green space per resident versus an average of 387 square feet per resident in Seattle. [12]

III. DIRTY DIESEL FROM GOODS MOVEMENT DISPROPORTIONATELY AFFECTS THE DUWAMISH VALLEY

Emissions from the movement of goods in particular, including trucking and shipping, deteriorates air quality in the neighborhoods of Georgetown, South Park, which sit at the heart of Seattle's freight corridor. South Park and Georgetown are exposed to higher levels of diesel exhaust than residents of Beacon Hill and Queen Anne.[13]

In 2020, Duwamish Valley Youth collected 80 moss samples in a Duwamish Valley youth led air monitor study using moss, a bio indicator. Professional scientists collected an additional 20 samples to help verify the results. They were analyzed for heavy metals and other elements. Data collected has shown high levels of arsenic and chromium; results were twice as high as what was found in Portland, where a similar study had been previously done.[14]

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[9] **Exhibit A**, Gould et al., *supra* note 2.

[10] *Id*.

[11] Wash. Dep't of Health, Lower Duwamish Waterway Site: Updated Fish Consumption Advisory

and Evaluation of Marine Tissue Collected from the Lower Duwamish

Waterway in August and September 2004, (2005), https://www.doh.wa.gov/Portals/1/Documents/Pubs/333-103.pdf.

[12] Seattle Parks Foundation, *South Park Green Space Vision Plan*, (Jun. 2014), https://www.seattle.gov/documents/Departments/Environment/EnvironmentalEquity/South-Park-Green-Space-Vision-Plan_6.17.14_Final-with-Appendix.pdf.

[13] Puget Sound Sage, *Diesel Exhaust Exposure in the Dumawish*, https://www.pugetsoundsage.org/research/clean-healthy-environment/deeds/.

[14] F. Villalobos, L. Gutierrez, C. Martinez, P. Lopez, T. Abel, *Duwamish Valley Youth Corps Moss and Metals Study*, DRCC & W. Wash. Univ., https://botanicgardens.uw.edu/wp-content/uploads/sites/7/2021/05/Moss-study-Presentation.pdf

In addition, air monitoring at the neighborhood scale is incomplete. Toxic pollution blindspots riddle an antiquated air monitoring network in the area. For instance, there are only two air toxics monitors in Seattle. The Department of Ecology manages an air monitor atop Beacon Hill. This monitor is located over a mile from any industry activity polluting the Duwamish Valley. The Puget Sound Clean Air Agency ("PSCAA") operates another air toxics monitor near the Federal Center South campus. PSCAA's air monitor is over a half-mile to any significant industrial polluter and failed to record air toxics data for five of the last 10 years.[15]

The Duwamish Valley is a near port community. Emissions from ships traveling into the harbor and docking in the port directly affect the Duwamish Valley and communities living near to ports in Washington. Ocean-going vessels that berth in the Port of Seattle are a major source of particulate matter, NOx, and sulfur dioxide—air toxins that harm lung function and contribute to smog formation. Shipping accounts for 15% of global NOx emissions, and diesel fuels used by ships can contain up to 500 times more sulfur than on-road diesel.[16] The shipping industry is the largest source of SOx pollution, second only to the energy industry. A harmful pollutant in its own right, SOx also contributes to the formation of airborne fine particulate matter.[17]

A. Ships are the Largest Source of Diesel Pollution from Washington's Ports.

Ocean-going vessels are the Ports largest source of emissions for both diesel particulate matter and greenhouse gasses. A 2021 Qualitative assessment by Washington State University, Port Air Modeling Study, using concentration "heat maps" found that the largest contributors of diesel particulate matter and greenhouse gases resulting in population impacts related to Port activities are ocean-going vessels at 157.81 tons per year of $PM_{2.5}$ emissions, and trucks as the second highest at 25.76 tons per year.[18]

In addition to emissions from ships, heavy-duty trucks that drive goods to and from OGVs primarily use diesel-engines that emit dangerous air toxins including diesel particulate matter and NO_x, which can cause serious health ailments including heart problems, respiratory disease and cancer.

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[15] https://southseattleemerald.com/2021/02/28/opinion-clean-air-everywhere-for-everyone-in-washington/

[16] J. Plester, "Dirty diesel: why ships are the worst offenders," *The Guardian*, May 18, 2017, https://www.theguardian.com/uk-news/2017/may/18/dirty-diesel-ships-worst-offenders-pollutionwatch.

[17] M. Gallucci, "At last, the shipping industry begins cleaning up its dirty fuels," *Yale Environment 360*, Jun. 28, 2018, https://e360.yale.edu/features/at-last-the-shipping-industry-begins-cleaning-up-its-dirty-fuels.

[18] M. Etisamifard, *Presentation: Puget Sound Ports Air Quality Study*, Washington State University, Jun. 10, 2021, http://lar.wsu.edu/nw-airquest/docs/20210608_meeting/NWAQ_20210610_0915_Etesamifard.pdf.

B. Heavy-Duty Trucks are Cumulatively one of the Largest Sources of Air Pollution in Washington.

Reducing the diesel emissions from trucks is a necessary step to improve Washington's air quality. The vast majority of trucks use diesel powered engines—75% of all trucks in America, and up to 97% of the heaviest classes.[19] These heavy-duty diesel vehicles are the largest source of diesel exhaust in the state.[20] When diesel fuel is burned, it emits several criteria pollutants known to have serious consequences for the health of both humans and the environment. In particular, pollution from diesel exhaust includes carbon monoxide (CO), particulate matter (PM), nitrogen oxides (NO_x), hydrocarbons (HC), as well as other hazardous air pollutants (HAPs) and air toxics.[21] In California, which also has a large trucking industry, heavy duty vehicles alone account for 31% of all NO_x emissions in the state.[22]

Curbing on-road gasoline and diesel emissions is also necessary to achieve Washington's climate goals. The transportation sector is the largest contributor of greenhouse gas emissions in Washington, and accounts for *close to half* of the state's Greenhouse Gas ("GHG") emissions.[23] Transportation-sector emissions are the principal factor causing an increase in total statewide GHG emissions.[24] On-road emissions from gasoline and diesel account for 30.8% of Washington's total GHG emissions, with diesel vehicles contributing 8.7% of the total state-wide GHG emissions.[25]

C. Diesel Emissions can be Deadly.

Emissions from diesel exhaust can have disastrous effects on the human respiratory, cardiovascular, and immune systems.[26] Diesel particulate matter and nitrous oxide ("NOx") emissions can harm respiratory function—causing asthma and asthmatic attacks,[27] inflammation

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[19] *See Trucking*, Diesel Tech. Forum, https://www.dieselforum.org/about-clean-diesel/trucking.

[20] Reducing Diesel Emissions, Wash. Dep't. Ecology (2021) https://ecology.wa.gov/Air-Climate/Air-quality/Vehicle-emissions/Diesel-emissions.

[21] About Diesel Fuels, U.S. Envtl. Prot. Agency (March 1, 2021), https://www.epa.gov/diesel-fuel-standards/about-diesel-fuels.

[22] Staff Report: Initial Statement of Reasons, Public Hearing to Consider the Proposed Heavy-Duty Engine and Vehicle Omnibus Regulation and Associated Amendments, Cal. Air Resources Board ES-1 (2020).

[23] Washington State Greenhouse Gas Emissions Inventory: 1990–2018, Wash. Dep't Ecology (2021), https://apps. ecology.wa.gov/publications/documents/2002020.pdf.

[24] *Id*.

[25] *Id*.

[26] A. Sydbom et al., *Health Effects of Diesel Exhaust Emissions*, 17 Eur. Respiratory J. 733 (2001).

[27] *Id*. at 741.

in the lungs, and decreased lung functionality.[28] These air toxins also harm the heart—causing alterations in blood pressure and heart rate,[29] heart disease,[30] and can lead to plaque instability.[31] Diesel particulate matter and NOx can also increase the prevalence and severity of allergic reactions to environmental conditions.[32] Further, diesel pollution can aggravate health harms for people with pre-existing asthmatic conditions and otherwise compromised pulmonary systems.[33]

Diesel exhaust can cause cancer. The U.S. Centers for Disease Control and Prevention (CDC) notes that up to 65% of diesel PM is made up of a group of organic compounds that includes several known carcinogens.[34] The National Institute for Occupational Safety and Health ("NIOSH") recommends regarding diesel exhaust as a human carcinogen based on findings of carcinogenic and tumorigenic responses in rats and mice.[35]

Diesel engines also emit large quantities NOx, a criteria pollutant regulated under the Clean Air Act because of its harmful health effects.[36] NOx irritates airways in the human respiratory system, and chronic exposure can contribute to the development of asthma.[37] Further, NOx can react with other air toxins including particulate matter and ozone to form smog—a noxious mix of air toxins that harm respiratory function.[38] One study found that in a single year, high levels of NO_x emissions from diesel engines contributed to 10,000 premature deaths across Europe.[39] The study concluded that compliance with stricter vehicle emissions standards could have avoided at least half of those deaths.[40]

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[28] *Id*.

[29] Simon Wilson et al., *Effects of Diesel Exhaust on Cardiovascular Function and Oxidative Stress*, 28 Antioxidants & Redox Signaling 819, 826 (2018).

[30] *Id*.

[31] *Id*. at 827.

[32] *Id*.

[33] Sydbom, *Health Effects* at 741.

[34] Carcinogenic Effects of Exposure to Diesel Exhaust, Ctrs. for Disease Control & Prevention, https://www.cdc.gov/niosh/docs/88-116/default.html (last reviewed June 6, 2014).

[35] *Id*.

[36] U.S. Envt'l Prot. Agency, *Criteria Air Pollutants*, https://www.epa.gov/criteria-air-pollutants.

[37] U.S. Envt'l Prot. Agency, *Basic Information About NO_2*, https://www.epa.gov/no2-pollution/basic-information-about-no2#Effects.

[38] *Id*.

[39] J. E. Johnson et al., *Impact of Excess NO_x Emissions from Diesel Cars on Air Quality, Public Health and Eutrophication in Europe*, 12 Envtl. Res. Letters 1, 9 (2017), https://doi.org/10.1088/1748-9326/aa8850.

[40] *Id*.

Lastly, chronic exposure to diesel is more deadly that short-term or acute exposure. Every 10 micrograms per cubic meter increase in the concentration of diesel exhaust over an extended period of time is associated with an 11% increase in cardiovascular mortality.[41]

D. Exposure to Diesel Emissions can Cause Increased Vulnerability to COVID-19.

Chronic exposure to diesel emissions increases a community's vulnerability to serious illness and death from diseases like COVID-19. The CDC found that individuals with certain pre-existing health conditions are more vulnerable to severe illness and death from COVID-19. These health conditions include cancer, serious heart conditions such as coronary artery disease, asthma, pulmonary hypertension and other pulmonary diseases, high blood pressure, and weakened immune systems.[42] As discussed above, chronic exposure to diesel exhaust can cause many of these health conditions, making a person more vulnerable to harm from COVID-19.

Further, a recent study found that increasing particulate matter by 1 ug/m^3 is associated with an 11% increase in mortality from COVID-19.[43] Exposure to excess levels of NO_2 also increases the risk of death due to COVID-19.[44] Areas with higher levels of NO_2 pollution saw a 16% increase in mortality rates. The authors concluded that "efforts to lower traffic emissions and ambient air pollution may be an important component of reducing population-level risk of COVID-19 case fatality and mortality."[45] With COVID-19 cases and hospitalizations once again on the rise in Washington, reducing environmentally driven vulnerabilities should be an urgent priority for all state agencies.

E. The Consequences of Diesel Exposure Disproportionately Fall on Low-Income Communities and Communities of Color in Seattle.

GIS mapping data shows that port cities in Washington including Everett, Seattle, Kent, and Tacoma, experience the worst diesel particulate matter ("PM") pollution in the state.[46] The

[41] Wilson, *Cardiovascular Function* at 821.

[42] People with Certain Medical Conditions, Ctrs. Disease Control & Prevention (May 13, 2021) https://www.cdc.gov/coronavirus/2019-ncov/need-extra-precautions/people-with-medical-conditions.html.

[43] X. Wu et al., *Air Pollution and COVID-19 Mortality in the United States: Strengths and Limitations of an Ecological Regression Analysis*, 6 Sci. Advances 1 (Nov. 4, 2020) https://doi.org/10.1126/sciadv.abd4049.

[44] Donghai Liang et al., *Urban Air Pollution May Enhance COVID-19 Case Fatality and Mortality Rates in the United States*, 1 Innovation 1 (Nov. 25, 2020) https://doi.org/10.1016/j.xinn.2020.100047.

[45] *Id*. at 5.

[46] Washington Environmental Health Disparities Map, Wash. State Dep't Health, https://www.doh.wa.gov/Dataand StatisticalReports/WashingtonTrackingNetworkWTN/InformationbyLocation/WashingtonEnvironmentalHealthDisparitiesMap (last accessed July 20, 2021).

first image below is taken from the Washington Environmental Health Disparities Map, which uses GIS to overlay population data with environmental pollution indicators. As shown in the images below, diesel emissions are concentrated in communities with a higher percentage of people of color.

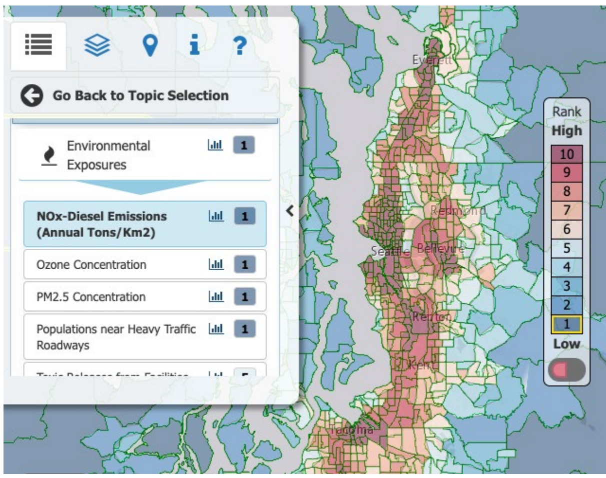

Figure A: NOx-Diesel Concentrations

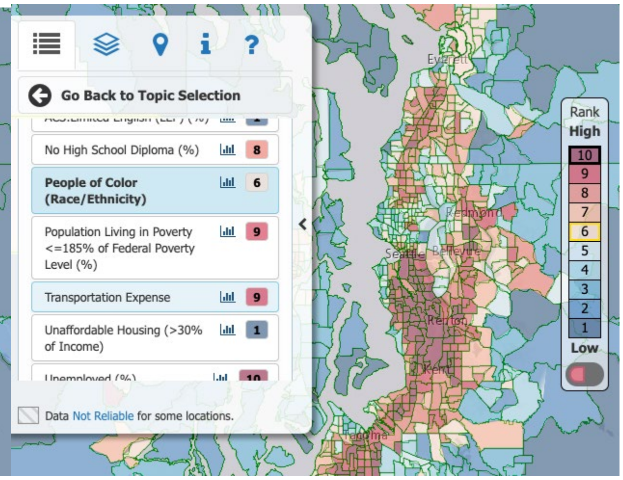

Figure B: Demographic data

Residents of Duwamish Valley living in the South Park and Georgetown neighborhoods face higher levels of pollution than other neighborhoods in Seattle because of their close proximity to major trucking routes. Unlike other residential neighborhoods in Seattle, numerous major trucking routes pass through the neighborhoods of South Park and Georgetown as shown in Figure C below.

Indoor air quality is directly related to the proximity of a home to roads and traffic.[47] Individuals living near busy roads and highways have a higher risk of exposure to air pollution than individuals living near less trafficked roads.[48] In particular, proximity to roads with diesel fuel combustion is directly correlated with indoor pollution levels.[49]

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[47] Shaodan Huang et al., *Road Proximity Influences Indoor Exposures to Ambient Fine Particle Mass and Components*, 243 Envtl. Pollution 978, 978 (2018).

[48] *Id*. at 985.

[49] *Id*. at 981.

Sixty percent of residents in South Park and Georgetown believe that pollution from commercial trucking is harming the health of their families.[50] And, they are right. A report prepared by the University of Washington monitored air quality in South Park and Georgetown, focusing on pollutants associated with diesel emissions.[51] The study found that "residents near busy roads and industrial areas face the greatest air quality impacts from proximate diesel sources."[52] Highest concentrations of pollution occurred at major transit throughways including the 1st Avenue Bridge between South Park and Georgetown, the Georgetown commercial district near Interstate 5, and the Georgetown industrial zone along E Marginal Way S.[53]

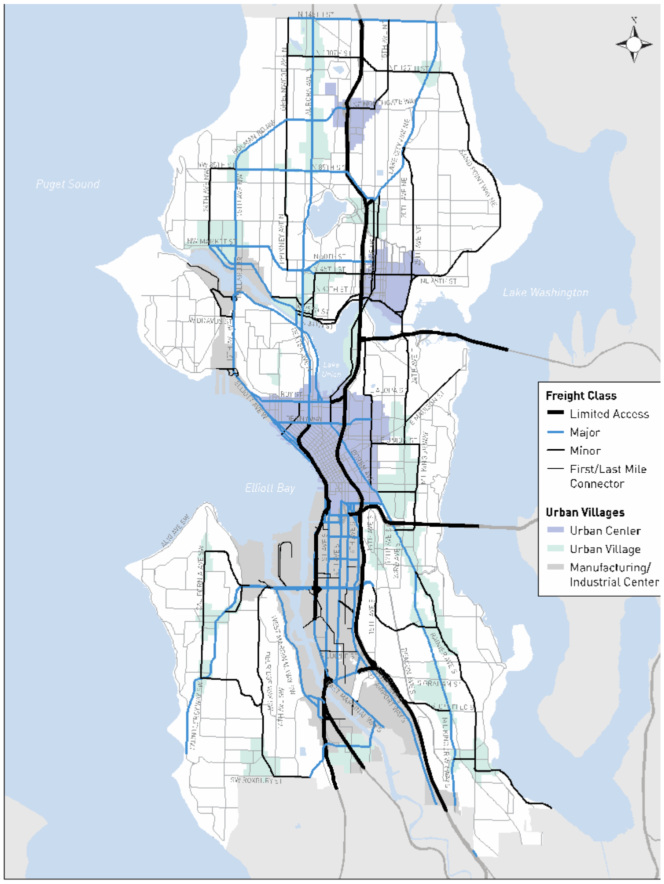

Figure C: Major Truck Streets Map for the City of Seattle

Of great concern, diesel pollution is the primary contributor to potential cancer risk in Seattle. In a 2010 study, PSCAA found that "diesel is still the largest contributor to potential cancer risk throughout Puget Sound. Diesel risk contributed over 70% of the potential cancer risk at sites the study evaluated in Seattle."[54] PSCAA found that the Duwamish Valley had the highest risk of cancer than any other neighborhood modeled in the study—450 potential cancers per million—and diesel pollution was the primary risk factor.[55]

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[50] Jill Schulte et al., *Diesel Exhaust Exposure in the Duwamish Study (DEEDS)*, U. Wash. Dep't Envtl. & Occup. Health Sci. 1, 59 (2013), http://dl.pscleanair.org/DEEDS/DEEDS_Tech_Report.pdf.

[51] *Id.*

[52] *Id.* at 59

[53] *Id.*

[54] Tacoma and Seattle Area Air Toxics Evaluation, Puget Sound Clean Air Agency 8 (2010).

[55] *Id.* at ES-4.

Total Potential Cancer Risk per Million People for Tacoma South L Street (270), Seattle Beacon Hill (360), and Seattle Duwamish (450), Subdivided into Largest Contributors

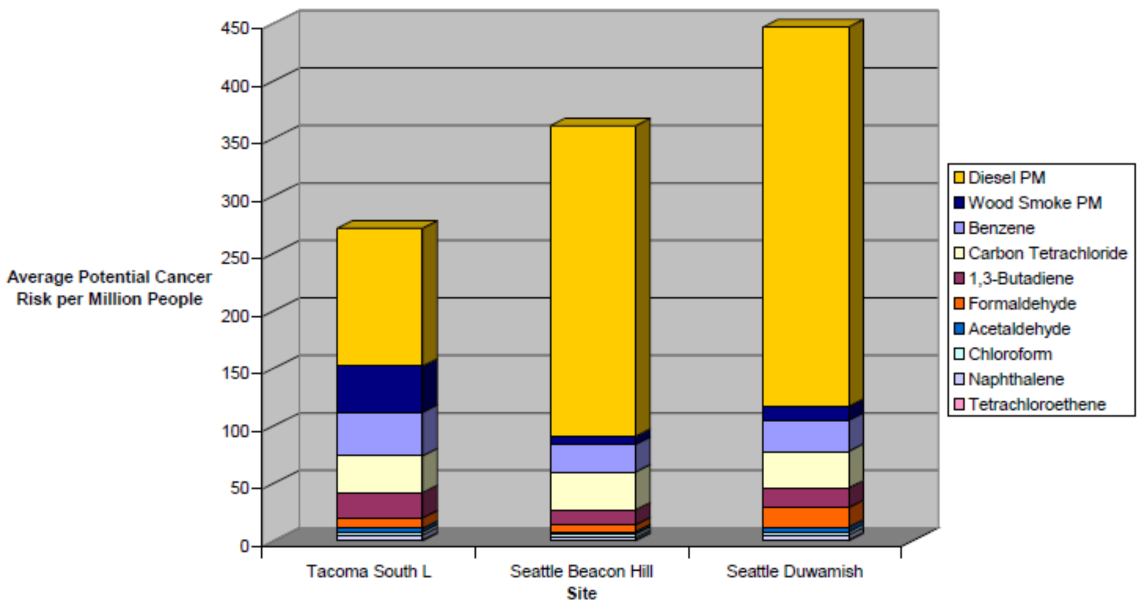

Figure D: Graph documenting contributing risks factors for cancer in the Duwamish Valley.[56]

IV. ADOPTION OF THE ADVANCED CLEAN TRUCK RULE IS NECESSARY TO REDUCE EMISSIONS FROM HEAVY DUTY TRUCKS.

The Clean Air Act preempts states from setting emissions standards for motor vehicles.[57] A motor vehicle is "any self-propelled vehicle designed for transporting persons or property on a street or highway."[58] The only state excepted from this blanket preemption is California.[59] California may promulgate regulations to strengthen emission standards for mobile sources as long as they are at least as health protective as the federal standards.[60] Other states can adopt California's motor vehicle emissions standards so long as they are *identical* to California's standards.[61]

We support Ecology's adoption of California's Advanced Clean Trucks rule, because this is a vehicle emission standard that will significantly reduce criteria air pollutant and GHG

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[56] *Id.*

[57] 42 U.S.C. § 7543(a).

[58] 42 U.S.C. § 7550 (2).

[59] *Engine Mfrs. Ass'n v. S. Coast Air Quality Mgmt. Dist.*, 498 F.3d 1031, 1043 (9th Cir. 2007).

[60] *Id.*

[61] *Id.*; 42 U.S.C. § 7507.

emissions from the trucking sector in the long term. We also recommend that Ecology promulgate rulemaking to adopt a fleet reporting requirement. A fleet reporting requirement is not an emission standard, but rather a one-time reporting requirement. Because it is not an emission standard, Ecology does not need to mirror California's fleet reporting requirement, but rather could tailor this reporting requirement to document the disproportionate impacts of trucking and aid the agency in providing financial incentives to low-income truck drivers to upgrade their vehicles.

A. We Support Ecology's Adoption of the Zero Emissions Mandate of the Advanced Clean Trucks Rule.

Recommendation: We strongly support adoption of the emissions standards described in the Advanced Clean Truck rule and applaud Ecology for taking this critically important step to improving air quality in port communities like the Duwamish Valley. Additionally, we recommend that Ecology adopt the correct enforcement penalties, and establish a severability clause to ensure that the Advanced Clean Truck rule avoids unnecessary legal hurdles.

The Advanced Clean Truck rule requires large truck manufacturers to progressively sell more zero-emissions trucks over time.[62] The goal of this regulation is to reduce emissions from the transportation sector by accelerating the widespread adoption of zero-emission vehicles in the medium-duty and heavy-duty truck sectors. Reducing mobile source emissions from medium and heavy-duty trucks would create substantial pollution reduction benefits because currently mobile sources are the largest source of fine particulate matter, and diesel particulate matter pollution.[63] The Advanced Clean Truck Rule requires truck manufacturers to build and sell progressively more zero-emission medium- and heavy-duty vehicles over time.[64] The Advanced Clean Truck rule will lead to significant reductions in emissions of criteria air pollutants including nitrogen oxides ("NOx") and fine particulate matter ("PM2.5").[65]

NOx pollution is harmful because it irritates the lungs, and chronic exposure can cause serious health impacts, as discussed above. NOx also reacts with chemicals in the air to form ground level ozone and particulate matter.[66] Because NOx is a precursor for $PM_{2.5}$, reducing NOx pollution will have the added benefit of lowering $PM_{2.5}$ pollution levels as well.[67] Medium and heavy-duty vehicles are the primary source of NOx pollution.[68]

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[62] Cal. Air Res. Bd., Staff Report: Initial Statement of Reasons, Proposed Advanced Clean Truck Rule, at ES-2 (Oct. 22, 2019) ("*ACT Staff Report*").

[63] *Id*. at ES-1.

[64] *Id*.

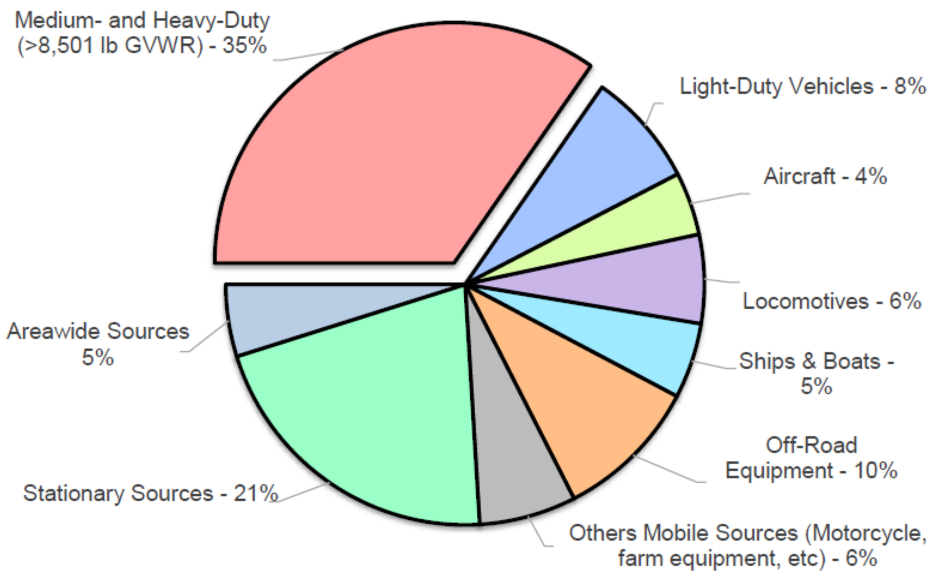
[65] *Id*. at ES-5.

[66] *Id*. at II-3.

[67] *Id*.

[68] *Id*. at II-4.

Figure II-2: 2019 NOx Emissions by Source



The figure above documents the sources of NOx pollution statewide in California by pollution source and demonstrates that medium to heavy duty vehicles are the largest source.[69] Consequently, transitioning the medium- and heavy-duty vehicle sector to zero-emission technology would achieve significant statewide reductions in emissions of criteria air pollutants. It would also eliminate tailpipe GHG pollution. Electric vehicles also have higher energy efficiency than fossil-fuel powered vehicles—reducing overall energy consumption.[70]

The Advanced Clean Truck rule would mandate that truck manufacturers sell an increasing number of zero-emission trucks, starting in 2024.[71] By 2035, seventy-five percent of heavy-duty trucks manufactured and sold must be zero emission, in the Class 4-8 vehicle group.[72] The goal of this regulation is to achieve at least 200,000 ZEVs or 10% of the total truck population by 2030.[73]

Converting diesel trucks to electric vehicles would go a long way toward reducing diesel pollution in the Duwamish Valley. **Accordingly, we strongly support Ecology's proposed adoption of the Advanced Clean Truck rule, with some amendments to protect the rule from unnecessary legal challenge and to ensure it achieves ZEV adoption goals.** These

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[69] *Id*.

[70] *Id*.

[71] 13 Cal. Code Regs. 1963.1(b)

[72] *Id*.

[73] Cal. Air Res. Bd., *Final Statement of Reasons*, at 13 https://ww2.arb.ca.gov/sites/default/files/classic/regact/2019/act2019/fsor.pdf.

amendments include: adopting the correct penalty structure for violations of the Advanced Clean Truck rule, and correcting the incentives and credits for early action.

Penalty Structure: Given the large differences in vehicle size and emission levels (both GHG and criteria pollutants), the ZEV program and ACT rule have different penalty structures. The proposed rulemaking correctly identifies a penalty ceiling of $5,000/vehicle for the ZEV Program. However, missing from the proposal is the penalty schedule for various medium- and heavy-duty vehicle classes. The correct penalty structure that accommodates the larger vehicles regulated by the ACT rule should be included and/or clarified in the final rule. Correcting the penalty structure is necessary to ensure that Washington adopts an emission standard that is identical to California's standards as required by federal law.[74]

Correcting Incentives: We understand that the Department of Ecology is adopting the California Code of Regulations Section 1963.2 by reference and that this allows for early action credits to be generated starting with model year 2021. However, adopting California's law without changing the year credits start generating would allow for four years of early credit generation, and may the stringency and as a result the benefits of the rule. In comparison, other states adopting the ACT rule this year, such as New Jersey, have proposed beginning early crediting one year before the rule is enforced. We encourage Ecology to consider the value of modifying early action credit components within relevant rulemakings in the future to maximize benefits to Washington residents.

In addition to the Advanced Clean Truck rule, we also recommend adoption of the Fleet Reporting Requirement to document the disproportionate impact of trucking on the Duwamish Valley and other port communities in Washington. A reporting requirement would provide useful information that Ecology can use to help provide financial incentives to low-income truck drivers.

B. <u>The Fleet Reporting Requirement is Necessary to Document the Disproportionate Impact of Trucking on the Duwamish Valley, and to provide financial incentives for low-income truck drivers.</u>

<u>Recommendation</u>*: We request that the Department of Ecology promulgate rulemaking through a CR-101 form to require fleet reporting of truck fleets, especially drayage trucks, which is a requirement included in California's Advanced Clean Truck rule.*

California's Advanced Clean Truck rule includes two policies: first, it mandates that truck manufacturers produce zero-emission trucks, and second, it requires fleet owners to report on their truck inventory ("Fleet Reporting Mandate").[75] The California Air Resources Board intends to use information collected from the Fleet Reporting Mandate to develop regulations to accelerate the purchase of ZEVs by fleet owners.[76] Although the Department of Ecology has not

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[74] *See* 42 U.S.C. § 7507.

[75] *Id*. at ES-2, ES-3.

[76] *Id*.

proposed adopting the Fleet Reporting Mandate in this rulemaking, it should promulgate regulation through the CR-101 process to adopt this requirement. The Department of Ecology should move now to adopt the Fleet Reporting Mandate because information obtained through such a mandate will be critical to transitioning away from diesel-powered heavy-duty trucks. **Further, because the Fleet Reporting Requirement is not an emissions standard, Ecology could change the requirement to focus on documenting the disproportionate impact of trucking on port communities, and obtaining information that would help the agency provide financial incentives to low-income truck drivers.**

The Duwamish Valley Clean Air Program seeks to work with drayage truck drivers to identify barriers and opportunities to ultimately reduce idling and emissions, centering fair and just outcomes. The Duwamish Valley Clean Air Program and a community priority driven action plan to improve air quality, reduce rates of asthma and additional health disparities in the Duwamish Valley.

1. A Fleet Reporting Requirement Could Document the Disproportionate Impact of Trucking on the Duwamish Valley.

The Fleet reporting requirement is important because it will provide critical information on the location of truck fleets. As documented extensively above, the Duwamish Valley is disproportionately impacted by diesel pollution because it is a high traffic transportation corridor. Three freeways border the Duwamish Valley, Interstate 5, Highway 99 and the West Seattle Bridge. Currently the West Seattle Bridge is closed for repair, rerouting an average of 100,000 West Seattle Bridge drivers through the Duwamish Valley.[77] Numerous major trucking routes pass through Georgetown and South Park, carrying freight from the Port of Seattle, and nearby industry. A one-time reporting requirement that requires truck fleets to document the number of trucks they own and where they operate would provide valuable information regarding the disproportionate impact of trucking activity. A fleet reporting requirement could also document the age of vehicles, particular diesel trucks operating with pre-2007 engines. This would enable Ecology to target financial incentives on outdated trucks.

2. Ecology could also use fleet reporting to facilitate providing financial incentives to truck-owners for heavy-duty vehicle upgrades

A fleet reporting requirement that captures information about truck fleets, would provide the Department of Ecology with valuable information that it could later use to provide financing in the form of grants to drayage truck drivers. California's inventory form requires information about annual vehicle miles travels, age of the trucks, total revenue, and whether the entity owns the trucks, or contracts for trucking services, the NAICS industry code for the business, and whether the business owned trucks registered in-state.[78] This type of information would prove useful in developing a program to help finance the conversion of old dirty diesel trucks to low-

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[77] City of Seattle, *West Seattle Bridge Program*, https://www.seattle.gov/transportation/projects-and-programs/programs/bridges-stairs-and-other-structures/bridges/west-seattle-bridge-program

[78] Cal. Air Res. Bd., *Appendix J: Large Entity Reporting Sample Response*

emitting or zero-emitting vehicles. California's Fleet Reporting Mandate would apply to fleet owners or operators with at least 50 trucks.[79] However, to assist individual truck owners, the Department of Ecology could include smaller fleets in this reporting requirement as well.

Financing new trucks and engine retrofits is the biggest barrier that low-income drayage truck drivers face, in trying to meet air quality regulations. In a 2018 strike, port drivers objected to emission standards that would require them to upgrade their trucks to meet drayage truck emission standards because they could not afford to purchase the new equipment.[80] Drivers objected that even though they care about clean air, they could not afford the $40,000 to $60,000 cost to retrofit their trucks with cleaner technology.[81] At the time, the Port estimated that less than half of drayage trucks met the required vehicle emission standards.[82] In a 2013 study, researchers found that 31% of drayage truck drivers who own their own truck earned below $20,000, and half of those drivers paid more in maintenance costs than they earned.[83] Providing grants to low-income truck drivers to help them transition into low-emitting and zero-emitting vehicles would help achieve Clean Air Act policy objectives, while also achieving economic justice. More so, low-income drivers must be prioritized given environmental justice considerations as these drivers are often operating in environmental justice communities as well.

Cash incentives have repeatedly proven successful in reducing pollution from mobile sources. In California, the Carl Moyer Program has allocated over $900 million in grants to clean up over 50,000 older polluting engines in California.[84] This program targets heavy-duty diesel vehicles, and has funding available to replace old trucks, or retrofit engines.[85] The program prioritizes funds for small fleets owning less than 10 trucks, and local air districts must allocate at least a portion of their funds for small-fleet owners.[86] Incentives available through this program can cover up to $165,000 in costs, making battery electric trucks cheaper than used diesel trucks.[87] The Carl Moyer Program is funded by a $0.75 tax on tire sales, and a $6 SMOG

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[79] Cal. Air Res. Bd., *Advanced Clean Truck Regulation: Final Statement of Reasons*, at 17 (Mar. 2021), https://ww2.arb.ca.gov/sites/default/files/classic/regact/2019/act2019/fsor.pdf.

[80] J. Davidow, "Port's Deal Leaves Truck Drivers Worried," *Crosscut*, Feb. 7, 2018, https://crosscut.com/2018/02/ports-seattle-tacoma-deal-leaves-truck-drivers-worried-emissions.

[81] *Id*.

[82] *Id*.

[83] J. Drescher, "Economic Characteristics of Drayage Drivers at the Port of Seattle," Univ. of Wash., at 16 (2015), http://hdl.handle.net/1773/33670.

[84] Cal. Air Res. Bd., *Carl Moyer Program Guidelines,* at 1-1, (2017), https://ww2.arb.ca.gov/sites/default/files/classic/msprog/moyer/guidelines/2017/2017_cmpgl.pdf

[85] *Id*. at 4-1.

[86] *Id*. at 4-12.

[87] J. Di Fillippo et al., *Zero Emission Drayage Trucks: Challenges and Opportunities for the San Pedro Bay Ports*, UCLA Luskin Center for Innovation, at 43 (Oct. 2019),

fee on vehicle registration.[88] California also set aside $90 million in funding from the VW Mitigation Settlement to pay up to 75% for a private-owner's cost to purchase a zero-emission drayage truck.[89]

Here in Washington, however, financial incentives are woefully deficient for low-income drayage truck drivers. The Port of Seattle used to provide funding to help pay for 50% of the cost of drayage truck upgrades, but this program no longer has any funds.[90] The U.S. EPA supported a similar program in Maryland, successfully replacing 270 trucks over 10 years.[91] The Clean Diesel grants program disbursed by the Department of Ecology has $15 million in funds available to reduce emissions from diesel powered engines, but this program focuses primarily on school bus replacement.[92] The recent Justice40 initiative, enacted by President Biden, may provide opportunities for additional federal support for a diesel pollution reduction program, given that the Port of Seattle is located in the Duwamish Valley—a disadvantaged community due to its disproportionate exposure to pollution.[93]

Grunt funding for electric trucks, and low emission heavy duty trucks should prioritize low-income drayage truck drivers. Focusing grant funds on converting the oldest and dirtiest trucks would likely most benefit these drivers, because they are least able to convert their vehicles. Further, focusing grant funding on drayage trucks and individual truck owners specifically would provide a targeted approach that would most benefit low-income drivers. Eliminating pollution from old dirty diesel trucks that accumulates in environmental justice communities, including the Duwamish Valley would directly achieve the statutory requirements of the Heal Act, which requires Ecology to prioritize overburdened communities.[94] It would also achieve the Heal Act's goal of ensuring that the benefits of those investments directly accrue to local communities.

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https://innovation.luskin.ucla.edu/wp-content/uploads/2019/08/Zero-Emission_Drayage_Trucks.pdf.

[88] *Carl Moyer Program Guidelines*, *supra* note 84 at 1-4.

[89] Cal. Mitigation Trust, *Zero-Emission Class 8 Freight and Port Drayage Truck Category*, https://xappprod.aqmd.gov/vw/zero-emission.html.

[90] Port of Seattle, "Clean Truck Program," https://www.portseattle.org/programs/clean-truck-program.

[91] U.S. Envt'l Prot. Agency, *Drayage Truck Replacement Programs Improve Air Quality in the Mid-Atlantic*, at 2 (Feb. 2020), https://www.epa.gov/sites/default/files/2020-02/documents/420f20006.pdf.

[92] Dep't of Ecology, "Clean Diesel Grant," https://ecology.wa.gov/About-us/How-we-operate/Grants-loans/Find-a-grant-or-loan/Clean-diesel-grants.

[93] Ofc. Budget & Mgmt, *Interim Implementation Guidance for the Justice40 Initiative*, https://www.whitehouse.gov/wp-content/uploads/2021/07/M-21-28.pdf.

[94] RCW § 70A.001.0016(2)(a).

Lastly, a fleet reporting requirement is **crucial** for documenting the number of low-income truck drivers operating in Washington, and this information would in turn aid Ecology in providing financial incentives to these drivers. It is imperative that a fleet reporting requirement generate data that will document the financial burdens on low-income truck drivers, resulting from their misclassification as independent contractors. Misclassification is prevalent in the industry, leading to environmental injustice for both the Duwamish Valley community and independent low-wage-earning truck drivers. Truck companies must take responsibility for high capital costs and other financial burdens.[95]

V. STRICTER EMISSIONS STANDARDS FOR HEAVY-DUTY VEHICLES WILL IMPROVE AIR QUALITY IN THE DUWAMISH VALLEY.

We applaud Ecology's expressed intention to adopt the Heavy Duty Omnibus rule, and recommend that it start rulemaking *now* because that rule is final in California. All aspects of the Heavy Duty Omnibus rule should be adopted, including emissions testing procedures, and vehicle warranty and lifetime requirements. The Heavy-Duty Omnibus rule will save thousands of lives and enable children to breathe easier, because it would significantly reduce NOx and PM2.5 pollution.

In addition to the Heavy-duty Omnibus Rule, we recommend that Ecology adopt California's emission standards for ports and diesel trucks to reduce emissions from on-road trucks and marine vessels. While the Heavy-duty Omnibus Rule applies to newly manufactured trucks, it does not take existing dirty diesel trucks off the road. Accordingly, we recommend that Ecology *act now* to adopt California's emissions standards that would take dirty old diesel trucks off the road, and would dramatically reduce diesel pollution from ocean-going vessels.

A. Ecology Should Quickly Adopt the Heavy-Duty Omnibus Rule.

Recommendation – The California Air Resources Board has approved the Heavy Duty Omnibus Rule, and the Department of Ecology should take the necessary steps to begin rulemaking to adopt these health protective emission standards for heavy duty trucks.

The California Air Resources Board has approved the Heavy Duty Omnibus rule, and the rule is now awaiting approval by the Office of Administrative Law, which ensures compliance with procedural and statutory requirements and and codifies the rule. Approval by the Office of Administrative Law is expected by mid-September of this year.

Accordingly, the Department of Ecology should take steps *now* to promulgate a proposed rulemaking to adopt the Heavy Duty Omnibus rule before the end of 2021. We strongly support adoption of the Heavy Duty Omnibus Rule, including its extension of vehicle warranty, vehicle lifetime, and emission testing requirements. These requirements were amended in the California regulations to require manufacturers to build better trucks that reduce pollution during low-load, low-speed driving. Warranty requirements will also reduce maintenance costs for truck owners. The testing, lifetime and warranty requirements directly and

[95] https://laborcenter.berkeley.edu/pdf/2019/Truck-Driver-Misclassification.pdf

indirectly reduce pollution emissions from heavy duty trucks, and as such are emission standards. Because the Clean Air Act requires that Washington adopt identical standards, these emission standards must be also adopted in addition to limits on criteria pollutant emissions.

The Heavy-duty Omnibus Rule changes NOx emission requirements for heavy-duty vehicles and makes them more restrictive for model year vehicles built in 2024-2031.[96] The rule allows automakers to meet a less protective emission standard if they agree to apply the emission standards to their vehicles manufactured nationwide.[97]

The proposed rule also changes testing procedures to better account for on-road, low-load emissions, which typically emit higher amounts of NOx.[98] California officials found that previous testing emissions failed to account for vehicle emissions during different drive conditions. During on-road conditions, trucks emitted pollution greatly in excess of pollution standards, in some cases ten-times in excess of pollution limits.[99] By revising the testing procedures, California sought to ensure that heavy-duty vehicles met pollution control standards during all modes of operation.[100]

Lastly, the Heavy-Duty Omnibus Rule increases warranty and useful life requirements, such that manufacturers must warranty equipment and emissions performance over a longer period of time.[101] This requirement would reduce out of pocket costs for vehicle repair. It would also reduce costs to truck owners of having to upgrade once the useful life of the vehicle expires.[102] Lifetime and warranty requirements affect pollutant emissions because they ensure that vehicles meet the required emission standards for a longer period of time.

We strongly support adoption of the Heavy-duty Omnibus rule, including testing procedures, warranty, and vehicle useful-life requirements because this rule will significantly reduce pollution in the Duwamish Valley, and other port communities over the next several decades. The Heavy-duty Omnibus rule is expected to reduce emissions of NOx, which irritates the lungs and can aggravate lung diseases like asthma.[103] Reducing NOx will also reduce concentrations of fine particulate matter, because NOx is a precursor for $PM_{2.5}$. Fine particulate matter is a dangerous air toxin that aggravates lung and heart diseases and contributes to premature death. The California Air Resources Board determined that the Heavy Duty Omnibus rule would result in 3,900 fewer deaths from cardiopulmonary diseases, 620

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[96] Cal. Air Res. Bd., *Heavy Duty Omnibus Rule – Staff Report: Initial Statement of Reasons*, ES-7, ES-8 (Jun. 23, 2020), https://ww2.arb.ca.gov/sites/default/files/classic/regact/2020/hdomnibuslownox/isor.pdf.
[97] *Id*.
[98] *Id*. at ES-9.
[99] *Id*. at ES-5.
[100] *Id*. at ES-9.
[101] *Id*. at ES-9, ES-10.
[102] *Id*. at ES-9 to ES-14.
[103] Cal. Air Res. Bd., *Appendix E: Health Benefits Analysis for the Heavy Duty Omnibus Rule*, at 1 (Jun. 23, 2020), https://ww2.arb.ca.gov/sites/default/files/classic/regact/2020/hdomnibuslownox/appe.pdf.

fewer hospitalizations for cardiovascular illness, 740 fewer hospitalizations for respiratory illness, and 1,800 fewer asthma-related emergency room visits.[104]

This means fewer families scared they could lose a loved-one when they are rushed to the hospital. It means children can breath while running, without having to rely on an inhaler.

The bill recently signed by Governor Inslee mandates adoption of this California regulation because it is a motor vehicle emission standard, and we strongly support Ecology's recommendation to promulgate rulemaking on this standard.[105]

B. Ecology can also Take Action NOW to Adopt Existing California Emissions Standards that Would Take Dirty Diesel Trucks off the Road.

Recommendation: *California currently imposes more strict emissions standards on heavy-duty vehicles, and ocean-going vessels than federal standards. Ecology should promulgate a rulemaking to adopt California's regulations including California Code of Regulations Title 13, §§ 2025 (heavy-duty trucks must achieve MY 2010 emissions standards by 2023), 2027 (all drayage trucks must achieve MY 2010 emissions standards by 2023), and 2299.1 (requiring use of low-sulfur fuel in ships, and use of electric shore-power), because these standards would significantly reduce diesel and particulate matter pollution in port communities, including the Duwamish Valley. Adoption of these California regulations would advance the Department of Ecology's obligation to "reduce or eliminate the environmental harms and maximize the environmental benefits … on overburdened communities and vulnerable populations." RCW 70A.001.0014(6).*

A recent article published in *Science*, found that California's regulations targeting diesel-powered vehicles and ocean-going vessels sharply reduced diesel pollution. California's regulations reduced overall state-wide diesel pollution by 78%, achieving greater reductions than national emission standards, which only reduced diesel pollution by 51%.[106] Given that diesel pollution is the biggest risk factor for cancer in the Duwamish Valley, sharper reductions in diesel emissions means lives saved and fewer children with asthma.

The study identified three policies as particularly effective at reducing diesel pollution, and we recommend that Ecology promulgate rulemaking to adopt all of them. *First*, California requires that all on-road heavy duty diesel vehicles comply with model year ("MY") 2010 emission requirements.[107] This emission standard reduced diesel emissions from heavy-duty diesel vehicles by a whopping 85%, compared with federal standards which only reduced emissions by 58%.[108] Reducing diesel pollution from trucks means better indoor and outdoor air

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[104] *Id*. at 3.

[105] RCW 70A.30.010(1).

[106] **Exhibit B**, M. Schwarzman, et al., "Raising Standards to Lower Diesel Pollution," *Science*, Vol. 371, Issue 6536 (Mar. 26, 2021).
[107] Cal. Code Regs. tit. 13, § 2025.
[108] **Exhibit B**, M. Schwarzman, *supra* note 99.

quality for Duwamish Valley residents that live next to busy truck corridors, and three freeways. It also means lower NOx pollution, lower PM2.5 pollution, and less smog in the Duwamish Valley, and other port communities.

Second, California mandates that older drayage trucks replace their engines to meet MY 2010 emission standards.[109] Researchers found that by adopting this regulation, California reduced black carbon emissions by 70%, and reduced particulate matter emissions by 75% in and around the ports of Oakland and Los Angeles.[110] Pollution from drayage trucks directly affects communities in the Duwamish Valley, and dramatic reductions in diesel particulate matter emissions, as California achieved, would significantly reduce human health hazards associated with these emissions, including cancer risk.

Third, California enacted regulations to control emissions from marine vessels. California requires marine vessels to use electric shore-power while docked in port. Another regulation banned vessels from using heavy fuel oil, when operating vessels within 24 nautical miles of ports, and required the use of lower-sulfur content fuels. These policies caused a statewide 51% reduction in marine diesel particulate matter emissions.[111] In San Francisco Bay, switching away from heavy fuel oil, combined with speed reduction requirements caused a 90% reduction in marine diesel particulate matter.[112] The deep cuts in diesel emissions achieved through this regulation would greatly benefit the Duwamish Valley, which currently experiences some of the worst diesel particulate matter pollution in the state. They would also reduce GHG emissions from Washington's ports.

Since Washington has not yet adopted California's standards for heavy-duty vehicles, it currently applies federal emissions standards. California's emissions standards for heavy-duty vehicles manufactured after 2007 are largely the same as federal requirements.[113] However, there is one critical difference. Federal regulations only apply to newly manufactured heavy-duty vehicles. In contrast, California's regulations apply to newly manufactured heavy-duty vehicles *and* all on-road heavy-duty vehicles must comply with emissions standards.[114] Under the California regulations, a heavy-duty truck built in 1999 must still meet the emissions standards set out in Cal. Code Regs. tit. 13, § 1956.8 for trucks manufactured on or after 2007. In contrast, under federal law and in Washington, old dirty diesel trucks can remain on the road.[115]

The Department of Ecology should adopt Cal. Code Regs., tit. 13, § 2025, and require that on-road medium- and heavy-duty trucks meet model year 2010 emission standards for particulate matter and NOx by 2023. Adoption of this standard would substantially reduce carcinogenic diesel particulate matter emissions from trucking in the

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[109] Cal. Code Regs. tit. 13, § 2027.
[110] **Exhibit B**, M. Schwarzman, *supra* note 99.
[111] **Exhibit B**, M. Schwarzman, *supra* note 99.
[112] *Id*.
[113] *Compare* Cal. Code Regs. tit. 13, § 1956.8, *with* 40 C.F.R. § 86.007-11.
[114] Cal. Code Regs. tit. 13, § 2025.
[115] *See* 40 C.F.R. § 86.007-11 (applying standards only to newly manufactured trucks).

Duwamish Valley. State law requires adoption of this California regulation because it is a motor vehicle emission standard.[116]

With regard to California's requirement to upgrade drayage trucks, some Washington ports have attempted to informally achieve this same standard with uncertain results. The Port of Seattle requires drayage trucks to meet MY 2007 emission standards, but it's unclear how or whether that is enforced.[117] An article published in 2018 found that only 53% of all drayage truck drivers are compliant with the program.[118] The NW Seaport Alliance reports that 98% of trucks that move cargo to and from the ports' facilities meet this emission standard, but it is unclear whether this requirement applies to all drayage trucks.[119] According to its strategy plan, the prohibition on pre-2007 trucks only applies to Seattle's international terminal, and does not currently apply to domestic terminals.[120]

The Department of Ecology should adopt Cal. Code Regs., tit. 13, § 2027, and require that all drayage trucks have a 2010 model year emissions equivalent engine. Adoption of this standard would substantially reduce carcinogenic diesel particulate matter emissions from trucking in the Duwamish Valley. State law requires adoption of this California regulation because it is a motor vehicle emission standard.[121] Unfortunately, the financial burden of this regulation will likely fall primarily on low-income truck drivers, misclassified as independent truck drivers. Thus, it is imperative that the Department of Ecology ensure that grants are available to assist low-income truck drivers upgrade their vehicles to emission control standards.

Adoption of this California regulation would likely disproportionately impact low-income drayage truck drivers, and accordingly Ecology should develop and fund grant programs to help drayage truck drivers purchase new trucks. Providing grant funding to low-income drivers would both reduce carcinogenic diesel emissions and generate financial benefits for low-income drivers. These goals would directly achieve the mandates of the Heal Act, which requires Ecology to "[f]ocus applicable expenditures on creating environmental benefits that are experienced by overburdened communities and vulnerable populations, including reducing or eliminating environmental harms, creating community and population

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[116] RCW 70A.30.010(1).

[117] *See* Port's Clean Truck Program, https://www.portseattle.org/programs/clean-truck-program.

[118] B. Mongelluzo, "Seattle-Tacoma assures drayage capacity in deal with drivers," *Journal of Commerce Online*, Feb. 6, 2018, https://www.joc.com/port-news/us-ports/seattle-tacoma-assures-sufficient -drayage-capacity-compromise-deal-drivers_20180206.html.

[119] NW Ports Clean Air Strategy 2020, at 23 https://www.portseattle.org/sites/default/files/2021 -04/NWP_CAS_Report_2012_WEB%20%28002%29.pdf.

[120] Northwest Seaport Alliance, *Draft Northwest Ports Clean Air Strategy Implementation Plan*, at 38-39 (Jun. 30, 2021).

[121] RCW 70A.30.010(1).

resilience, and improving the quality of life of overburdened communities and vulnerable populations[.]"[122]

Lastly, with regard to electrifying ports, Washington's ports are woefully behind the curve. The Northwest Seaport Alliance set a goal of installing shore power at all major cruise and container berths by 2030, but California ports have already electrified.[123] Further, Washington ports do not require ocean going vessels to use shore power while docked. Absent a mandate, Washington ports instead rely on the charity of ship owners to "do-the-right-thing" and plug-in to reduce emissions.

Instead of centering polluting ship-owners, Ecology should center the health of communities in the Duwamish Valley and regional air quality and adopt Cal. Code Regs., tit. 13, Sec. 2299.1. California ports have demonstrated that ships can rely on shore-power for 100% of their power needs while docked at port, and science demonstrates that this regulation reduced carcinogenic diesel particulate matter emissions by at least 51%. There is no reason to continue allowing idling ships to poison community members, when currently feasible technology exists that would lower carcinogenic air toxins and greenhouse gas emissions.

VI. CONCLUSION

DRCC supports Ecology's proposed rulemaking to adopt the Advanced Clean Truck rule, and the zero-emission vehicle rules. Further, we recommend that Ecology promulgate rulemaking to adopt California's emission standards for heavy-duty vehicles, and ocean-going vessels to reduce the noxious burden of diesel pollution in the Duwamish Valley. Getting dirty diesel trucks off the road, and cleaning up emissions from ships would greatly improve the health of communities living in the Duwamish Valley.

Sincerely,

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[122] RCW § 70A.001.0016(2)(a).
[123] NW Ports Clean Air Strategy 2020, at 23, https://www.portseattle.org/sites/default/files/2021-04/NWP_CAS_Report_2012_WEB%20%28002%29.pdf.

Exhibit A

DUWAMISH VALLEY CUMULATIVE HEALTH IMPACTS ANALYSIS: SEATTLE, WASHINGTON

Photo: Paul Joseph Brown

Linn Gould, Just Health Action

Principal Investigator

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Table of Contents

The following Appendices are available online at:
www.duwamishcleanup.org/programs/duwamish-community-health-initiative

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Executive Summary

South Seattle's Duwamish Valley has long been referred to as a community with environmental injustices—a community with disproportionately high environmental health burdens and risks and fewer positive environmental benefits than the rest of Seattle—but limited evidence has been available to date to validate or quantify this characterization. The Duwamish River Cleanup Coalition/ Technical Advisory Group (DRCC/TAG) received an Environmental Justice (EJ) Research grant from EPA to conduct a Cumulative Health Impacts Analysis (CHIA) to document and quantify the Duwamish Valley's environmental health status relative to other areas of Seattle. Cumulative impacts are defined as: "any exposures, public health, or environmental effects from the combined emissions and discharges, in a geographic area, including environmental pollution, from all sources, whether single or multimedia, routinely, accidently, or otherwise released" (OEHHA, 2010).

In accordance with California EPA's cumulative impacts ranking methodology, a total of 15 indicators in five categories were selected and input into a formula to calculate cumulative heath impact scores for ten representative Seattle ZIP codes. Indicators included socioeconomic factors; sensitive populations; environmental exposures; environmental effects; and public health effects (OEHHA, 2010). From an environmental exposures perspective, Beacon Hill/Georgetown/South Park (ZIP code 98108) had the highest ranking for air pollution and for exposure to confirmed and suspected contaminated sites. This area also had one of the highest rankings in the city for unhealthy environmental effects, i.e., lack of access to a healthy built environment. Cumulatively, these poor environmental scores combined with high ranks for social vulnerabilities (socioeconomic factors and sensitive populations) and a medium ranking for public health effects resulted in the highest cumulative impact score of Seattle ZIP codes in the study. The results of this cumulative analysis provide a firm basis for characterizing the Duwamish Valley as an area with disproportionate health impacts and environmental injustices.

Additional evidence, including at the larger Duwamish watershed scale and at the smaller census tract scale, reinforce these cumulative findings, and further suggests that the ZIP code level analysis may obscure even greater disparities in the riverside communities of South Park and Georgetown. In comparing residents of the Duwamish Valley to King County, Duwamish Valley residents are more likely to live in poverty, be foreign born, have no health insurance or leisure time, and are more likely to be sick. Georgetown and South Park residents have up to a 13-year shorter life expectancy (at birth) than wealthier parts of Seattle.

In light of these cumulative findings, the Duwamish Valley merits attention from decision-makers regarding health protective and proactive environmental regulations, policies, practices, and actions. The results of this analysis will inform recommendations that DRCC/TAG will make to EPA, Washington state, and local government agencies regarding the Lower Duwamish River Superfund Site. In addition, DRCC/TAG will provide this report to federal, state, regional, and local governments; community-based organizations; and other stakeholders and decision-makers, to help guide the development of policies and actions to improve overall environmental health and equity in the Duwamish Valley.

I. Introduction

South Seattle's Duwamish Valley has long been referred to as a community with environmental injustices—a community with disproportionately high environmental health burdens and risks and fewer positive environmental benefits than the rest of Seattle—but limited evidence has been available to date to validate or quantify this characterization. The Duwamish River Cleanup Coalition/Technical Advisory Group (DRCC/TAG) represents an alliance of community, tribal, environmental, and small business groups affected by ongoing pollution and cleanup plans for Seattle's lower Duwamish River, a 5.5-mile-long Superfund Site.[1] The Duwamish Valley's riverfront neighborhoods of South Park and Georgetown are home to residents who are among those most impacted by the Superfund Site, with potential exposures from contact with contaminated sediments on neighborhood beaches, swimming or wading in the river, and from fishing. South Park and Georgetown are among Seattle's lowest income neighborhoods, and South Park, in particular, is one of the city's most ethnically diverse neighborhoods. As the US Environmental Protection Agency's (EPA) Community Advisory Group for the Duwamish River Superfund Site, DRCC/TAG received an Environmental Justice (EJ) Research grant from EPA to conduct a Cumulative Health Impacts Analysis (CHIA) for the surrounding residential community, in order to document and quantify the Duwamish Valley's environmental health status relative to other areas of Seattle and inform EPA's site cleanup decisions.

Photo: Colin Wagoner, Ridolfi Inc. 2004

This report compares geographic neighborhoods in the Seattle area and provides evidence of disproportionate health, socioeconomic, and environmental impacts in the Duwamish Valley. Based on these findings, DRCC/TAG will make recommendations to EPA and other appropriate agencies to reduce or mitigate risks and impacts for Duwamish Valley residents that are related to the Superfund site. The purpose of those recommendations will be to:

1. inform EPA's Duwamish River Superfund Site cleanup decisions;
2. develop risk reduction strategies for communities impacted by the site; and
3. improve health outcomes in the affected community.

In addition, the information compiled in this report is expected to inform action by regional public and private agencies on a variety of other health risk factors affecting the Duwamish Valley and other Seattle communities where disproportionate impacts are evident.

This report reviews relevant definitions, regulations, and policies in Section II; the cumulative impacts analysis method in Section III; indicators chosen for the analysis in Section IV; discussion of results in Section V; other lines of evidence in Section VI; limitations in Section VII; and conclusions and next steps in Section VIII. More detailed information can be found in the appendices, available online at: www.duwamishcleanup.org/programs/duwamish-community-health-initiative.

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1 A Superfund Site is one listed by the US Environmental Protection Agency on the National Priorities List, a designation for the most toxic hazardous waste sites in the country, which require cleanup under the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA).

II. Key Definitions and Relevant EPA Regulations

The following terms mean different things to different audiences and in various contexts. For the purpose of this report, the following definitions and relevant regulations and policies are used and reflect the context of the Duwamish Valley and the Duwamish River Superfund Site.

Environmental Justice (EJ): The US Environmental Protection Agency (EPA) defines EJ as "the fair treatment and meaningful involvement of all people regardless of race, color, national origin, or income with respect to the development, implementation, and enforcement of environmental laws, regulations, and policies." EPA's goal is "to provide an environment where all people enjoy the same degree of protection from environmental and health hazards and equal access to the decision-making process to maintain a healthy environment in which to live, learn, and work" (http://www.epa.gov/environmentaljustice/).

Environmental justice addresses the disproportionate environmental risks borne by low-income communities and communities of color

In Washington State, EJ is described in the *Governor's 2012 State Policy Action Plan to Eliminate Health Disparities* as "the right to a safe, healthy, productive, and sustainable environment, where 'environment' is considered in its totality to include the ecological, physical, social, political, aesthetic, and economic environment. Environmental justice addresses the disproportionate environmental risks borne by low-income communities and communities of color resulting from poor housing stock, poor nutrition, lack of access to healthcare, unemployment, underemployment, and employment in the most hazardous jobs" (Governor's Interagency Council on Health Disparities, December 2012).

Environmental Justice Executive Order 12898: In 1994, *Executive Order 12898: Federal Actions to Address Environmental Justice in Minority and Low-Income Populations* was issued by President Clinton. The Order stated that "each federal agency shall make achieving environmental justice part of its mission by identifying and addressing, as appropriate, disproportionately high and adverse human health or environmental effects of its programs, policies, and activities on minority populations and low-income populations…" The Order goes on to state that federal agencies shall, "at a minimum: (1) promote enforcement of all health and environmental statutes in areas with minority populations and low-income populations; (2) ensure greater public participation; (3) improve research and data collection relating to the health of the environment of minority populations and low-income populations; and (4) identify differential patterns of consumption of natural resources among minority populations and low-income populations" (EOP, 1994).

Plan EJ 2014: Inclusion of EJ principles in all of EPA's decisions has been cited as a top agency priority by former EPA Administrator Lisa Jackson. In recognition of the 20th anniversary of the EJ Executive Order, EPA has released Plan EJ 2014. The overarching strategy of the Plan is to:

1. protect the environment and health in overburdened communities;
2. help communities to take action to improve their health and environment; and
3. establish partnerships with local, state, tribal, and federal governments and organizations to achieve healthy and sustainable communities.

This strategy will be achieved by implementing and seeking to strengthen agency efforts in: (1) incorporating environmental justice into rulemaking; (2) considering environmental justice concerns in EPA's permitting process; (3) accelerating compliance and enforcement initiatives; (4) supporting community-based action programs; and (5) fostering administration-wide action on environmental justice (EPA, September 2011).

Locally, Region 10 has committed itself to Plan EJ 2014 and has adopted *EPA Region 10's Approach for Implementing Administrator Jackson's Seven Priorities: FY 2011–15,* which includes an EJ Strategic Plan (EPA, November 2011). Goals of Region 10's EJ Strategic Plan include:

1. eliminate, reduce, or mitigate the burden of pollution and disproportionate, adverse public health and environmental impacts on low-income and minority communities and vulnerable populations;
2. systematically facilitate the integration of environmental justice—principles, practices, guidance, tools, and methods—into the programs, policies, and actions of Region 10; and
3. engage communities in empowerment processes to identify existing and emerging environmental justice issues and collaboratively assist them in addressing those impacts.


Photo: BJ Cummings

With regard specifically to Superfund cleanup decisions, the Plan EJ 2014 *Legal Tools* document states that EPA's authority to consider public health and welfare and the environment provides "the basis for considering cumulative risk in taking response actions" (EPA, December 2011). Furthermore, EPA can use its authority to accommodate EJ considerations in assessing remedial alternatives, per its nine criteria for evaluating cleanup alternatives. These considerations include: the threshold criteria of overall protectiveness of human health and the environment, compliance with state statutes, and the modifying criteria of community acceptance (EPA, October 2012).

ACHIEVING HEALTH EQUITY MEANS THE ELIMINATION OF DISPARITIES AND VALUING EVERYONE EQUALLY WITH FOCUSED AND ONGOING SOCIETAL EFFORTS TO ADDRESS AVOIDABLE INEQUALITIES.

Environmental Justice Gap: Refers to the difference between low income and/or minority communities who systematically experience disproportionately greater environmental risks and impacts, and fewer positive environmental benefits, as compared with high income/non-minority communities.

Cumulative Impacts: The EJ Executive Order specifically states that when conducting an EJ analysis, "multiple and cumulative exposures" should be identified when practicable and appropriate (EOP, 1994). While traditional human health risk assessments have been conducted for the Duwamish River Superfund Site, as well as several other contaminated sites in the Duwamish Valley, cumulative health impacts that account for all exposures and other risk factors have not yet been evaluated. Cumulative impacts are defined as: "any exposures, public health or environmental effects from the combined emissions and discharges, in a geographic area, including environmental pollution, from all sources, whether single or multimedia, routinely, accidently, or otherwise released" (OEHHA, 2010). The Order further directs that: "impacts will take into account sensitive populations and socioeconomic factors, where applicable and to the extent the data are available" (EOP, 1994).

Health disparity vs. health inequity: A health disparity (or inequality) is a "particular type of difference in health in which disadvantaged social groups—such as the poor, racial/ethnic minorities, women, or other groups who have persistently experienced social disadvantage or discrimination—systematically experience worse health or greater health risks than more advantaged social groups" (Braveman, 2006). In contrast, a health inequity is a disparity that is not only unnecessary and avoidable but, in addition, is considered unfair and unjust (Whitehead, 1992). Achieving health equity means the elimination of disparities and "valuing everyone equally with focused and ongoing societal efforts to address avoidable inequalities, historical and contemporary injustices" (US Department of Health and Human Services, Office of Minority Health, 2010).

As part of Plan EJ 2014 and its goal to achieve EJ as required by EO 12898, the EPA is collaborating with multiple federal institutions to ensure the integration of environmental justice and health equity considerations into the policies, actions, and programs across the federal government.

III. Cumulative Impacts Analysis Method

Although 23 states have developed a range of qualitative to complex quantitative methods to evaluate disproportionate impacts, Washington State has not (Payne-Sturges, 2012). As part of its goal to achieve environmental justice for low-income and minority communities, the US Environmental Protection Agency (EPA) has been developing and improving reliable scientific data for identifying disproportionate environmental and health impacts among racial and ethnic minorities, low income populations, and indigenous people and tribes, while working to address and reduce environmental disparities. The approach chosen for the Duwamish Valley Cumulative Health Impacts Analysis (CHIA) is California EPA's (Cal EPA) cumulative impacts ranking methodology, which uses a quantitative, easy to understand approach (OEHHA, 2010). For a state-of-the-science review of cumulative impacts and the selected methodology, an excellent summary can be found in California's Cumulative Impacts: Building a Scientific Foundation (OEHHA, 2010).

The Cal EPA cumulative impacts method uses multiple indicators that are divided into five categories (referred to as components), each with an established range of ranking scores.

The Cal EPA rationale for the range of ranking scores for each component is based on the certainty of evidence in the literature (OEHHA, 2010). For socioeconomic factors and sensitive populations, the relatively broad ranking of 1–3 is based on literature indicating that there are several-fold differences in the way that vulnerable populations respond to environmental contamination. For the finer environmental exposure ranking of 1–10, there is abundant evidence on the types and extent of potential expo-

Component	Definition	Ranking Score
Socioeconomic factors	Community characteristics that result in increased vulnerability to pollutants	1–3
Sensitive populations	Populations with traits that may magnify the effects of pollutant exposures	1–3
Environmental exposures	Contact with pollution	1–10
Environmental effects	Adverse built environment conditions	1–5
Public health effects	Disease and other heath conditions	1–5

sures in communities and how they are associated with health (e.g., air pollution). Environmental effects and public health effects are assigned a mid-range ranking of 1–5 because there is less certainty and less information on the link between exposure and effect than with environmental exposures, but more certainty than is available for the link between socioeconomic status/vulnerable populations and health.

Three indicators for each component are selected from specified communities or geographic areas, for a total of 15 indicators. Indicator data for each community or geographic area are then ordered from highest to lowest, divided into equal subgroups, and assigned a ranking score for input into the following formula:

Cumulative Impact = (Socioeconomic factors + Sensitive populations) x
(Environmental exposures + Environmental effects + Public health effects)

Using this formula, the total cumulative impact score can range from a minimum of 6 to a maximum of 120. High scores indicate disproportionate impacts. These highly ranked areas can then be identified as priorities for action by EPA, states, communities, and other decision-makers.

This CHIA was designed to examine whether disproportionate impacts occur in the Duwamish Valley, as compared to other Seattle neighborhoods, in order to inform Superfund cleanup decisions and other relevant policies and actions. The geographic scale of analysis is the Zone Improvement Plan (ZIP) code, because indicator data were most readily available in this format. Ten Seattle ZIP codes are included in the CHIA analysis, as shown in Figure 1 (page 10). The ten ZIP codes were chosen based on a range of factors that are representative of differences (high, medium, and low) between Seattle geographic areas. ZIP codes were chosen according to ranges in income levels, racial/ethnic makeup, and pollution concentrations, as well as differences in neighborhood's access to resources, such as housing costs, park access, and education. Finally, as part of a Community Based Participatory Research (CBPR) effort helping to inform the project, areas that are often discussed by Duwamish Valley residents themselves when they compare their circumstances to other Seattle neighborhoods are included (Appendix B, online). Additional data were collected at the smaller neighborhood scale and larger Duwamish Valley scale, using available census tract data, but were not used in the quantitative CHIA equation shown above. These results are discussed separately in Section VI.

Figure 1. ZIP codes included in the Duwamish Valley Cumulative Health Impact Analysis

IV. Indicators for Cumulative Health Impacts Analysis

Data were collected for 24 available indicators for all ten ZIP codes, as shown in Table 1 on page 12. The 15 indicators used in the cumulative impacts scoring formula are highlighted and were selected based on:

a) established indicators from the US Environmental Protection Agency's (EPA) EJ definition (e.g., percent minorities, percent poverty);
b) information from Duwamish Valley residents about their environmental health concerns (e.g., air pollution, access to green space), collected through a Community Based Participatory Research project (Appendix B, online);
c) scientific evidence compiled from public environmental, demographic, and health databases; and
d) best professional judgment.

A series of Geographic Information System (GIS) maps created for each of the 15 indicators selected are shown in Figures 2–16.

Socioeconomic component (Rank range 1-3)

A growing body of research provides evidence that low-income and/or minority communities are more vulnerable to pollution exposure than higher income, non-minority populations, which in turn affects health (OEHHA, 2010; Hicken et al, 2012). The causes of health disparities from pollution are diverse and complex. However, correlations have been drawn between various factors, such as living in low-income conditions and compromised health; lower education level and increased risk of dying from lung cancer; lower birth weight infants born to black mothers exposed to particulate pollution as compared to white mothers; violence and increased risk of asthma in children; and stress and poor health outcomes (OEHHA, 2010; Payne-Sturges et al, 2006).

Selected Indicators

- Educational attainment (Figure 2, page 13)
- Income/poverty level (Figure 3, page 14)
- Race/ethnicity (Figure 4, page 15)

Sensitive populations component (Rank range 1–3)

A growing body of scientific literature has established that certain populations are more vulnerable to pollution because of their age (e.g., children and the elderly), pre-existing conditions (e.g., diabetes, cardiovascular disease, pregnancy), and/or cultural practices (e.g., subsistence fishing in contaminated rivers) (OEHHA, 2010).

Selected Indicators

- Presence of children (Figure 5, page 16)
- Presence of elderly (Figure 6, page 17)
- Number of foreign-born (Figure 7, page 18)

Table 1. Indicators Evaluated for Cumulative Health Impacts Analysis

Component	Indicator	Data Sources	Figure #
Socioeconomic Factors (Rank 1-3)	Percent Adults 25 and older Without a College Degree, by ZIP Code, Seattle, WA, 5-year Average 2006–2010	US Census Bureau, American Community Survey. Provided by Public Health-Seattle & King County; Assessment, Policy Development & Evaluation Unit.	2
	Percent Below 200% Poverty Level, by ZIP Code, Seattle, WA, 5-year Average 2006–2010	US Census Bureau, American Community Survey. Provided by Public Health-Seattle & King County; Assessment, Policy Development & Evaluation Unit.	3
	Percent Non-white Population, by ZIP Code, Seattle, WA, 2010	US Census Bureau, Census 2010	4
	Percent Adults (18-64 years) With No Health Insurance, by ZIP Code, Seattle, WA, 5-year Average 2007–2011	Behavioral Risk Factor Surveillance System (BRFSS)	A1
	Percent Adults With No Leisure Time Physical Activity, by ZIP Code, Seattle, WA, 5-year Average 2007–2011	Behavioral Risk Factor Surveillance System (BRFSS)	A2
Sensitive Populations (Rank 1-3)	Percent Presence of Children Under 5 years, by ZIP Code, Seattle, WA, 2010	US Census Bureau, Census 2010	5
	Percent Presence of Elderly 65 years and Older, by ZIP Code, Seattle, WA, 2010	US Census Bureau, Census 2010	6
	Percent Foreign-Born by ZIP Code, Seattle, WA, 5-year Average 2006–2010	US Census Bureau, American Community Survey. Provided by Public Health-Seattle & King County; Assessment, Policy Development & Evaluation Unit.	7
Environmental Exposures (Rank 1-10)	Annual Average Diesel Particulate Matter in Human Breathing Zone (ug/m^3), by ZIP Code, Seattle, WA, 2005	Environmental Protection Agency, Community-Focused Exposure Risk Screening Tool	8
	Annual Average Benzene in Human Breathing Zone (ug/m^3), by ZIP Code, Seattle, WA, 2005	Environmental Protection Agency, Community-Focused Exposure Risk Screening Tool	9
	Summed Site Ranking for Confirmed and Suspected Contaminated Sites, by ZIP Code, Seattle, WA	Washington State Department of Ecology, Toxics Cleanup Program, Washington Ranking Method	10
Environmental Effects (Rank 1-5)	Percent Tree Canopy, by ZIP Code, Seattle, WA	King County Department of Natural Resources and Parks, USGS National Land Cover Database	11
	Square Feet per Resident of Park Area by ZIP Code, Seattle, WA	King County Department of Natural Resources and Parks	12
	Number of Toxic Release Inventory Sites, by ZIP Code, Seattle, WA	Environmental Protection Agency, Enviromapper, Toxic Release Inventory	13
Public Health Effects (Rank 1-5)	Life Expectancy at Birth in Years, by ZIP Code, Seattle, WA, 5 year average, 2005–2009	Death Certificate Data: Washington State Department of Health, Center for Health Statistics. Public Health - Seattle & King County; Assessment, Policy Development & Evaluation	A3
	Percent Adults Overweight or Obese by ZIP Code, Seattle, WA, 5-year Average 2007–2011	Behavioral Risk Factor Surveillance System (BRFSS)	A4
	Heart Disease Death rate per 100,000, by ZIP Code, Seattle, WA, 5-year average, 2006–2010	Death Certificate Data: Washington State Department of Health, Center for Health Statistics.	14
	Stroke Death rate per 100,000, by ZIP Code, Seattle, WA, 5-year average, 2006–2010	Death Certificate Data: Washington State Department of Health, Center for Health Statistics.	A5
	Percent Adults With Doctor Diagnosed Diabetes by ZIP Code, Seattle, WA, 5-year Average 2007–2011	Provided by Public Health-Seattle & King County; Assessment, Policy Development & Evaluation Unit., BRFSS	A6
	Percent Adults with Hypertension, by ZIP Code, Seattle, WA, 2003–2011 odd years	Provided by Public Health-Seattle & King County; Assessment, Policy Development & Evaluation Unit., BRFSS	A7
	Childhood (0-17) Asthma Hospitalization Rate per 100,000, by ZIP Code, Seattle, WA, 5-year average, 2006–2010	Hospitalization Discharge Data: Washington State Department of Health, Office of Hospital and Patient Data Systems.	15
	Percent Adult Cigarette Smokers, by ZIP Code, Seattle, WA, 5-year Average 2007–2011	Provided by Public Health-Seattle & King County; Assessment, Policy Development & Evaluation Unit , BRFSS	A8
	Lung Cancer Death Rate Per 100,000, by ZIP Code, Seattle, WA, 5-year average, 2006–2010	Death Certificate Data: Washington State Department of Health, Center for Health Statistics.	16
	Assault Hospitalization Rate Per 100,000 , by ZIP Code, Seattle, WA, 5-year average, 2006–2010	Hospitalization Discharge Data: Washington State Department of Health, Office of Hospital and Patient Data Systems.	A9

Selected for Cumulative Impacts Analysis (Scenario 1)

Figure 2. Percent Adults 25 and older Without a College Degree, by ZIP Code Seattle, Washington, 5-year Average 2006-2010

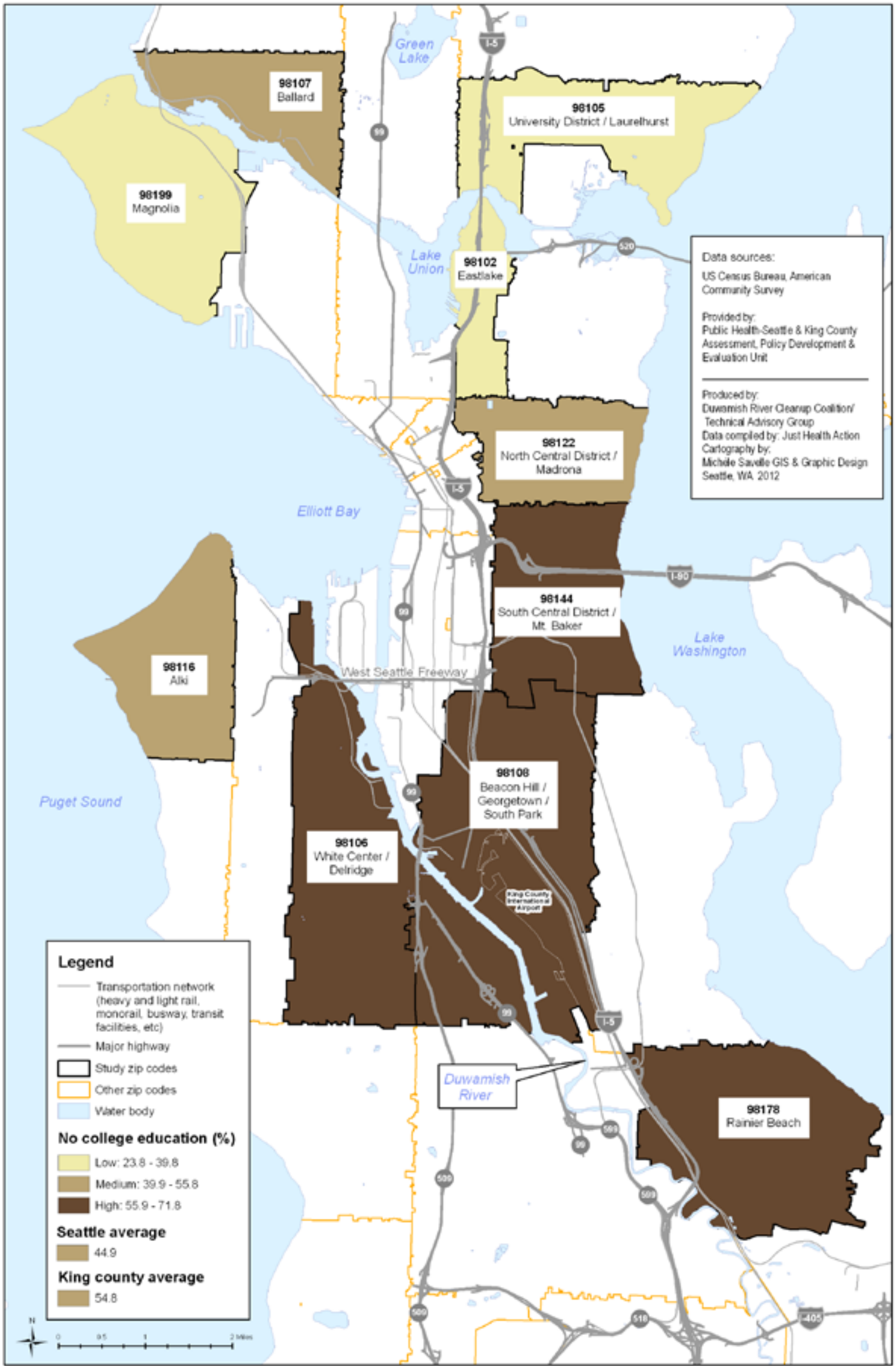


Figure 3. Percent Below 200% Poverty Level, by ZIP Code
Seattle, Washington, 5-year Average 2006-2010

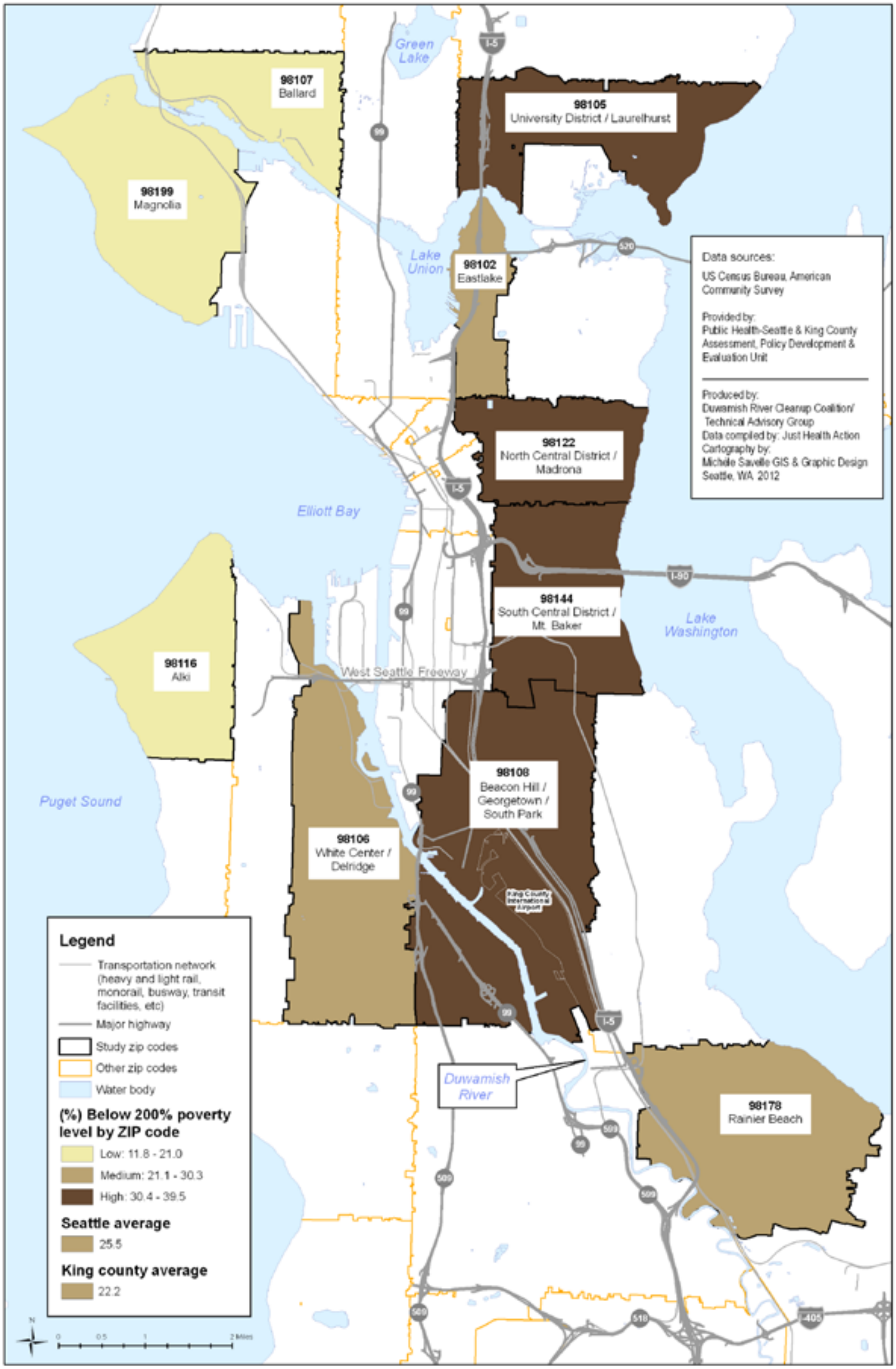


Figure 4. Percent Non-white Population, by ZIP Code
Seattle, Washington, 2010

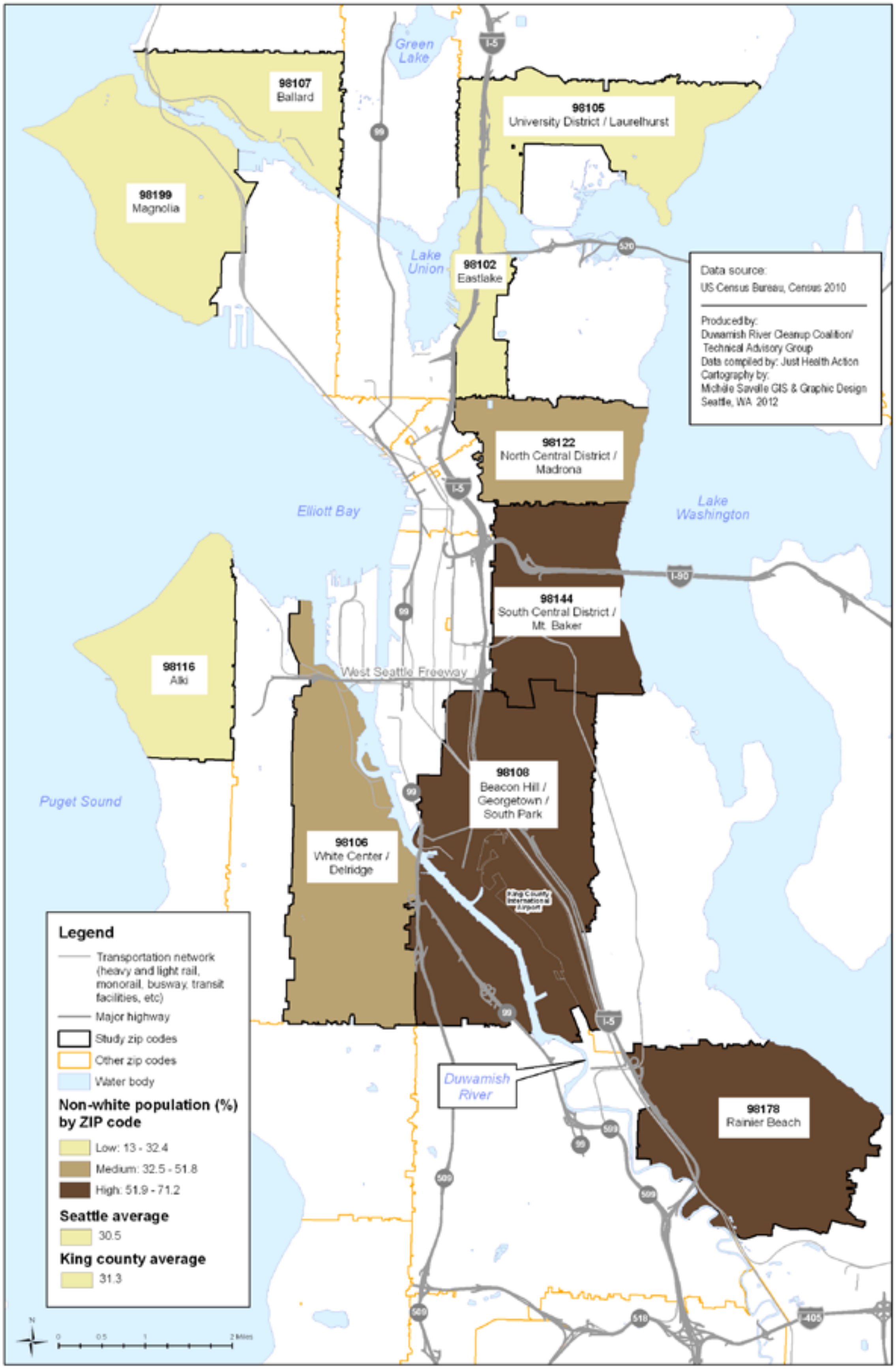


Figure 5. Percent Presence of Children Under 5 years, by ZIP Code
Seattle, Washington, 2010

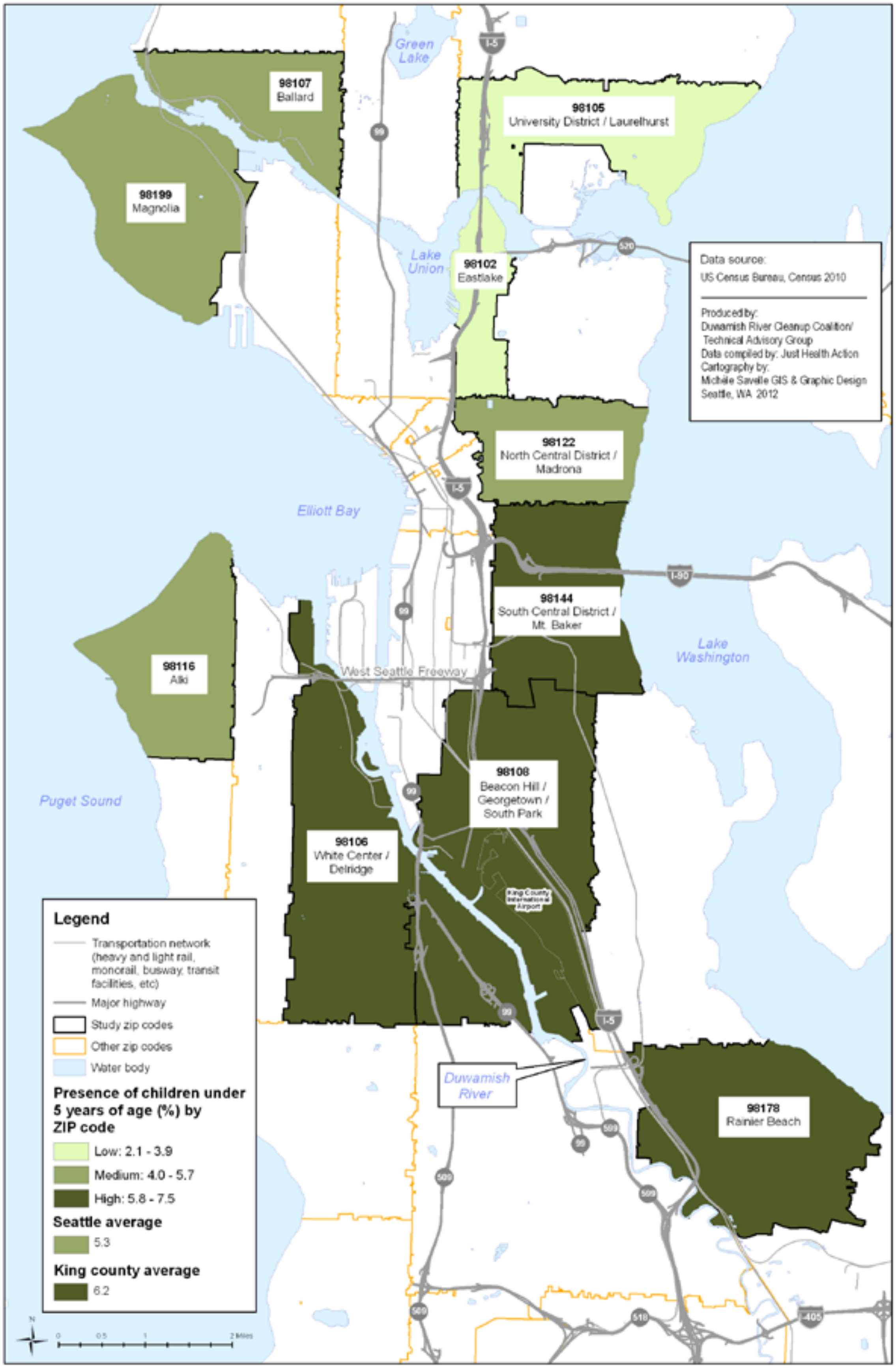


Figure 6. Percent Presence of Elderly 65 years and Older, by ZIP Code
Seattle, Washington, 2010

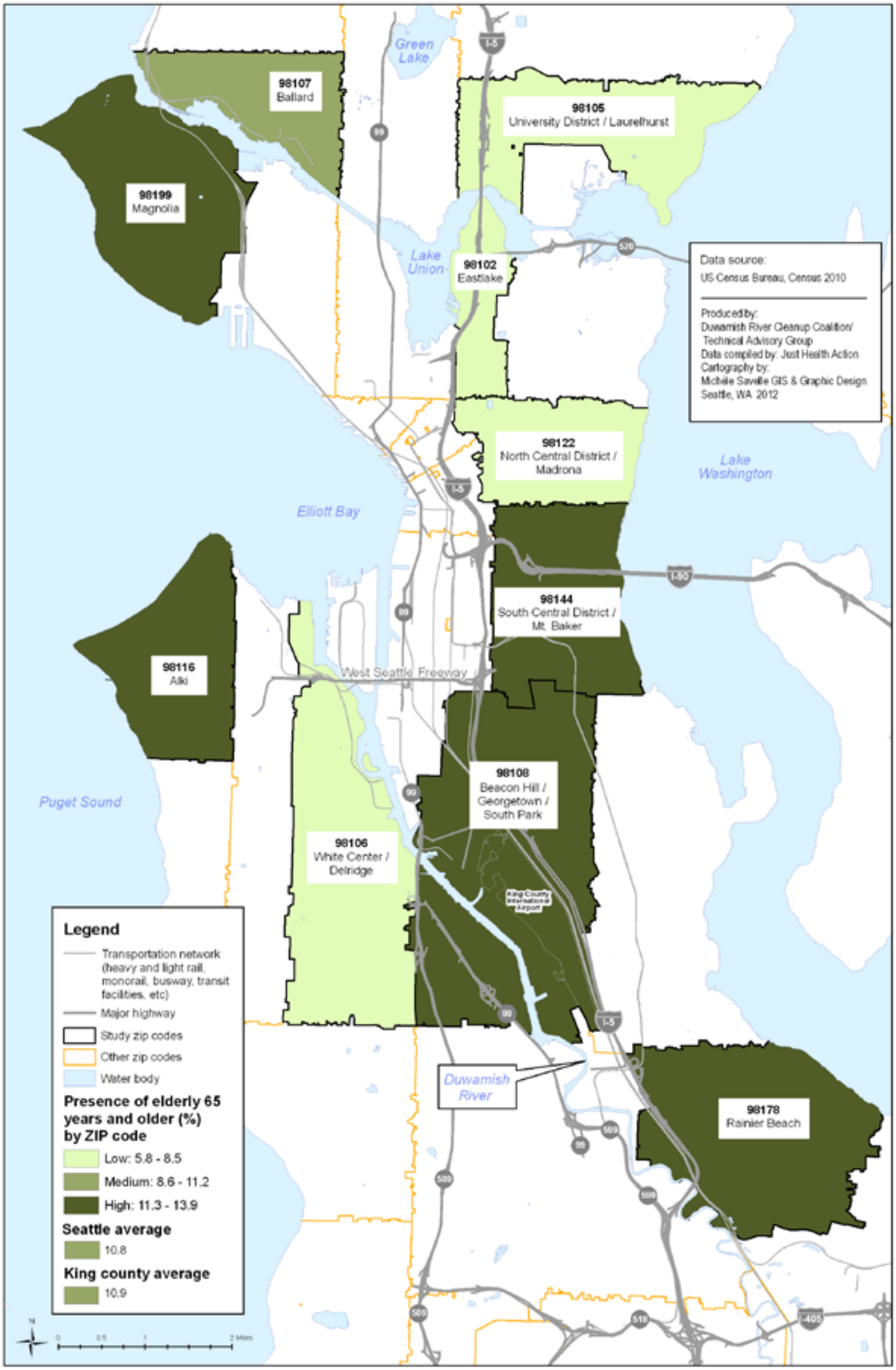


Figure 7. Percent Foreign-Born by ZIP Code
Seattle, Washington, 5-year Average 2006-2010

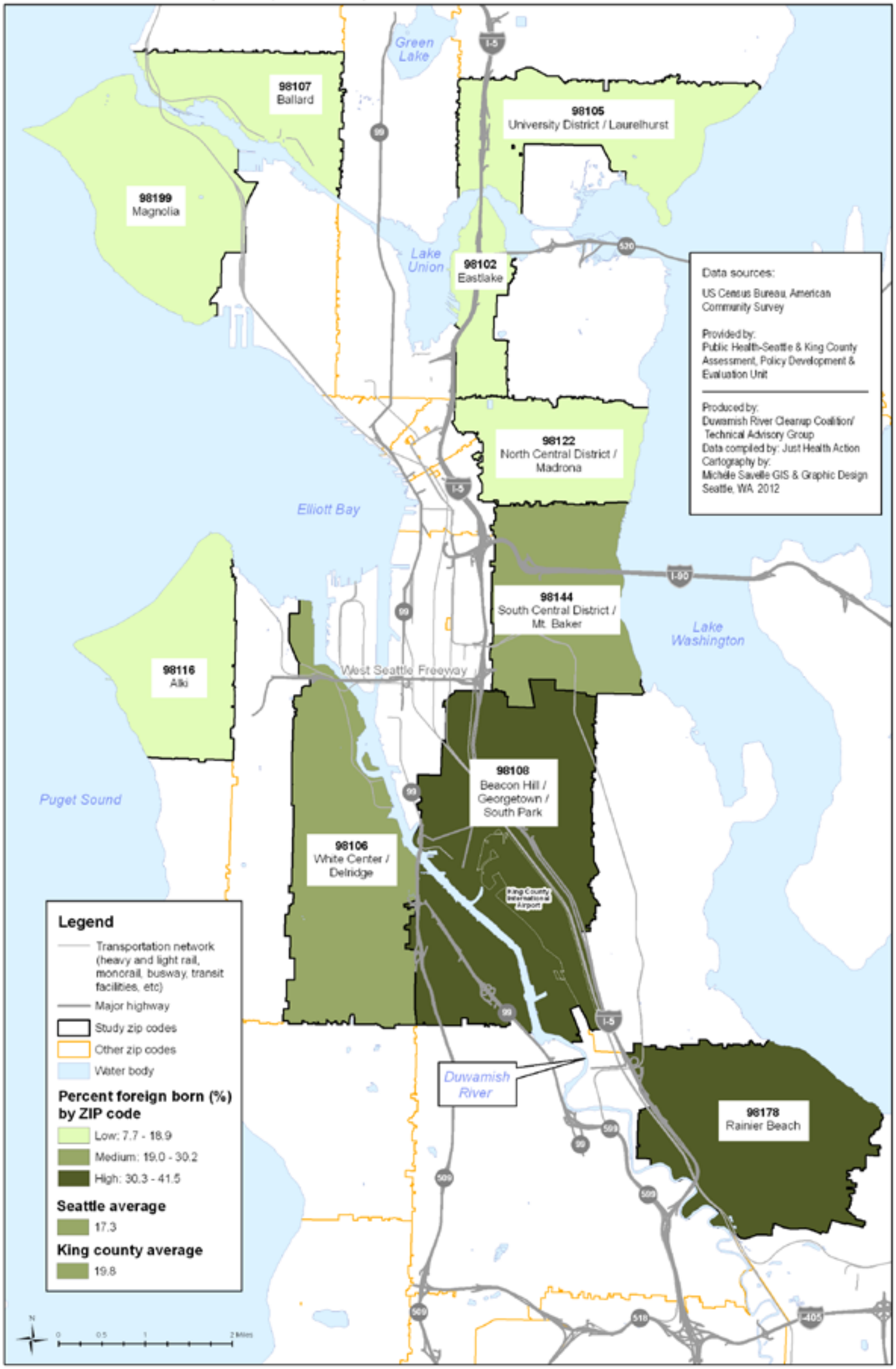


Photo: BJ Cummings

Certain populations are more vulnerable to pollution because of their age, pre-existing conditions, and/or cultural practices.

Environmental exposure component (Rank range 1–10)

Individuals can be exposed to contamination through various media (air, soils, sediments, ground water, surface water) by coming into contact with a chemical or physical agent. Examples of exposure are ingestion, inhalation, and direct contact (e.g., on the skin) with a pollutant. There is little research available that establishes a firm causal connection between contaminant exposures and health outcomes because of long latency periods, lack of body burden markers, and exposure to multiple possible causes of illness (Payne-Sturges et al, 2006). However, the health risks (potential for disease) of exposure to many pollutants is well understood, and it is well established that low-income and/or minority populations are disproportionately exposed to pollution and increased health risks because of their proximity to pollution sources such as industrial facilities, highways, low income housing (e.g, lead), and agricultural areas (e.g., pesticide application) (OEHHA, 2010).

Selected Indicators

- Concentration of diesel particulate mater in air (Figure 8, page 20)
- Concentration of benzene in air (Figure 9, page 21)
- Number and severity of confirmed and suspected contaminated sites (Figure 10, page 22)

Environmental effects component (Rank range 1–5)

Where a person lives affects their health, but not all communities are equal with respect to their exposure to pollution and access to resources or benefits that can make a community more or less healthy (http://www.kingcounty.gov/exec/equity.aspx). In addition to concerns about industry pollution, noise, and traffic, Duwamish Valley residents expressed concern through a Community

Figure 8. Annual Average Diesel Particulate Matter in Human Breathing Zone (ug/m^3), by ZIP Code Seattle, Washington, 2005

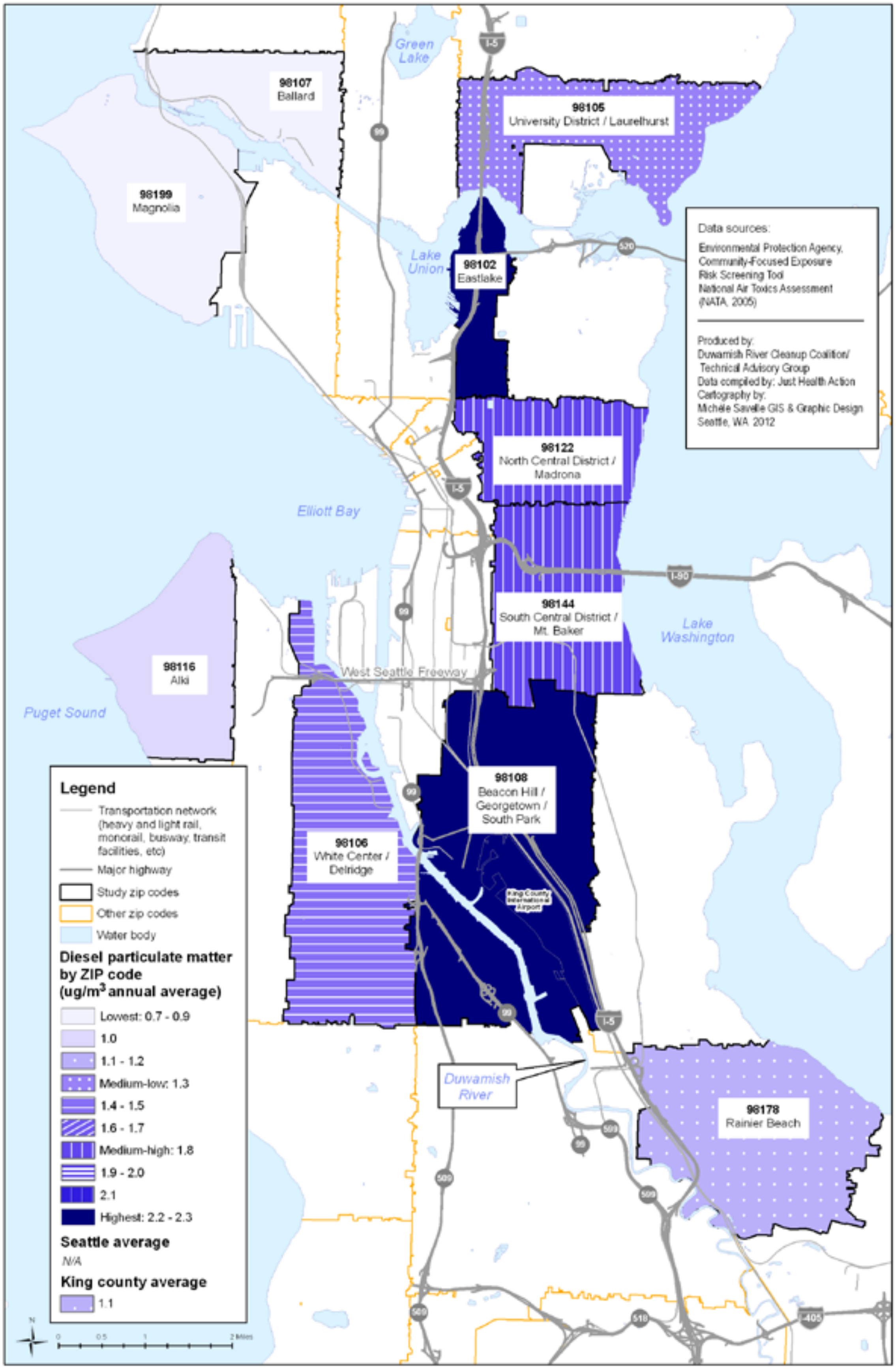


Figure 9. Annual Average Benzene in Human Breathing Zone (ug/m^3), by ZIP Code Seattle, Washington, 2005

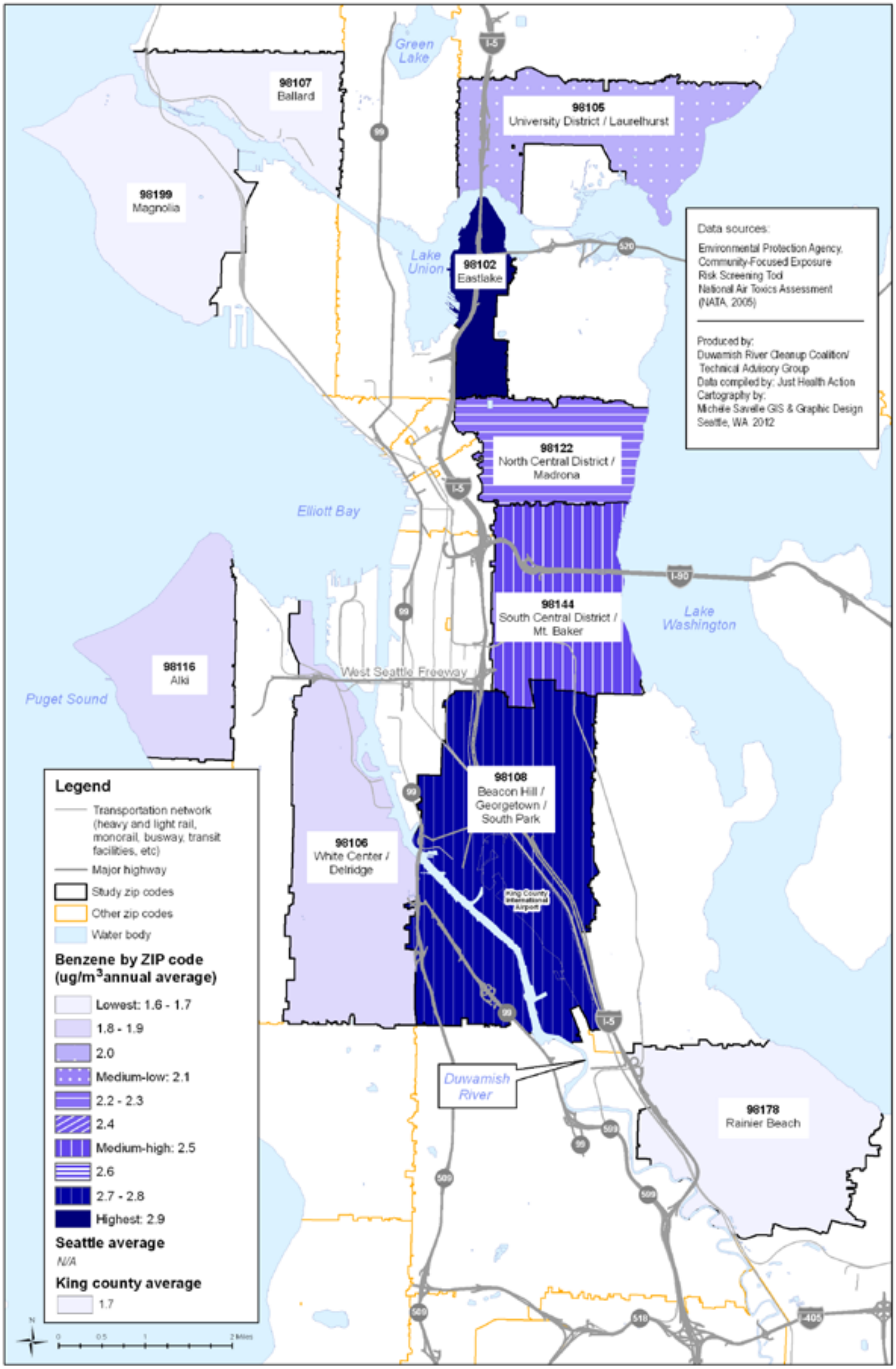


Figure 10. Summed Site Ranking for Confirmed and Suspected Contaminated Sites, by ZIP Code
Seattle, Washington

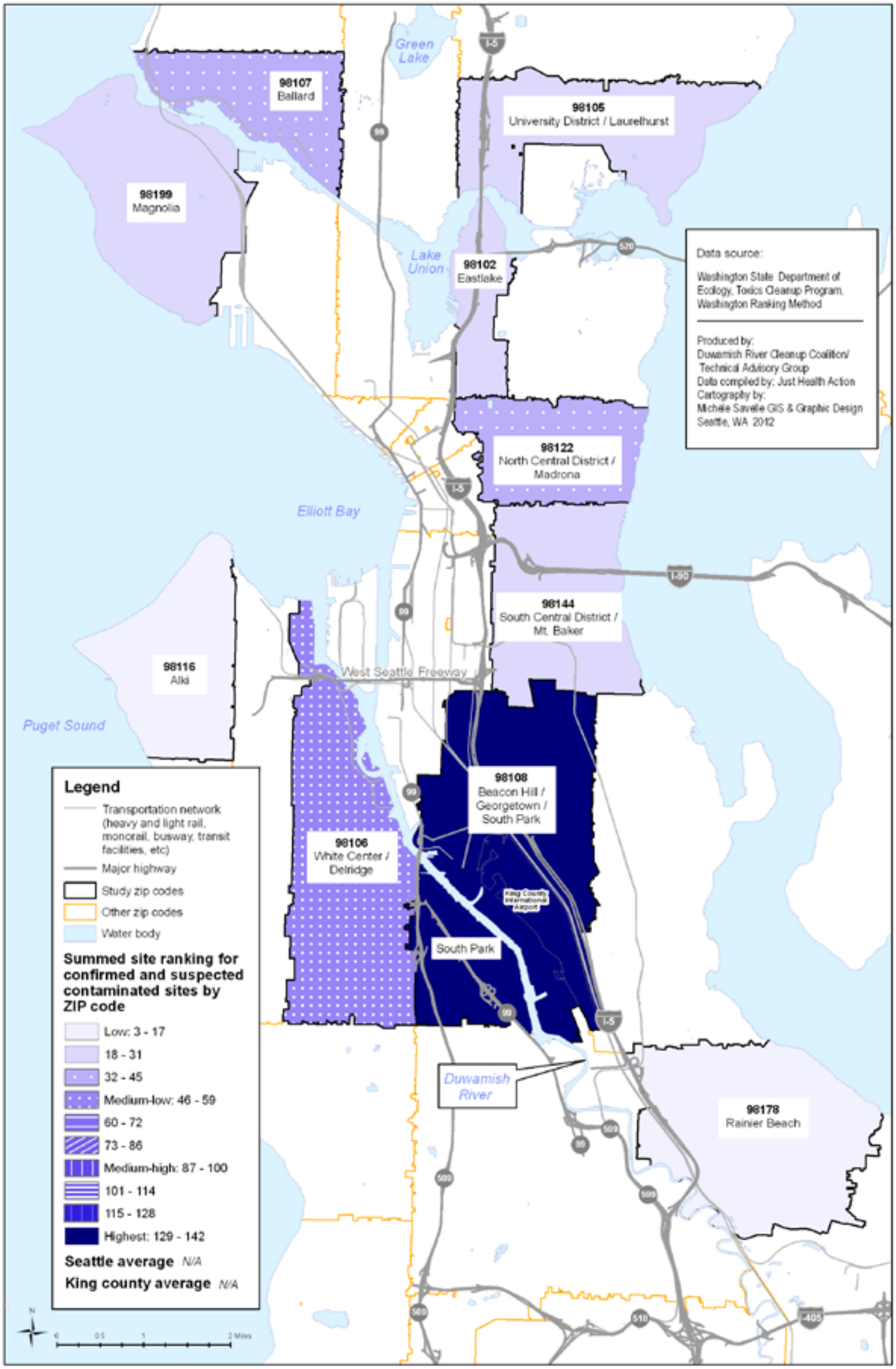


Photo: Paul Joseph Brown

Where you live affects your health

Based Participatory Research (CBPR) project (described in Appendix B) that they lacked adequate access to healthy food, green space, and places to play or exercise.

Selected Indicators

- Amount of forest canopy (Figure 11, page 24)
- Amount of park area per resident (Figure 12, page 25)
- Number of Toxic Release Inventory sites (Figure 13, page 26)[2]

Public health component (Rank range 1–5)

Health disparities have been well documented in the United States and locally and are the focus of growing community and government attention (CDC, 2011; Governor's Interagency Council on Health Disparities, 2012). Numerous public health indicators were compiled and reviewed for statistical significance and stability as well as alignment with the community's identified health concerns through the CBPR project.

Selected Indicators

- Heart disease (Figure 14, page 27)
- Childhood asthma (Figure 15, page 28)
- Lung cancer (Figure 16, page 29)

[2] Toxic Release Inventory (TRI) sites are those listed on EPA's database of facilities with large volumes of toxic chemical releases.

Figure 11. Percent Tree Canopy, by ZIP Code
Seattle, Washington

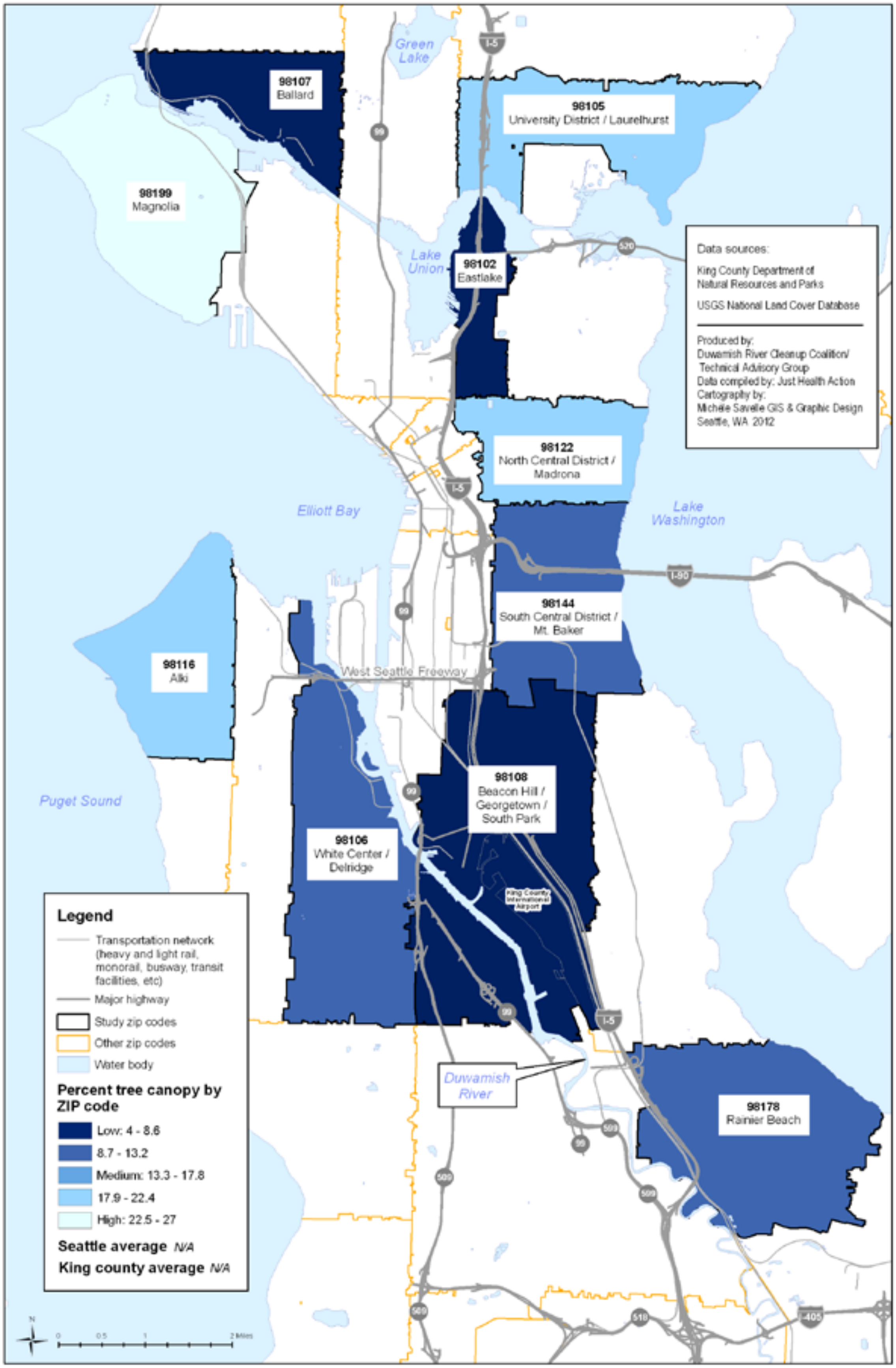


**Figure 12. Square Feet per Resident of Park Area, by ZIP Code
Seattle, Washington**

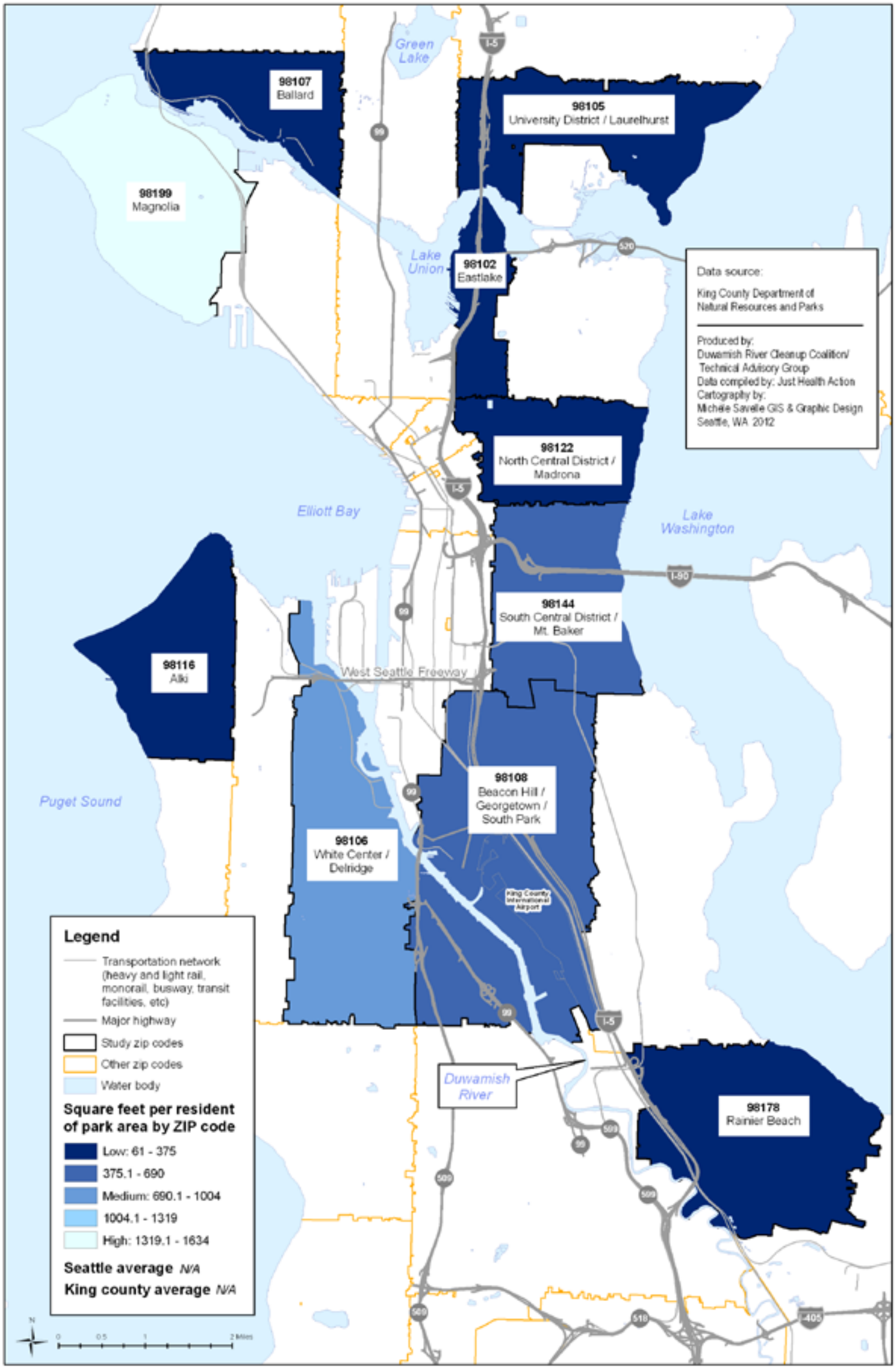


Figure 13. Number of Toxic Release Inventory Sites, by ZIP Code
Seattle, Washington

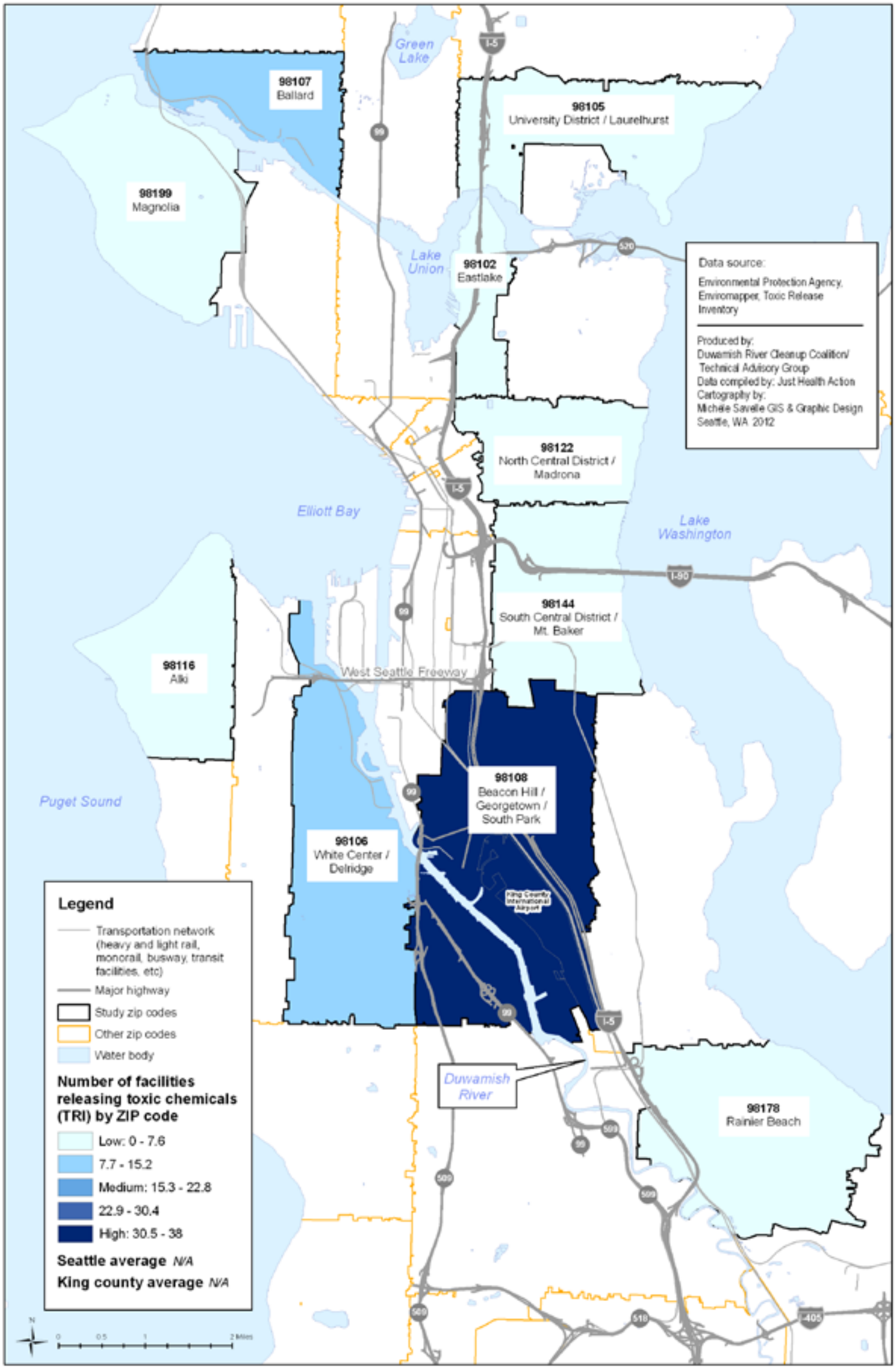


**Figure 14. Heart Disease Death rate per 100,000, by ZIP Code
Seattle, Washington, 5-year average, 2006-2010**

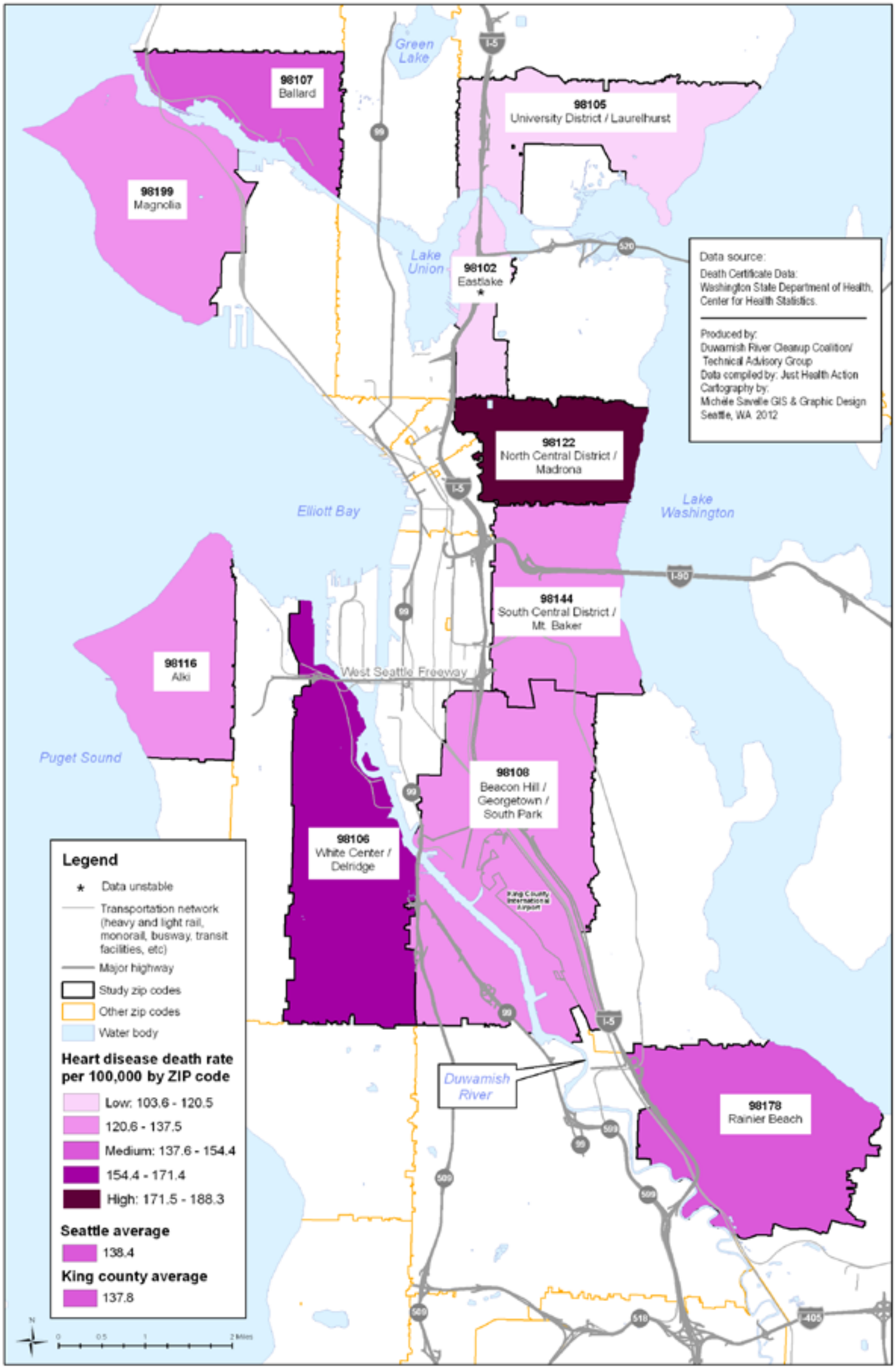


Figure 15. Childhood (0-17) Asthma Hospitalization Rate per 100,000, by ZIP Code
Seattle, Washington, 5-year average, 2006-2010

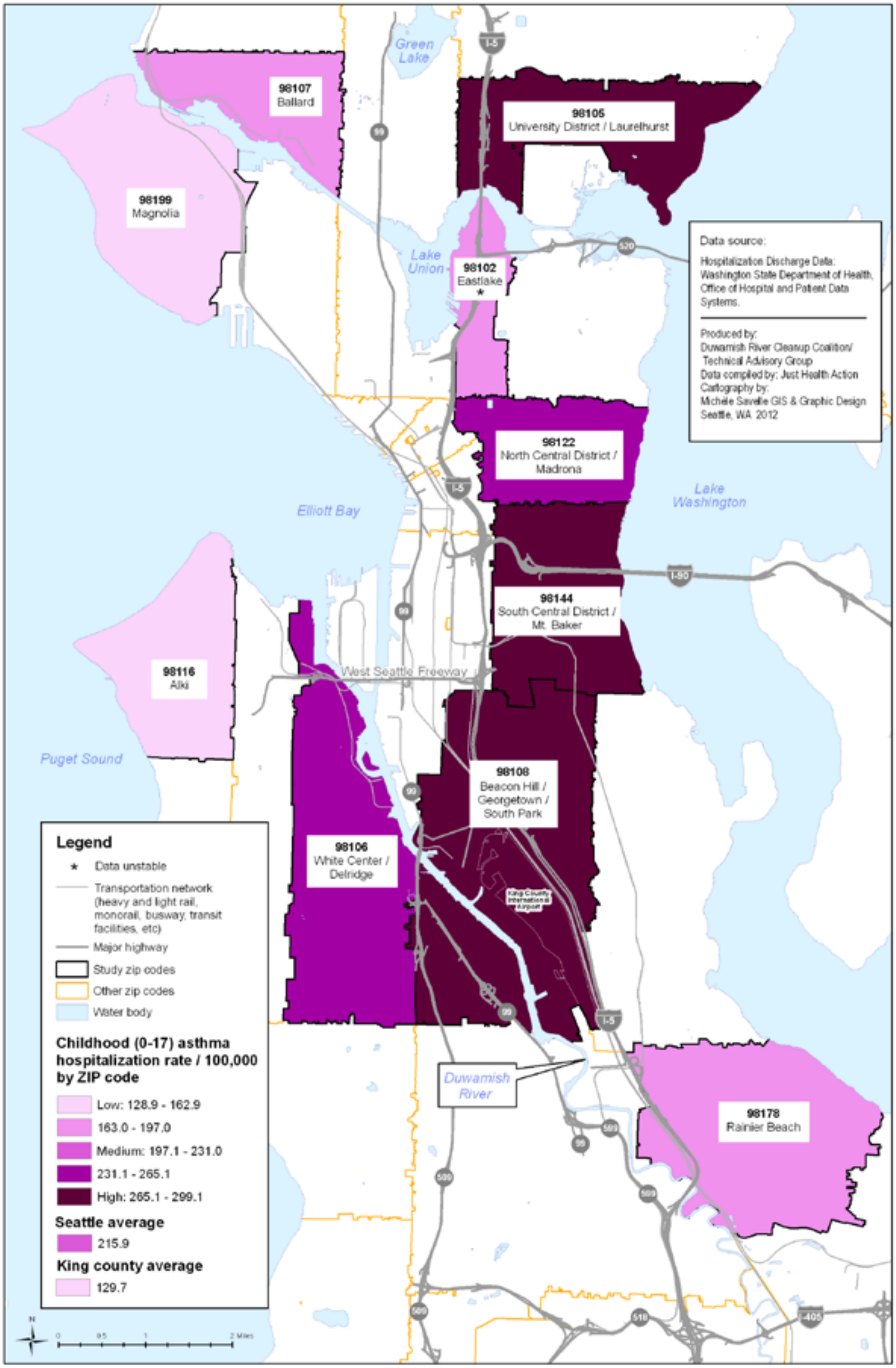
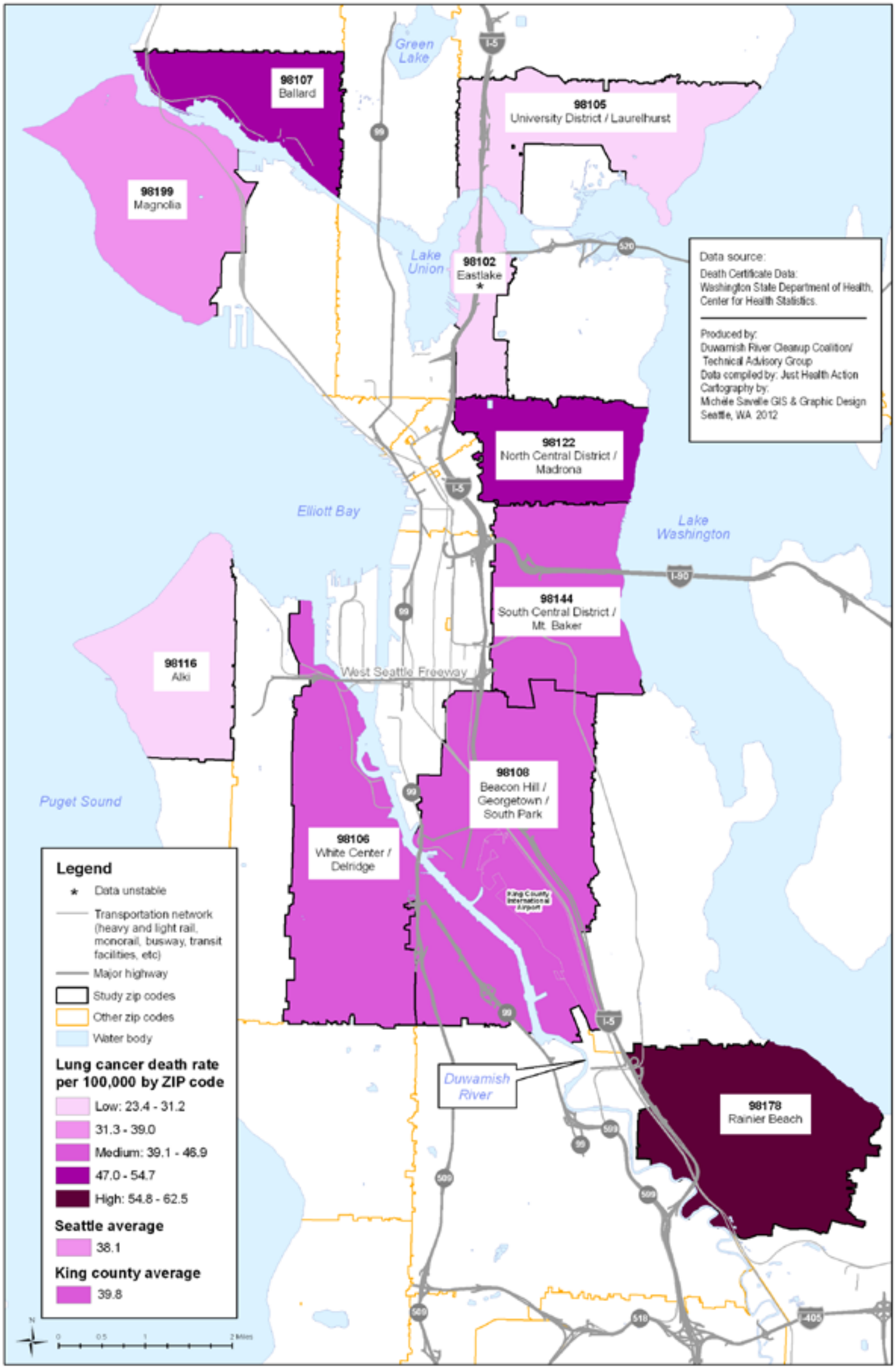


Figure 16.Lung Cancer Death Rate Per 100,000, by ZIP Code Seattle, Washington, 5-year average, 2006-2010



V. Cumulative Impacts Analysis Results

Data for each of the selected indicators described above were ordered from high to low, divided into equivalent portions based on the range of collected data, and assigned the corresponding rankings shown in Figures 2–16 and Table 2 (page 31). In calculating the cumulative impact score, the rank sums for each indicator were first averaged for each component. For example, for the socioeconomic factors component (Rank range 1–3) in the 98108 ZIP code (Beacon Hill/Georgetown/South Park), percent college education, percent below 200% of poverty level, and percent non-white minority each received a rank of 3. The 3 indicators were totaled (3+3+3=9) and then averaged, giving the 98108 ZIP code a socioeconomic factors rank of 3 (Table 2, page 31). In Table 2, each component is color coded to match the color spectrum used in Figures 2–17: the darker the coloring, the higher ranking the characteristic, or contribution to the overall cumulative impact. For example, for the socioeconomic factors component, which is color coded in a brown spectrum, the 98108 ZIP code is a 3 and dark brown, while a 1 ranking has a light tan color.

Social Vulnerability

Socioeconomic Factors component (Rank range 1–3)

Based on a ranking of 1–3, Table 2 shows that 3 ZIP codes (98108, Beacon Hill/Georgetown/South Park; 98144, Central District; and 98178, Rainier Beach) were each given the highest average ranking of 3 for the socioeconomic factors component (No college education; Percent below 200% poverty level; Percent non-white minority population).

Photo: Aiden Duffy

Table 2. Cumulative Health Impacts Analysis, by ZIP code, Seattle, Washington (colors correspond to color keys in Figures 2–17)

Component	Indicator	98108 Beacon Hill/ Georgetown/ South Park	98144 S. Central District/ Mt. Baker	98178 Rainier Beach	98106 White Center/ Delridge	98122 N. Central District/ Madrona	98102 Eastlake	98107 Ballard	98105 University District/ Laurelhurst	98116 Alki	98199 Magnolia
Socioeconomic Factors (Rank 1–3)	No college education (%)	3	3	3	3	2	1	2	1	2	1
	Below 200% poverty level (%)	3	3	3	2	3	2	1	3	1	1
	Non-white minority population (%)	3	3	3	2	2	1	1	1	1	1
	Adults with no health insurance (%)	*	*	*	*	*	*	*	*	*	*
	Adults with no leisure time (%)*	*	*	*	*	*	*	*	*	*	*
	Average	3	3	3	2	2	1	1	2	1	1
Sensitive Populations (Rank 1–3)	Children under 5 years (%)	3	3	3	3	2	1	2	1	2	2
	Elderly—65 years and older (%)	3	3	3	1	1	1	2	1	3	3
	Foreign born (%)	3	2	3	2	1	1	1	1	1	1
	Average	3	3	3	2	1	1	2	1	2	2
Social Vulnerability	*SUM (Socioeconomic + Sensitive Populations)*	6	6	6	4	4	2	3	3	3	3
Environmental Exposures (Rank 1–10)	Diesel particulate matter (ug/m³ annual average)	10	6	3	5	6	10	1	4	2	1
	Benzene (ug/m³ annual average)	9	7	1	2	5	10	1	3	2	1
	Confirmed and suspected contaminated sites (ISIS)	10	2	1	4	3	2	3	2	1	2
	Average	10	5	2	4	5	7	2	3	2	1
Environmental Effects (Rank 1–5)	Tree canopy (%)	5	4	4	4	2	5	5	2	2	1
	Park area per resident	4	4	5	3	5	5	5	5	5	1
	Number of toxic release inventory sites	5	2	1	3	1	2	4	1	1	2
	Average	5	3	3	3	3	4	5	3	3	1
Public Health Effects (Rank 1–5)	Live expectancy at birth (years)	*	*	*	*	*	*	*	*	*	*
	Adults overweight or obese (%)	*	*	*	*	*	*	*	*	*	*
	Heat disease death rate per 100,000	2	2	3	4	5	1	3	1	2	2
	Stroke death rate per 100,000	*	*	*	*	*	*	*	*	*	*
	Adults—doctor-diagnosed diabetes (%)	*	*	*	*	*	*	*	*	*	*
	Adults—hypertension (%)	*	*	*	*	*	*	*	*	*	*
	Childhood (0-17) asthma hospitalization rate per 100,000	5	5	2	4	4	2	2	5	1	1
	Adult cigarette smokers (%)	*	*	*	*	*	*	*	*	*	*
	Lung cancer death rate per 100,000	3	3	5	3	4	1	4	1	1	2
	Average	3	3	3	4	4	1	3	2	1	2
Environmental Vulnerability	*SUM (Environmental Exposures + Environment Effects + Public Health Effects)*	18	12	8	11	12	13	9	8	6	4
IMPACT SCORE	*(Social Vulnerability x Environmental Vulnerability)*	106	66	50	46	43	30	28	21	19	13

* These indicators were evaluated and can be viewed in Appendix A.

Sensitive Populations Component (Rank range 1–3)

Table 2 (page 31) shows that sensitive populations (presence of children under 5 years, presence of elderly, and percent foreign born) were given the highest average ranking of 3 in the same three ZIP codes (98108, 98144, and 98178) as for the socioeconomic factors component.

Social vulnerability is the sum of the socioeconomic factors component rank plus the sensitive populations component rank and can range from 2–6 for the ten Seattle ZIP codes. ZIP codes 98108 (Beacon Hill/Georgetown/South Park), 98144 (Central District), and 98178 (Rainier Beach), received the highest ranking of 6 while the lowest ranked was 98102 (Eastlake), with a ranking of 2, as shown in Table 2.

Environmental Vulnerability

Environmental Exposures component (Rank range 1–10)

The environmental exposures component includes exposure to airborne diesel particulate matter and benzene via inhalation, as well as the potential to be exposed to nearby confirmed and suspected contaminated waste sites. Table 2 (page 31) shows that two areas of Seattle—Eastlake (98102) and Beacon Hill/Georgetown/South Park (98108)—have particularly high exposures to air pollution. In addition, 98108 has the highest exposure to contaminated waste sites. When the three indicators are summed, averaged and ranked from 1–10, 98108 receives the highest ranking of 10, followed by 98102 with a ranking of 7. Magnolia (98199) with a ranking of 1, has the lowest environmental exposures ranking.

Environmental Effects component (Rank range 1–5)

The environmental effects component consists of three built environment attributes: percent tree canopy, amount of park area per resident, and proximity to Toxic Release Inventory Sites, and is ranked from 1–5. Table 2 shows that two areas of Seattle—Beacon Hill/Georgetown/South Park (98108) and Ballard (98107)—have the poorest built environment characteristics, with a ranking of 5. Magnolia (98199) has the best built environment attributes, with a ranking of 1.

Public Health Effects Component (Rank range 1–5)

The three indicators used to make up the public health effects component are heart disease death rates, childhood asthma hospitalization rates, and lung cancer death rates, with a ranking from 1 to 5. White Center (98106) and North Central District/Madrona (98122) had the highest public health effects, with a ranking of 4; the lowest public health effects, with a ranking of 1, are in Eastlake (98102) and Alki (98116). Beacon Hill/Georgetown/South Park (98108) ranked as 3.

Environmental vulnerability is the sum of the environmental exposures component, plus the environmental effects component, plus the public health effects component, and can range from 3 to 20. Beacon Hill/Georgetown/South Park (98108) had the highest ranking of 18, as shown in Table 2. The next highest environmental vulnerability ranking was 13, for Eastlake (98102), and the lowest was for Magnolia (98199), with a ranking of 4.

Photo: Cari Simson

Cumulative Impacts

The cumulative health impact scores for the ten Seattle ZIP codes are shown in Table 3 (page 34) and Figure 17 (page 35).

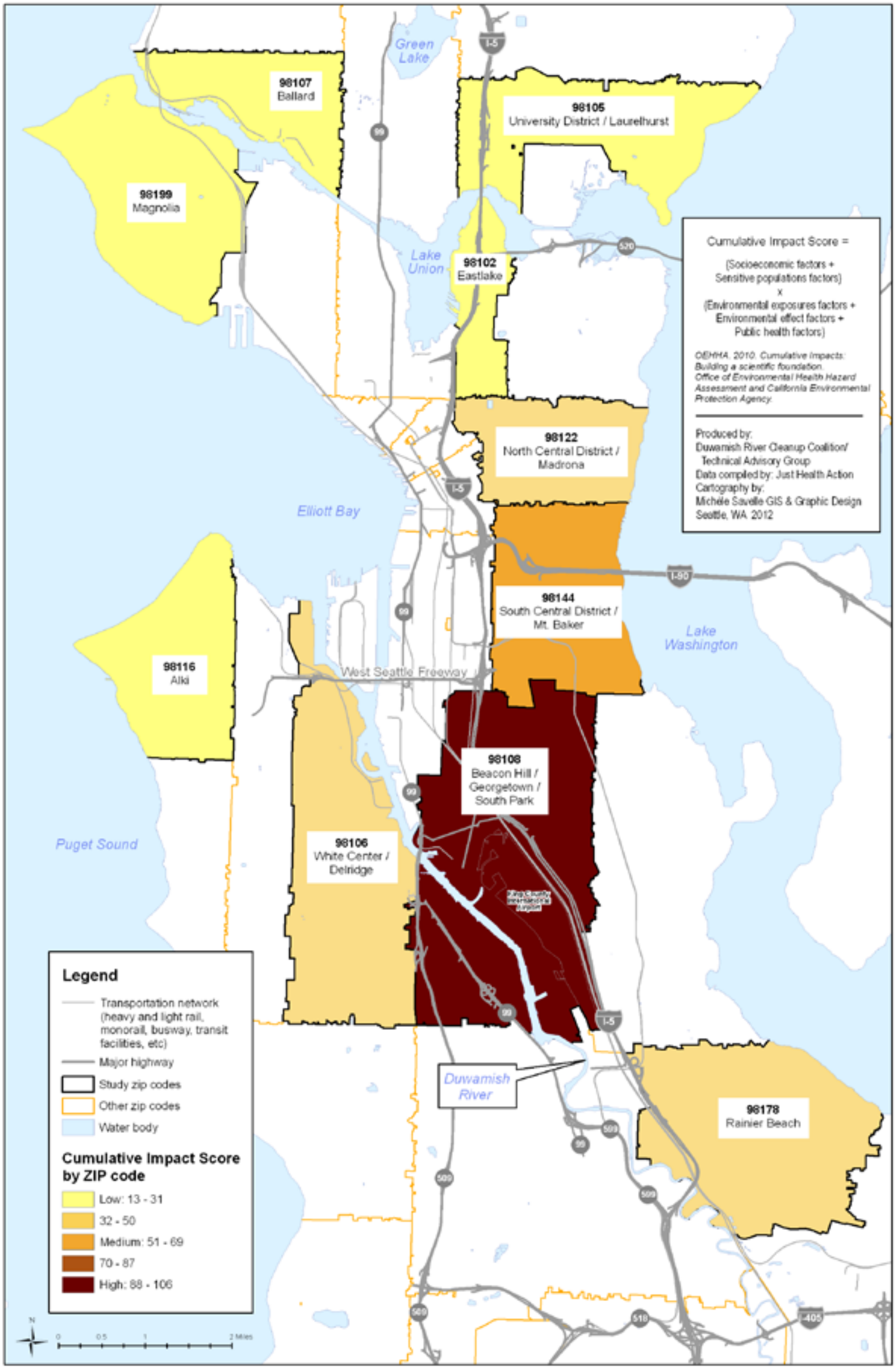
> Cumulative Impact = (Socioeconomic factors + Sensitive populations) x
> (Environmental exposures + Environmental effects + Public health effects)

In a cumulative impact range of 6 to 120, the highest cumulative score is 106 for ZIP code 98108 (Beacon Hill/Georgetown/South Park). The high score indicates that this area is burdened with disproportionately greater impacts relative to the other areas of Seattle. South Central District/Mt. Baker (98144), receives the second highest score of 66. Rainier Beach (98106), White Center/Delridge (98106), and North Central District/Madrona (98122) receive medium-low scores of 50, 46, and 43, respectively. Eastlake (98102), Ballard (98107), University District/Laurelhurst (98105), Alki (98116), and Magnolia (98199) all receive relatively low cumulative impact scores of 30, 28, 21, 19, and 13, respectively.

Table 3. Cumulative Health Impacts Analysis, by ZIP code, Seattle, Washington (colors correspond to color keys in Figures 2–17)

Component	98108 Beacon Hill/ Georgetown/ South Park	98144 S. Central District/ Mt. Baker	98178 Rainier Beach	98106 White Center/ Delridge	98122 N. Central District/ Madrona	98102 Eastlake	98107 Ballard	98105 University District/ Laurelhurst	98116 Alki	98199 Magnolia
Socioeconomic Factors	3	3	3	2	2	1	1	2	1	1
Sensitive Populations	3	3	3	2	1	1	2	1	2	2
Social Vulnerabillity	6	6	6	4	4	2	3	3	3	3
Environmental Exposures	10	5	2	4	5	7	2	3	2	1
Environmental Effects	5	3	3	3	3	4	5	3	3	1
Public Health Effects	3	3	3	4	4	1	3	2	1	2
Environmental Vulnerability	18	12	8	11	12	13	9	8	6	4
CUMULATIVE IMPACT SCORE	106	66	50	46	43	30	28	21	19	13

Figure 17. Cumulative Impact Score by ZIP Code, Seattle, Washington



VI. Other Lines of Evidence

While the Cumulative Health Impacts Analysis (CHIA) used 15 indicators (3 indicators per component) to measure cumulative impacts, other indicators were reviewed to examine disparities and are shown in Appendix A (www.duwamishcleanup.org/programs/duwamish-community-health-initiative). Figures A1–A9 show that residents of Beacon Hill/Georgetown/South Park (98108 ZIP code) have additional disparities, including the highest ranking in percent adults with no health insurance, percent adults with no leisure time, and stroke death rate. ZIP code 98108 also ranks medium high in assault hospitalization rates, percent adults with hypertension, percent adults overweight or obese and medium in life expectancy, percent adult cigarette smokers, and percent adults with doctor diagnosed diabetes.

While this report analyzed data at the ZIP code level, other data, where available and statistically stable, were reviewed at two other geographic levels: (1) the greater Duwamish Valley watershed, a geographic area that extends from the southern part of Elliott Bay to as far south as the southern end of the Beacon Hill ridge; and (2) the Georgetown and South Park neighborhoods. The greater Duwamish Valley data set is large and therefore contains more statistically stable data. The South Park/Georgetown data set, which is composed of two census tracts, is smaller and therefore contains fewer statistically significant and stable indicators.

Duwamish Valley Watershed

The total population included in the greater Duwamish Valley watershed is approximately 132,000, using 2010 census data. In 2011, Public Health-Seattle & King County's Policy Development & Evaluation Unit conducted a health and demographics analysis of the Duwamish Valley using this geographic scale (Appendix C–Table 3, online). In comparing the greater Duwamish Valley to King County residents, greater Duwamish Valley residents are more likely to live in poverty (17.6% vs. 9.7%), be foreign born (31.9% vs. 19%), not attend high school (20.1% vs. 8.2%), have no bachelor's degree (75.4% vs. 55.2%), have no health insurance (20% vs. 13%), and have no leisure time physical activity in the past month (24% vs. 15%). All of these differences are statistically significant. [3]

Low birth weight is an indicator commonly used to illustrate racial and income health disparities between populations because it is major factor for several chronic diseases of adulthood and is linked to long-term health effects, including intergenerational health outcomes (Collins et al, 2002; OEHHA, 2010). The low birth weight difference between greater Duwamish Valley and King County residents is also statistically significant (6.0% vs. 4.9%).

In terms of mortality characteristics represented as a rate per 100,000, lung cancer (52.3 vs. 41.4), unintentional injuries (41.3 vs. 32.7), and homicide (10.5 vs. 3.4) are significantly higher in the greater

[3] Statistical significance in this report is based on a 95% confidence interval.

Duwamish Valley than in King County overall. With regard to hospitalization rates per 100,000, Duwamish Valley residents are more likely to be hospitalized for asthma than King County residents (youth under 18 [240.4 vs. 143.4] and adults [83.4 vs. 53.6]) and more likely to be hospitalized for assault (70.9 vs. 31). In addition to air pollution, there is evidence that increased anxiety and violence can trigger asthma attacks (Wright et al, 2004).

Life expectancy, often used as a measure of overall health and well being, is significantly lower in the greater Duwamish Valley, compared to the King County average (79.4 vs. 81.5).

Georgetown and South Park

The neighborhoods of Georgetown and South Park have a total population of of approximately 5,160 (2010 Census) and are represented by two census tracts (109 and 112). Heart disease and life expectancy data available and statistically stable at the census tract level suggest that Georgetown and South Park residents' health characteristics are worse than portrayed by the 98108 ZIP code data. For example, although the heart disease death rate (Figure 14, page 27) for the 98108 ZIP code is ranked medium-low (2) relative to the other ten ZIP codes, a closer examination of data available for

Photo: Paul Joseph Brown

Duwamish Valley residents are more likely to be hospitalized for asthma than King County residents overall.

> Life expectancy in Laurelhurst is 86.4 years, a full 13 years longer than for Georgetown and South Park residents.

the South Park and Georgetown census tracts show a greater health disparity. Heart disease death rates in South Park and Georgetown between 2006–2010 were 202.9 per 100,000, which falls above the highest range in the CHIA (171–188).

Residents of 98108 have an average life expectancy of 80.8 years, which is ranked as a 3, or medium (80.7–82.6 years), and is similar to both the Seattle and King County average. However, census tract data show that in Georgetown and South Park, life expectancy is 73.3 years, which is significantly lower than the Seattle and King County average of 81.5. Additionally, Georgetown and South Park residents often compare their circumstances to other Seattle neighborhoods that they perceive as more privileged, such as Laurelhurst, a relatively wealthy lakefront community located in the 98105 ZIP code. Life expectancy in Laurelhurst is 86.4 years, a full 13 years longer than for Georgetown and South Park residents.

Photo: Joe Mabel/wikipedia.com

VII. Duwamish Valley CHIA Limitations

Although the findings of this report are significant, these data have limitations. First, although the majority of data are by ZIP code, this geographical unit of analysis is not ideal for examining neighborhood differences. For example, only the residents of the west slope of Beacon Hill, which is a part of ZIP code 98108 but across the I-5 corridor from the river, live in the Duwamish Valley. It is likely that residents of Beacon Hill do not have the same exposure to contamination in the Duwamish Valley as do those in Georgetown and South Park. In addition, health data can vary by neighborhoods within the same ZIP code, as demonstrated by the limited available census tract data discussed in Section VI. Due to the availability and use of ZIP code data, the Cumulative Health Impacts Analysis (CHIA) results represent the combined characteristics of the Beacon Hill, Georgetown, and South Park neighborhoods in the 98108 ZIP code, obscuring any differences among those neighborhoods.

A second limitation of the Seattle CHIA is that the study was limited to only ten Seattle ZIP codes. It is possible that other ZIP codes merit scrutiny with regard to health disparities and/or that some disparities in environmental regulations, policies, and practices have been missed. Despite this concern, this CHIA selected ZIP codes that capture a representative range of income levels, minority vs. white status, contaminated vs. uncontaminated environments, and related community concerns, addressing the US Environmental Protection Agency's (EPA) mandate for analyzing cumulative impacts, environmental heath disparities, and environmental justice.

Third, this ranking methodology is relative. This means that it is not accurate to say that Beacon Hill/ Georgetown/SouthPark (98108) with a rank of 106 is 1.6 times worse than the next highest ranking area of South Central District/Mt Baker (98144) with a rank of 66. However, it indicates that from a cumulative health impacts perspective, residents of ZIP code 98108 are disproportionately affected by multiple stressors compared to other Seattle neighborhoods.

Fourth, the indicators that were selected for analysis and the ranking applied to each component could be considered subjective or biased. To test validity, the cumulative impact algorithm was quality checked in two ways. First, an alternative cumulative impacts scenario using all indicators shown in Table 1 (page 12) was run through the cumulative impacts equation, averaged according to the number of indicators entered for each component, and a ranking for each ZIP code was calculated (Appendix A–Table A-1, online). Another cumulative impacts scenario was tested in which the environmental exposures ranking range was changed from 10 to 5, which would alter the possible range of cumulative scores from 1 through 90 (Table A-2). In both of these alternate scenarios, the ranking numbers changed by only a few points and the relative order of the ten ZIP code rankings remained unchanged, validating the CHIA results using the selected indicators.

VIII. Conclusions and Next Steps

The Duwamish Valley Cumulative Health Impacts Analysis (CHIA) supports the identification of Seattle's 98018 ZIP code (Beacon Hill/Georgetown/South Park) as a geographic area with disproportionate health burdens and fewer environmental benefits as compared with other areas of Seattle. These disproportionate burdens are a result of the cumulative impact of social and environmental vulnerabilities, including socioeconomic factors, sensitive populations, environmental exposures and effects, and public health effects. When indicators representing all of these impacts are taken into account, the 98108 ZIP code ranks highest for cumulative health impacts among the ten ZIP codes studied citywide. Additional evidence, including at the larger Duwamish Valley watershed scale and at the smaller South Park and Georgetown census tract scale, reinforce these findings, and further suggests that the ZIP code level analysis may obscure even greater health disparities in the riverside communities of South Park and Georgetown. The results of this study justify characterizing the Duwamish Valley as a community with environmental injustices, or an Environmental Justice Gap. In light of these findings, the Duwamish Valley merits attention from decision-makers regarding health protective and proactive environmental regulations, policies, practices, and actions.

The results of this analysis will inform recommendations that the Duwamish River Cleanup Coalition/Technical Advisory Group, the US Environmental Protection Agency's (EPA) Community Advisory Group for the Duwamish River Superfund Site, will make to EPA, Washington state, and local government agencies regarding cleanup of the river and related pollution source control efforts, institutional controls, and risk reduction strategies for communities impacted by the site. In addition, DRCC/TAG will provide this report to federal, state, regional, and local governments; community-based organizations; and other stakeholders and decision-makers, to help guide the development of policies and actions to improve overall environmental health and equity in the Duwamish Valley.

Photo: Paul Joseph Browns

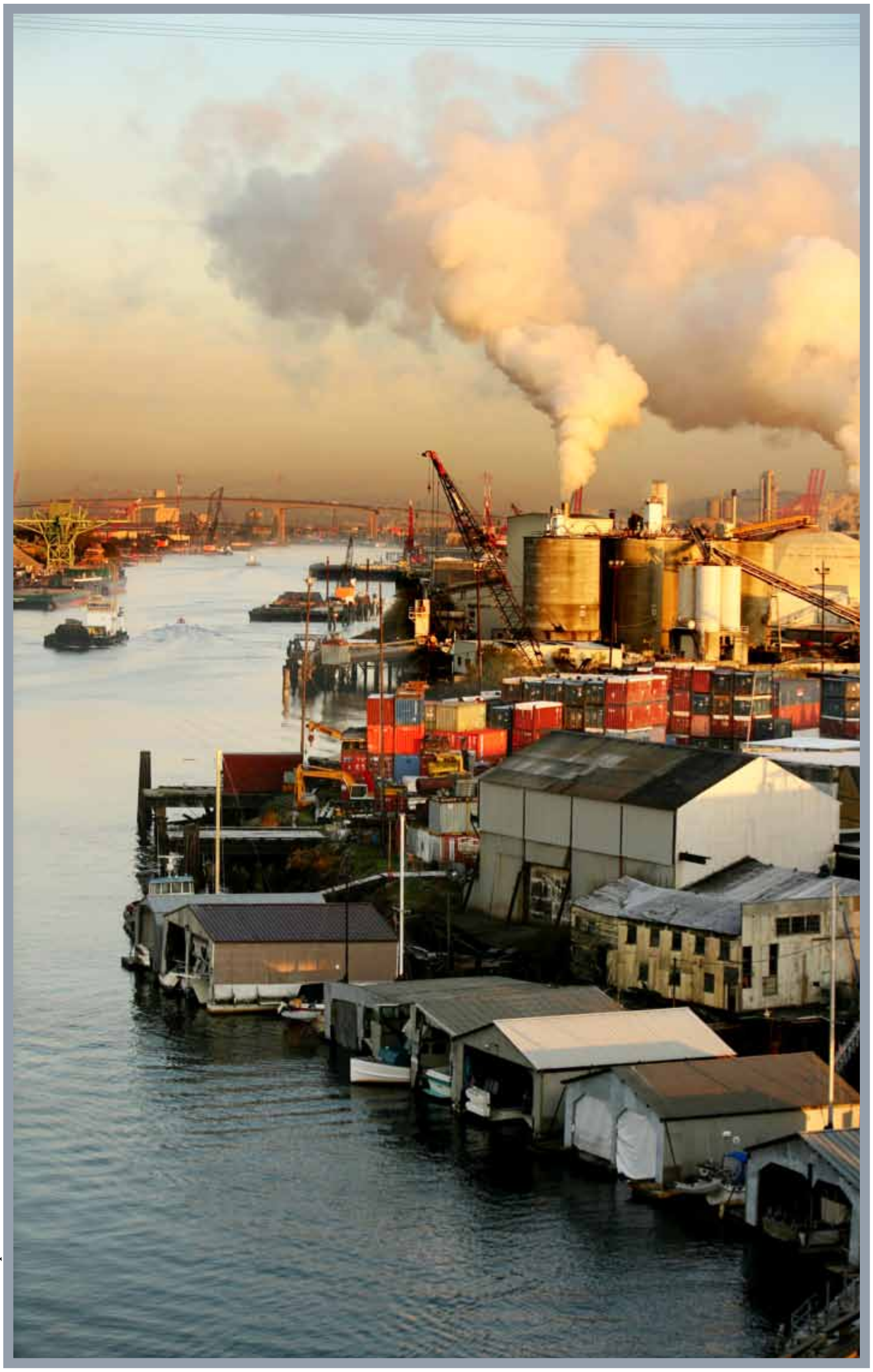


Photo: Paul Joseph Brown

The Duwamish Valley merits attention from decision-makers regarding health protective and proactive environmental regulations, policies, practices, and actions.

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Exhibit B

POLICY FORUM

AIR POLLUTION

Raising standards to lower diesel emissions

California policies protect vulnerable communities the most and should be adopted nationwide

By Megan Schwarzman[1], Samantha Schildroth[1]*, May Bhetraratana[2], Álvaro Alvarado[2]†, John Balmes[1,3]

Air pollution from fine particulate matter ($PM_{2.5}$) is increasingly driving the global burden of disease (*1*), and diesel-powered vehicles are substantial contributors. Recognizing the public health impacts of diesel $PM_{2.5}$ (DPM) (*2*), many countries have reduced emissions of DPM from both on- and off-road mobile sources over the past three decades. The previous US federal administration, however, changed course by eliminating or weakening policies and standards that govern these emissions. In contrast, the State of California has continued to reduce mobile-source DPM emissions using the state's long-standing authority under the Clean Air Act (CAA) to regulate air pollution more stringently than the federal government. Our analysis of mobile-source DPM emissions suggests that many California sector-based policies have been highly effective relative to the rest of the US. To improve health in communities disproportionately affected by these emissions, we point to opportunities to further reduce DPM emissions in California, in the US more broadly, and in parts of the world where countries have less aggressive vehicle emissions policies than the US (*3*).

The US has targeted emissions of nitrogen oxides (NO_x) and DPM from diesel trucks and buses, railway locomotives, marine vessels, and off-road engines used in construction and agriculture through successively tighter emissions standards phased in since 1994 (table S1). These standards require low- and ultralow-sulfur diesel fuels (LSDF and ULSDF), establish emissions limits, and institute systems for portable emissions measurement and onboard diagnostics (table S1).

The US Environmental Protection Agency (EPA) estimated that full implementation of Obama-era US emissions standards by 2030 would prevent some 12,000 premature deaths annually (*4*). Despite this, EPA leadership disbanded the PM review panel ahead of the scheduled 2020 update of federal PM standards; it also rolled back, or attempted to roll back, 85 federal air pollution policies (*5*) and moved to restrict the ability of states to set more stringent emissions standards (*6*).

CALIFORNIA VERSUS THE REST OF THE UNITED STATES

California, whose economy would rank fifth largest in the world if it were a sovereign nation, hosts the country's two largest ports and moves 60% of its container cargo (see supplementary materials). With the associated truck and rail traffic, California stands out as the largest emitter of DPM in the country. At the same time, California has also led the nation with the largest overall reduction in metric tons of DPM emissions from mobile sources. Over the past three decades, California's policies have systematically targeted high-emitting sectors, reducing mobile-source DPM emissions by, for example, substituting electric for diesel power where feasible, tightening emissions limits for new and existing diesel engines, and requiring ULSDF, which emits substantially less $PM_{2.5}$ than higher-sulfur fuels upon combustion and can be combined with particle filters to further reduce emissions.

To understand the impact of California's portfolio of policies, we used DPM emissions data from the EPA National Emissions Inventory (NEI), which assembles a comprehensive estimate of air pollution emissions using data reported by states, combined with modeled and measured inputs. We compared mobile-source DPM emissions in California versus the rest of the US for the period 1990 to 2014, the earliest and most recent year for which consistent NEI data are available (*7*). During that time, California reduced overall mobile-source DPM emissions by 78% while the rest of the US saw only a 51% reduction. These reductions came despite a concurrent steady rise in diesel fuel consumption: 20% in California and 28% in the rest of the US (data S1).

Emissions reductions from heavy-duty diesel vehicles (HDDVs)—commercial trucks and buses—caused most of this decline, accounting for 67% of DPM emissions reductions in California and 57% in the rest of the US. Although the federal phase-in of ULSDF, off-road emissions standards, and the Heavy-Duty Engine and Vehicle Rule has reduced HDDV emissions across the US, California's reductions from HDDVs have been steeper and contribute even more to the overall reductions than would be predicted from the sector's size. Analyses of DPM emissions over time and the relative contributions made by each sector point to the effectiveness of California's policies that require diesel engine retrofits (adding emissions controls to existing HDDVs) and early replacement of older engines with newer, cleaner engines.

DIFFERENT ERAS, DIFFERENT OUTCOMES

Our analysis identifies three distinct phases in mobile-source DPM emissions between 1990 and 2014. Emissions fell overall from 1990 to 2001 in California and from 1990 to 2005 in the rest of the country. Reduced emissions from HDDVs contributed the largest share of the overall drop (see the figure and data S1). These changes are attributable to the introduction of LSDF nationwide, and to California's new requirements for vehicle inspections (table S2).

Then, from 2001 to 2005 in California and from 2005 to 2008 in the rest of the country, emissions rose during an economic boom, driven primarily by increasing emissions from HDDVs and marine sources. Finally, overall DPM emissions once again fell, beginning in California in 2005 and in the rest of the US in 2008. The recession played a role in the early part of this drop (*8*), but emissions reductions continued through 2014 despite the economic recovery and the corresponding upturn in diesel use. During this final phase, California's 67% drop in DPM emissions outpaced the 40% reduction seen in the rest of the country (see the figure and data S1). Our analysis of individual sectors and each state's HDDV emissions suggests that California policies specifically targeting emissions from HDDVs and marine sources drove this decline.

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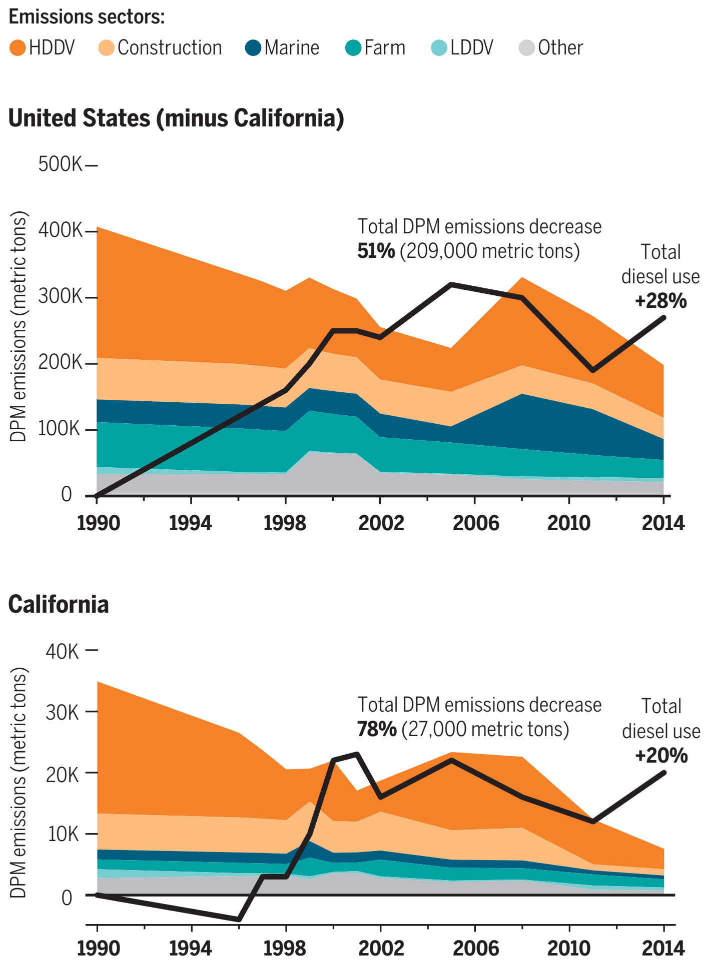
California versus the rest of the United States: Mobile-source DPM emissions declined differently

Mobile-source diesel $PM_{2.5}$ (DPM) emissions by sector in California versus the rest of the US from 1990 to 2014. HDDV, heavy-duty diesel vehicle; LDDV, light-duty diesel vehicle. All percentage changes reflect values relative to 1990 values.



GRAPHIC: N. CARY/*SCIENCE*

SECTOR-BASED POLICY: CALIFORNIA

The later phases of California's emissions reductions correspond to the implementation of two overarching plans by the California Air Resources Board (CARB): the Diesel Risk Reduction Plan and the Emission Reduction Plan for Ports and Goods Movement (Goods Movement Plan), both of which encompassed multiple policies governing emissions from trucks and buses, ports, and off-road engines (table S2). Key policies targeting on-road HDDVs took effect in 2006 and 2007, further lowering the sulfur content of diesel fuel to 15 ppm (table S2) and tightening DPM emissions standards by 90% for new HDDVs (table S2). Beginning in 2010, with a rolling compliance period starting in 2015, all on-road HDDVs that operate in California were required to either retrofit existing engines with particle filters or replace engines older than the 2007 model year (table S2).

By comparison, federal policies do not require retrofit or replacement of old diesel engines to meet emission standards, and HDDV engines typically operate for almost two decades, or about a million miles, before retirement. Our state-level analysis shows that by 2014 California HDDVs were emitting 139 metric tons of DPM for every billion vehicle-miles traveled (VMT), far less than the next-closest state (Oklahoma, 250 metric tons DPM per billion VMT) and the average in the rest of the country (345 metric tons DPM per billion VMT) (data S1). Although HDDVs remain California's largest source of DPM emissions, regulatory actions by CARB (over and above federal standards) have reduced HDDV emissions by 85% since 1990. If California's HDDV sector had followed the trajectory of other US states and DC, HDDV emissions in the state would have dropped only 58% (95% confidence interval, 52 to 64%) in that period (data S1).

Also notable is the impact of two key CARB policies targeting marine sources. The 2007 At-Berth rule requires that ocean-going vessels switch to electric shore power while in port or use alternative control technologies to reduce emissions by an equivalent amount (table S2). The Cleaner Ocean Vessel fuel policy, finalized in 2008, requires that ships within 24 nautical miles of California's shoreline replace heavy fuel oil in their main engines with lower-sulfur fuels (table S2). Between 2008 and 2014, marine DPM emissions in the state dropped 51% overall (see the figure and data S1), and by 2018 emissions measured at the Port of Los Angeles had declined by 37% (fig. S3, A and B, and data S1).

By contrast, California has struggled to target diesel emissions from agriculture (table S2). The sector is responsible for up to 18% of the state's total DPM emissions from mobile sources, but it accounted for less than 1% of the total emissions reductions in California between 1990 and 2014. Although these figures do not reflect gains from voluntary tractor engine replacements that are reported differently, opportunities remain to reduce off-road farm emissions in the nation's leading agricultural state.

Voluntary programs have further reduced DPM emissions beyond California's regulatory requirements. Incentives to bring engines and equipment to a standard cleaner than required by law are estimated to have reduced DPM emissions by more than 6000 metric tons since 2001 (table S2). A program established in 2006 has provided $1 billion in grants to update trucks, locomotives, and ships at berth, eliminating an estimated 2200 metric tons of DPM emissions (table S2). Like other policies targeting emissions along goods-movement corridors, this program particularly benefits neighboring communities, which tend to be lower-income communities of color (table S4).

Taken together, CARB's policies reduced emissions to the extent that by 2014 California was emitting less than half the DPM that would be expected had the state followed the same trajectory as the rest of the US (fig. S2 and data S1). Correspondingly, we estimate that more than twice as many Californians would have died from DPM-attributable cardiopulmonary disease in 2014 alone if the state had not so markedly reduced emissions (data S1).

SECTOR-BASED POLICY: THE REST OF THE UNITED STATES

The impact of targeted emissions regulation is also evident nationally, but it has come later and never as meaningfully as in California. Farming and construction emissions fell following the 2007 EPA Heavy Duty Engine and Vehicle Rule and the 2008–2015 phase-in of Tier 4 standards targeting off-road emissions from farm and construction equipment (table S1). Federal requirements for LSDF in the 1990s and ULSDF beginning in 2006 reduced HDDV emissions from both nonroad and on-road sources (table S1).

In the marine sector, US coastal areas caught up to California's fuel standards in 2012 when ULSDF was required for smaller marine engines (table S1) and in 2015 for the largest vessels when requirements for lower-sulfur marine diesel came into effect in the North American Emissions Control Area established by the International Maritime Organization (table S1). By contrast, California has taken not only earlier action on marine emissions but also aggressive steps to target emissions from the many engines that pollute the air near ports, including marine auxiliary engines, short-haul trucks, cargo-handling cranes, and yard trucks (table S2).

Individual states that have reduced HDDV emissions more than the national average are more likely to have adopted California's standards, as permitted under the CAA (table S5 and data S1), and the rest of the US could do the same.

GROUND-TRUTHING EMISSIONS REDUCTIONS

Coordination across states and between state and federal agencies means that methodological differences in data collection are unlikely to account for the observed differences in DPM emissions between California and the rest of the US (see supplementary materials). But how do we know that emission inventories are accurate and, furthermore, that CARB policies are responsible for the observed reductions?

Field studies measuring changes in concentrations of DPM serve to ground-truth emissions inventories and substantiate the link between policy interventions and observed outcomes (table S4). For example, following the suite of interventions under the 2006 Goods Movement Plan, California communities in close proximity to goods-movement corridors saw significantly greater air quality improvements relative to non–goods-movement corridors and control areas monitored during the same time period (table S4). These findings show specific, local impacts of regulations targeting high-emitting sectors, distinguishing those changes from secular trends in air pollution and demonstrating their potential to advance environmental justice.

The 2007 CARB regulation requiring retrofit or replacement of older HDDV engines for short-haul "drayage trucks" that operate at ports and railyards corresponded to a 70% reduction in black carbon emissions (a DPM proxy) and a 75% reduction in PM mass specific to drayage trucks measured in and around the ports of Oakland and Los Angeles between 2009 and 2011 (table S4). These changes mirror the emissions reductions measured in laboratory testing of the low-sulfur fuels and retrofit technologies used to meet the drayage truck standards (table S3).

Likewise, the 2009 CARB requirement for low-sulfur fuels in oceangoing vessel engines operating within 24 nautical miles of the California coastline was associated with a measured 64% drop in San Francisco Bay Area concentrations of vanadium, a marker for combustion of heavy fuel oil (table S4). Sampling conducted by aircraft flying in the exhaust plume of a container ship approaching the coast showed that the fuel switch, combined with a required speed reduction, dropped DPM emissions by 90% (table S4). That these changes all occurred in the setting of continued growth in California's population, gross state product, and diesel consumption (figs. S4 and S5) further supports the assertion that the observed reductions track to the policies targeting DPM emissions. Observed emissions reductions are further corroborated by epidemiological data that link specific CARB policies to regional reductions in children's exposure to particle pollution and show corresponding improvements in both lung function and development in children with and without asthma (*9*).

Finally, comparing HDDV sector emissions in California to the rest of the country likely underestimates the actual impact of CARB policies, which apply not only to the nearly half-million trucks and buses registered in California but also to the same number of out-of-state HDDVs estimated to drive California's highways each year (*10*). This requirement reduces emissions outside of California as well, although those reductions are attributed to federal policy.

IMPLICATIONS FOR FUTURE STANDARDS

In California, cleaner air has not come at the expense of the state's economy, which in recent years has grown at double the average national rate (*11*). CARB estimates that every dollar the state has spent controlling air pollution has generated $38 in benefits attributable to reduced air pollution–related illness, premature death, and lost productivity. California's overall economic gain from health benefits linked to air pollution reduction, including CARB rules and programs, is estimated to have exceeded $250 billion between 1973 and 2014 (*12*). The link between $PM_{2.5}$ exposure and increased risk of hospitalization and death from COVID-19 (*13*) further underscores the public health importance of cleaner air, particularly for communities of color that are disproportionately affected by both.

California could benefit from additional measures to reduce emissions from off-road sectors, such as construction and agriculture, which CARB has not tackled as aggressively (*14*). Indeed, the nation as a whole could reduce mobile-source DPM emissions by requiring ships at berth to use shore power, and by requiring replacement or retrofit of existing on-road and off-road HDDVs in advance of fleet turnover. Given the long service life of older, dirty diesel engines, the current federal policy of mandating engine upgrades only with vehicle turnover is simply too slow.

As the US initiates new federal rule-making on the proposed Cleaner Trucks Initiative to reduce NO_x emissions from HDDVs, industry and environmental groups are calling on EPA to address NO_x and DPM emissions in tandem and to create consistent "50-state" standards (*15*). In doing so, the EPA should align with CARB rules. EPA should also remove federal preemption of state emissions limits for off-road engines used in construction and agriculture. Even absent more aggressive federal policy, states' authority to set and implement their own stricter emissions standards must be protected. ■

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SUPPLEMENTARY MATERIALS

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Science

Raising standards to lower diesel emissions

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Supplementary Materials for

Raising standards to lower diesel emissions

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Table S1.

Date adopted	Date effective	Rule	Requirements	Sector	References
Non-Road*					
1994; 1998	• 1996-2000 phase-in engines > 37 kW • 2000-2008 phase-in engines < 37 kW	Tier 1	Set emissions standards for CO, NMHC, NOx, and PM.	Non-road diesel engines	(*16*),(*17*),(*18*)
1998	2001-2006 phase-in	Tier 2	Tightened emissions standards over Tier 1 for CO, NMHC, NOx, PM	Non-Road diesel engines	
1998	2006-2008 phase-in	Tier 3	Tightened emissions standards over Tier 2 for CO, NMHC, NOx, PM Applied to engines >37 kW.	Non-Road diesel engines	
2004	2008-2015 phase-in	Tier 4	Tightened emission standards over Tier 3 for CO, NMHC, NOx, PM Applied to all engines.	Non-Road diesel engines	
2004	• 500 ppm by 2007 • 15 ppm by 2012 (marine and locomotive engines), and 2010 (all others)	Non-road Diesel Program (NRDP, NRLM)	Required non-road diesel fuel sulfur content ≤ 500 ppm by 2007, and ≤15 ppm by 2010 for non-road fuel and 2012 for marine and locomotive fuels.	Non-Road diesel engines	(*19*),(*20*)
2008	• 1,000 ppm by 2015 • Technology by 2016	International Convention for the Prevention of Pollution from Ships (MARPOL) Annex VI	International agreement adopted by the U.S. in 2008 requiring category 3 marine engines operating in Emission Control Areas (ECAs) to limit fuel sulfur to ≤ 1,000 ppm. The North American ECA was established in 2012. Required advanced technology to reduce NOx by 2016.	Marine	(*21*)(*22*)
On-Road					
1990	• 500 ppm by 1993 • 15 ppm phase in 2006-2010	Highway Diesel Program	Limited diesel fuel to sulfur content ≤500 ppm by 1993 and <15 ppm by 2010.	On-Road HDDVs	(*19*),(*20*),(*23*)
2000	• 2007 for PM • 2007-2010 phase-in for NOx	Heavy-Duty Highway Engine	Limited PM emissions to 0.01 g/bhp*hr. Limited NOx emissions to 0.20 g/bhp*hr.	On-Road HDDVs	(*24*)
2011	2016 (voluntary 2014-2015)	Greenhouse Gas Emissions Standards and Fuel Efficiency Standards for Medium- and Heavy-Duty Engines and Vehicles: Phase I	Set fuel consumption and CO2 emissions standards for semi-trucks, heavy-duty pick-up trucks/vans, and vocational vehicles starting with 2016 model year.	On-Road HDDVs	(*25*)

*U.S. EPA "non-road" designation is equivalent to the California Air Resources Board's "off-road" designation.
CO= carbon monoxide, CO2= carbon dioxide, NMHC= non-methane hydrocarbons, NOx= nitrogen oxides, PM= particulate matter, kW= kilowatt, ppm= part per million, NRLM= non-road/locomotive/marine, HDDV= heavy duty diesel vehicle, bhp= brake horsepower

U.S. diesel emissions policies 1990-2014 for on-road and non-road engines.

Table S2

Date adopted	Date(s) effective	Rule	Requirements	Sector	References
1988	1993 all engines except rail and marine	Diesel Fuel Regulation (reformulated fuel, LSDF)	Reduced diesel fuel sulfur content to ≤ 500 ppm for all on- and off-road HDDV except locomotives and marine engines.	On- and off-road HDDV (except rail and marine)	(*26*)
1988	1991-1993 phase-in (suspended) 1998 re-implementation	Heavy-duty Vehicle Inspection Program (HDVIP) See also PSIP below	Required inspection of HDDVs for tampering. Limited smoke opacity to < 55% or < 40%, depending on model year. Voluntary compliance during suspension. Re-implementation updated testing procedures	On-road HHDV	(*27*),(*28*)
1992	1996 1998 (updated)	Periodic Smoke Self-inspection (PSIP)	Required fleet owners to perform annual smoke self-inspections. Engine repair required for failed inspections. Testing procedures updated in 1998.	On-road HDDV	(*28*)
1992	1996	Heavy-Duty Off-Road Diesel Engines	Set NOx emissions standards for HDDV engines above 130kW equivalent to U.S. EPA Tier 1 off-road emissions standards.	Off-road HDDV	(*29*)
	1998 – current	Carl Moyer Memorial Air Quality Standards Attainment Program	Voluntary program offering incentives for diesel engine and equipment retrofits, replacements, and repowers.	All diesel sectors	(*30*)
2000*	Retrofit: • pre-1990 buses by 2003 • pre-1995 buses by 2005 • pre-2003 busses by 2009 LSDF rules effective 2002	Public Transit Bus Fleet Rule + Emission Standards for New Urban Buses (Public Transit)	Required transit agencies to retire or retrofit existing urban buses, purchase low-emission, alternative-fuel buses, and use LSDF to reduce fleet DPM by 85%.	On-Road HDDV	(*31*)
2001*	2007	On-road Heavy-Duty Diesel Engine Reduced Emissions Standards (HDDE Standards)	For 2007 and subsequent model yr HDDVs compared to 2004 model yr vehicles, required to reduce NOx (90%), non-methane hydrocarbon (>70%), and PM (90%).	On-Road HDDV	(*32*)
2003*	2006	Ultra-low Sulfur Diesel Fuel (ULSDF)	Reduced diesel fuel sulfur content below 15 ppm.	On-Road HDDV	(*26*)
2003	2003	Airborne Toxic Control Measure to Limit School Bus Idling	School bus engines must be off when stopped within 100 feet of a school and not started >30 seconds prior to departure. No idling >5 minutes when 100 feet or further from a school.	On-Road HDDV (school busses)	(*33*)
2004*	2007	Heavy-Duty Diesel Emission Control Label (ECL) Inspection Program Regulation	Required drivers selected for inspection to have federal emission control systems verified. Required HDDVs to meet smoke opacity specifications in the HDVIP/PSIP.	On-road HDDV	(*34*)
2004 Amended 2010, 2011	Phased-in 2009-2018 based on model yr and emission level	Airborne Toxic Control Measure for Transport Refrigeration Units (TRU)	Required TRUs to meet standards for "low emissions TRU" (LETRU) or "ultra-low TRU" (ULETRU). Model yr 2001 & older: LETRU by 2009; ULETRU by 2016 Model yr 2002: LETRU by 2010; ULETRU by 2017 Model yr 2003: LETRU by 2011; ULETRU by 2018	On-Road and off-road HDDVs	(*35*),(*36*)
2004	Phased-in 2004- 2010	Solid Waste Collection Vehicle Regulation	Required solid waste vehicles to implement best available control technologies to reduce particulate matter emissions.	On-Road HDDVs	(*37*)
2005 Amended 2011	2006; (2012 for amendments)	Mobile Cargo Handling Equipment Regulation	Required newly purchased/leased/rented yard and non-yard trucks to meet emissions standards for CA on-road (registered vehicles), Tier 4 off-road (non-registered vehicles)	Ports & Rail	(*38*) (*39*)
2006	2008-current	Proposition 1B: Goods Movement Emission Reduction Program	Gives funds for the voluntary upgrade or replacement of diesel engines and equipment for freight operations in trade corridors.	On-road HDDV, off-road HDDV, marine	(*40*)
2006	For model yr up to 2002: • 20% of fleet by 2007 • 60% by 2009 • 100% by 2011 For model yr 2003-2006:	Fleet Rule for Public Agencies and Utilities	Required utility and municipality vehicles to adopt best-available emissions control technology.	On-Road HDDVs (public utilities)	(*41*)

	• 50% of fleet by 2009 • 100% by 2010				
2007*	Early compliance 2010 Required compliance of: • 50% of fleet by 2014 • 70% of fleet by 2017 • 80% of fleet by 2020	Shore Power for Ocean Going Vessels (At-Berth Rule)	Limited operation of diesel engines while at berth to: • 3 hours per visit if vessel switched to shore power • 5 hours per visit if vessel did not switch to shore power	Marine	(42),(43)
2007*	Replace or retrofit to meet 2007 DPM emissions standards: • Phase I (2010) applied to pre-2003 model-yr engines. • Phase 2 (2013) applied to engine model-yrs 2004-2006.	Drayage Truck Regulation	Prohibited drayage trucks older than 1994 model yr. Required DPF retrofits or replacement with 2007+ model-yr for all on-road HDDVs "drayage trucks" that operate at ports and rail facilities.	On-road HDDVs	(31)
2007 Amended 2010	2008, with rolling adoption through 2022	Commercial Harbor Craft Regulation (CHC)	Required harbor craft to use ULSDF; tightened emissions limits for older commercial harbor engines.	Marine	(44)
2008 (Amended 2010)*	Idling limits & disclosure by 2008 Engine retrofit or replacement: • large fleets by 2014 • medium fleets by 2017 small fleets by 2019	In-Use Off-Road Diesel-Fueled Fleet Regulation (Off-Road Regulation)	Required installation of exhaust retrofits and accelerated turnover to cleaner engines. Imposed idling limits on off-road vehicles; required disclosure of limits on vehicle sale, and reporting of all vehicles to CARB. Amended in 2010 to delay implementation by 4 years and reduce annual emissions requirements.	Off-Road HDDV (farm, construction, and ports)	(45),(46),(47),(48)**
2008*	Phase I (2009) limited fuels to 0.5% (5,000 ppm) max sulfur content. Phase II (2014) limited fuels to 0.1% (1,000 ppm) max sulfur content.	Ocean-Going Vessel (OGV) Clean Fuel Regulation Fuel Sulfur and Other Operational Requirements for Ocean-Going Vessels within California Waters and 24 Nautical Miles	Required OGVs to reduce the sulfur content of fuels in main and auxiliary engines while operating within 24 nautical miles of the CA coastline.	Marine	(49), (50)
2008*	By 2010 all new engines meet 2007MY PM emissions standards. Retrofits to reduce DPM required by: • 2011 for 25% of fleet • 2012 for 50% • 2013 for 75% • 2014 for 100%	Statewide Truck and Bus Regulation "Truck and Bus Rule" (TBR)	Required truck and bus fleets to reduce PM and NOx emissions to 2007MY standard by retrofitting or replacing older vehicles. The agricultural vehicle extension delayed implementation for agricultural vehicles until 2023 for vehicles that travel less than 10,000 miles per year.	On-road HDDV	(51),(52),(53)

*Part of CARB's Diesel Risk Reduction Plan, passed in 2000. (54), (55) Most policies since 2006 are also part of the Emissions Reduction Plan for Ports and Goods Movement in California.(56)
**Construction Inventory Update for the In-Use Off-Road Diesel-Fueled Flee Regulation
CO= carbon monoxide, CO2= carbon dioxide, NMHC= non-methane hydrocarbons, NOx= nitrogen oxides, PM= particulate matter, kW= kilowatt, ppm= part per million, NRLM= non-road/locomotive/marine, HDDV= heavy duty diesel vehicle, bhp= brake horsepower, HDVIP= Heavy Duty Vehicle Inspection Program, PSIP= Period Smoke Self-inspection Program, LSDF= low sulfur diesel fuel (≤ 500ppm sulfur content), ULSDF=ultra-low sulfur diesel fuel (≤15ppm sulfur content), ECL= emissions control label, TRU= truck refrigeration units, LETRU= low emissions TRU, ULETRU= ultra-low emissions TRU, CARB= California Air Resources Board, OGV= ocean-going vessel, MY= model year.

California diesel emissions policies 1990 – 2014 for on-road and off-road engines.

Table S3.

Policy	Technology	DPM reduction	Reference
On-road Heavy Duty Diesel Engine Reduced Emission Standards (2007)			
	Diesel particulate filter (DPF)	>95%	(*57*)
	Active DPF	85%	(*58*)
	Passive DPF	60-90%	(*58*)
	Flow-through filter	50%	(*58*)
	Diesel oxidation catalyst (DOC)	20-40%	(*58*)
	DOC + emulsified diesel fuel	50%	(*58*)
Reformulated Fuel Rule (1993)			
	Diesel fuel sulfur content < 500ppm; aromatic 10%	25%	(*59*)
Ultra-Low Sulfur Fuel (2006)			
	Diesel fuel sulfur content < 15ppm	27%	(*59*)

SCR= selective catalytic reduction, DPF= diesel particle filter, DOC= diesel oxidation catalyst

Ground-truthing emissions inventories: Technologies required by select CARB policies and their measured effect on diesel emissions.

Table S4.

Line	Study date	Location	Reductions Measured During Study	Relevant Policy/Sector	Reference
1	Before and after policy implementation (2003-2007 vs. 2008-2013)	Los Angeles and Alameda counties, Goods Movement Corridors (GMCs)	6.4 ppb and 21.7 ppb average decrease in NO_2 and NO_x in GMCs. Reductions were higher in GMCs compared to non-GMCs and control areas.	Emission Reduction Plan for Ports and Goods Movement (“Goods-Movement Plan”) and Diesel Risk Reduction Plan (DRRP) policies implemented before 2007, on- and off-road HDDVs	Su et al. 2016. (*60*)
2	2005 to 2010	GMCs within 500 meters of major highways vs. distant areas	Comparing pre- and post-policy periods, GMCs showed greater NO_2 reductions compared to non-GMCs and control areas.	Goods Movement Plan and DRRP policies implemented before 2007, on- and off-road HDDVs	Su et al. 2020. (*61*)
3	2009 to 2010	Port of Oakland	54 +/- 11% average fleet BC, 41 +/- 5% average fleet NOx	Drayage Trucks Regulation, on-road HDDVs	Dallmann et al. 2011. (*62*)
4	2010	Caldecott Tunnel, Oakland	37 +/- 10% average fleet BC since 2006	Statewide Truck and Bus Rule, on-road HDDVs	Dallmann et al. 2012. (*63*)
5	2010	Marine vessel off the coast of Port of LA	After switching from high to low sulfur fuels, the vessel reduced emissions factors ≥90% for SO_2 and PM, 70% for organic matter and 41% for black carbon.	Ocean-Going Vessel (OGV) Clean Fuel Regulation Fuel Sulfur and Other Operational Requirements for Ocean-Going Vessels within California Waters and 24 Nautical Miles	Lack et al. (*64*)

6	2005 to 2014	Southern California	12 +/- 2% in BC during summer and 14 +/- 2% for fall	All HDDVs	Millstein et al. (*65*)
7	2009 to 2011	Southern California	70% in BC emissions factors	Drayage Truck Regulation, on-road HDDVs	Kozawa et al. (*66*)
8	March to May 2010	Port of Oakland	75% in port truck-specific PM mass	Comprehensive Truck Management Rule (Port of Oakland rule to meet Drayage Truck compliance), on-road HDDVs	Kuwayama et al. (*67*)
9	2005-2009 to 2011	San Francisco Bay	3.1 +/- 0.6% average in $PM_{2.5}$ emissions	Ocean-Going Vessel Clean Fuel, Marine	Tao et al. (*50*)
10	2008 to 2010	San Pedro Ports	30% for CO, 48% for NOx, and 54% for infrared opacity (measure of PM)	Drayage Trucks Regulation, on-road HDDVs	Bishop et al. (*68*)
11	2011 to 2013	Port of Oakland	69 +/- 15% for NOx, 92 +/- 32% for black carbon, and 66 +/- 35% for particle number comparing MY 2010-2013 with SCR and DPF to MY 2004-2006 without	Drayage Trucks Regulation, on-road HDDVs	Preble et al. 2015. (*69*)
12	2014 to 2018	Caldecott Tunnel, Oakland	79% for black carbon and 57% for NOx. DPF use increased from 15 to 91% and SCR from 2 to 59%.	All on-road HDDVs, Drayage trucks, construction trucks	Preble et al. 2019. (*70*)

MY= model year, SCR= selective catalytic reduction, DPF= diesel particle filter, BC= black carbon (PM proxy), GMC= goods movement corridor

Ground-truthing emissions inventories: Measured impact of CARB policies on diesel emissions measured at select California locations.

Table S5.

State	Date(s) adopted/effective	Rule/Program	Requirements	Sector	Connection to California Policies/Programs	References
Massachusetts	2005	MassDOT Diesel Retrofit Program for Non-road Construction Equipment	Requires non-road construction vehicles >50 horsepower to use catalysts or filters.	Construction	Technology used must be CARB or EPA verified.	(*71*)
New York	2004	Local Law 77	A New York City law that required public and private vehicles funded by city construction contracts to use ultra-low sulfur fuels and best available technology for engines above 50 horsepower.	Construction	Best available technology must be approved by CARB or the EPA. Legislative intent cites California Proposition 65 finding that diesel exhaust is carcinogenic.	(*72*)
New York	2009	Port Authority of New York/New Jersey Clean Air Strategy	Sets incentives and requirements for marine vessels, rail locomotives, drayage trucks and HDDVs operating in the port. The Clean Truck Program required drayage trucks operating in the port to have 1996 or newer engine by 2018 and trucks accessing the port to have 2007 or newer engine by 2016. Alternatively, vehicles could use alternative fuel or hybrid technology. These regulations were rolled back in 2016 from more stringent requirements originally passed.	Marine, HDDVs, rail	N/A	(*73*),(*74*),(*75*)
New York	2006 (effective in 2009, construction exempt until 2020)	New York State Diesel Emissions Reduction Act	Required that ultra-low sulfur fuel (15 ppm) be used, as well as retrofits using best available technology (filters, catalysts).	On-road and off-road vehicles exempting construction, off-road <50 hp and on-road <8,500 lbs.	Retrofits must be CARB or EPA approved; vehicles are exempt if the engine meets 2007 CARB emissions standard.	(*76*)(*77*)
Texas	2001	Texas Emissions Reductions Plan	Includes several voluntary programs, the Emissions Reduction Incentive Grants Program, that provides funds for retrofits, replacement, and repower of diesel engines.	On-road and off-road marine engines.	Retrofit technology must be CARB or EPA approved.	(*78*),(*79*),(*80*)
Texas	2005	Texas Low Emissions Diesel Standards (TxLED)	Set fuel requirements for all engine types for 110 counties: -Max 10% aromatic hydrocarbon content -Minimum cetane #48 -Or use CARB approved formulations	All sectors using on-road and off-road diesel engines	Required diesel fuel in Texas to be as clean as fuel used in California (based on CARB standards).	(*81*)(*82*)

Sample state policies targeting on- and off-road diesel emissions.

Many of these states use California standards and/or CARB approved technology for their retrofit requirements. In addition to the policies listed in Table S5, 10 other states have adopted California HDDV emissions standards under the Clean Air Act, Section 177. These states are: Connecticut, Maine, Massachusetts, New Jersey, New Mexico, New York, Pennsylvania, Delaware, Georgia, and North Carolina (*83*). These states have also all been the recipients of Diesel Emissions Reduction Act (DERA) Grants. For example, the state of New York has been awarded 15 grants targeting HDDV emissions between 2009 and 2019 totaling over $20 million (*84*).

Data S1 (separate file)
The Supplementary Data file includes the following tabs: Read.me; NEI DPM emissions, U.S.- CA; NEI DPM emissions, CA; CARB DPM emissions; NEI vs CARB DPM emissions; CARB DPM-NOx ratios; CA population, DPM mortality values; Mortality calculations; LA Ports data; U.S. pop & GDP data; CA pop & GDP data; Diesel use data; HDDV emissions per VMT by state; and HDDV state data.

R Code (separate file)
The Supplementary R Code file includes all code used in the following analyses: Imputation of missing or outlier values in NEI DPM data for CA and the U.S.; CA population and mortality for 1990-2014; CA DPM concentrations; spatial interpolation; DPM mortality analysis; and confidence intervals for state-level HDDV emissions reductions.

Materials and Methods
To understand how emissions of diesel $PM_{2.5}$ (DPM) changed following implementation of policies promulgated by the California Air Resources Board (CARB), we obtained $PM_{2.5}$ emissions data from the EPA National Emissions Inventory (NEI) (*7*).We compared mobile source DPM emissions in California to emissions in the rest of the U.S., which included all states, the District of Columbia, and U.S. territories, for the period 1990 to 2014. Our approach is detailed in the sections that follow.

Comparability of emissions data among states and over time
While each state reports its emissions to NEI independently, significant collaboration among states and with US EPA ensures methodological consistency. CARB emissions inventory staff coordinate closely with US EPA and other states on methodology, emission factors, data sources, and other parts of the emissions inventories. Where California leads in data acquisition or method development, rather than causing systematic discrepancies, California's methods flow to US EPA and to other states that compile their own inventories, and CARB uses data from EPA and other states in return. All states that quantify their own inventories either follow EPA inventory general guidelines or California's.

Furthermore, there is significant real-world ground-truthing of the emission sources on all sides. In California, emissions trends are corroborated by tracking, for example, the age of registered cars, the distribution of trucks visiting California, and the off-road equipment registered with CARB or visiting California ports. EPA and the other states similarly ground-truth against nationwide or statewide sources and see emissions trends reflected in the verified sources operating and the controls they use. Further information on emissions modeling methods are available for EPA (*85*) and CARB (*86*).

Although a 2017 emissions inventory was released in April, 2020, interim changes to models and data collection methods make the latest inventory non-comparable to earlier inventories. For example, between 2014 and 2017, both NEI and CARB made significant changes to their on-road emissions models. These changes invalidate comparisons between the 2017 inventory and earlier inventories. Similarly, non-road emissions modeling used by the US EPA changed significantly between 2014 and 2017, including a new model for marine power estimation (*87*)(*88*). Furthermore, data collection methods also changed in some sectors. For example, the EPA 2017 marine emissions inventory used a new satellite-tracking method for marine traffic, a method not used by previous NEI inventories nor by California in 2017.

Although pre-2017 inventory models and methods used by both NEI and CARB have also undergone periodic revisions, two findings suggest that comparing emissions over time across multiple NEI inventories would underestimate the actual impact of California's regulations targeting DPM pollution. First, inventory modeling has become more accurate over time, and earlier models appear to have underestimated DPM emissions, reducing the apparent declines over time compared to likely actual declines. A study conducted in 2012 measured on-road emissions and used those empirical values to compare the emission estimates produced by the on-road model used until 2010, MOBILE6, to estimates produced by MOVES10, the model gradually adopted beginning in 2010.(*89*) This study found that MOVES10 consistently predicted higher DPM emissions than the earlier MOBIL6 model, with the implication that the emissions reductions observed across the 2008, 2011 and 2014 inventories are likely to be lower than the actual reductions achieved. Second, although California uses its own emissions modeling system, EMissions FACtor (EMFAC), the same study found that EMFAC predictions were comparable to predictions by the MOVES10 model and were consistently higher than predictions by the MOBILE6 model, with the result that our comparisons are likely to underestimate the difference between emissions in California and the rest of the country. Given that both of these factors appear to bias a comparative time-series analysis toward the null hypothesis, suggests we can use the NEI data in this analysis despite periodic inventory revisions prior to 2014.

EPA National Emissions Inventory data retrieval and sorting

NEI reports emissions by source, dividing them into categories that designate the process by which the pollutant was emitted. Sources are organized into hierarchical tiers of increasing specificity: emissions are grouped into general categories in Tier 1 (e.g., highway vehicles, off-highway) and are then divided into increasingly specific categories in Tiers 2 and 3 (*90*). The methodology for reporting emissions data to NEI has been described elsewhere (*91*)(*92*)*,* and further descriptions of all source categories can be found on the EPA's website (*90*). We identified all source categories related to mobile sources of diesel emissions (Table S5) and downloaded data files for each year directly from the EPA NEI's website for all years for which data were available between 1990 and 2014: 1990, 1996, 1997, 1998, 1999, 2000, 2001, 2002, 2005, 2008, 2011 and 2014.

NEI data for years 2002 and later are stored as Access files, while data for years 2001 and earlier are stored as Text files, which we converted to Access files. Access files for years 2002 and later provide unique source classification codes (SCCs) and descriptions for Tier 1, 2, and 3 emissions. For example, marine emissions are categorized under the Tier 1 SCC 12 (Off-highway), Tier 2 SCC 04 (Marine vessels), and Tier 3 SCC 02 (Diesel). Because the converted Access files for 2002 and earlier do not provide descriptions, we used the 2-digit source codes included with later years (provided in Table S5) to identify by name the relevant sectors in the emissions data from 2002 and earlier.

NEI has provided state-level emissions data starting in 2002, however for years 2001 and prior, emissions data are provided at the county level. For those years, we aggregated emissions across all counties in each state for each sector in the data files to generate statewide data. To arrive at emissions data for the U.S. minus California, we subtracted California emissions data from national emissions data, in all available years from 1990-2014. California's state-level data was extracted for years 2001 and earlier using the state's unique identifier code (06). Because—as with the other states—emissions data within California are reported at the county-level for data files 2001 and earlier, we aggregated emissions data across all counties in California to reach state-level data for each sector. $PM_{2.5}$ was selected as the pollutant of interest by selecting "$PM_{2.5}$" under the pollutant column within the Access files. $PM_{2.5}$ was either aggregated in Access files as $PM_{2.5}$-primary, which includes both filterable and condensable $PM_{2.5}$, or reported as filterable, condensable, and primary. We selected primary $PM_{2.5}$ for years that reported emissions as primary, filterable, or condensable to be consistent with all years. Note that for 2011 and 2014, LDDV and light duty diesel trucks (LDDT) are combined into one category (Table S5).

To compare California's performance in diesel emissions reductions to other states, we compiled emissions data for all available states for the time period of interest 1990-2014 for the largest DPM emissions source, HDDVs. These data were compiled using methods described above and are presented in the Supplementary Data. Normalization of these data by vehicle-mile traveled is described below.

Table S6.

Tier 1 Sector	Tier 1 SCC	Tier 2 Sector	Tier 2 SCC	Tier 3 Sector	Tier 3 SCC
Fuel Combustion Electric Utility	01	Oil	02	Distillate	02
Fuel Combustion Industrial	02	Oil	02	Distillate	02
Fuel Combustion Other	03	Residential Other	06	Distillate Other	01
Highway Vehicles (2008 & earlier)	11	Diesel Fuel	04	Heavy duty	01
Highway Vehicles (2008 & earlier)	11	Diesel Fuel	04	Light duty trucks	02
Highway Vehicles (2008 & earlier)	11	Diesel Fuel	04	Light duty vehicles	03
Highway Vehicles (2011 & later)	11	Diesel Fuel	11	Heavy duty	01
Highway Vehicles (2011 & later)	11	Diesel Fuel	11	Light duty (combined)	02
Off Highway	12	Non-road Diesel	02	Recreational	01
Off Highway	12	Non-road Diesel	02	Construction	02
Off Highway	12	Non-road Diesel	02	Industrial	03
Off Highway	12	Non-road Diesel	02	Lawn/garden	04
Off Highway	12	Non-road Diesel	02	Farming	05
Off Highway	12	Non-road Diesel	02	Commercial	06
Off Highway	12	Non-road Diesel	02	Logging	07
Off Highway	12	Non-road Diesel	02	Airport transportation	08
Off Highway	12	Non-road Diesel	02	Rail	09
Off Highway	12	Non-road Diesel	02	Recreational marine	10
Off Highway	12	Marine Vessels	04	Diesel	02

National Emissions Inventory sectors selected for analysis. SCC is Source Classification Code.

Addressing missing values in NEI data

Emissions values were missing in specific sectors for some years (U.S.: 1990 oil electric; CA: 1990-1998 oil electric, 1999 and 2002 recreational, 2011 logging, 1999 and 2002-2011 rail, and 1999 and 2002 recreational marine). We used linear regression to impute missing data by regressing the $PM_{2.5}$ emissions from each sector on the year. First, we checked the linear correlation between the variables for emissions and year and used linear imputation for correlation values of 0.60 or higher, which is considered moderate-to strongly correlated (*93*).

Values with linear correlation less than 0.60 were imputed as the average of the two closest years where consecutive years of data were available (i.e., 1999 was imputed by the average of 1998 and 2000 if those years had data available). Values with a correlation of 0.60 or less, and without two surrounding years of data, were imputed by assigning the value of the closest year of available data. For those values that did not have a consecutive year of data (for example, 2011), we used the linearly imputed value even if the correlation was below 0.60; two California values for 2011 (farming and logging) were imputed in this manner. We made one exception for the missing value for the U.S. 1990 oil electric missing value, whose linear imputation correlation was <0.60: we imputed this value with the closet year (1996) because the linearly imputed value was several magnitudes higher than the 1996-1998 values (see R code). All imputed values are clearly labeled (Data S1 Read.me), and the method used to impute each value is indicated. We imputed all California data first, used these imputed values to calculate US-CA emissions values, and then imputed missing US data, where appropriate.

Finally, we used an imputed value over a reported value in four instances: the reported value for California's recreation sector in 2005, marine sector in 2002 and 2005, and the farming sector in 2011. The farming sector in 2011 was an order of magnitude lower than expected based on reported emissions in both surrounding years, 2008 and 2014. Agricultural emissions data obtained directly from CARB for that year (*94*), although not directly comparable because of differences in categories of emissions included, confirmed the 2011 NEI value was likely an error. We therefore replaced the reported value with an imputed value, as described above. Similarly, the 2005 recreation reported value was much higher than the closest reporting years (2002 and 2008). We, therefore, also imputed this value. We further censored and imputed two values for California reported marine emissions in 2002 and 2005, which were similarly higher than the closest reporting years and did not follow the overall emissions reduction trend observed for the rest of the time-period.

All data imputation analyses were conducted in RStudio version 1.2.5042.

NEI data analysis
After extracting and aggregating NEI emissions data for all relevant diesel sectors, we converted the emissions estimates (in U.S. tons) to metric tons. We then calculated percent change in emissions over the time-period, indexed to 1990 for California and for the rest of the U.S. for each sector, and across all sectors combined. For a given time period, we calculated the emissions reduction attributable to a specific sector by calculating the absolute change in emissions per year in the sector of interest and dividing by the absolute change in emissions over all sectors combined for that time period (Equation 1).

$$Emissions\ reductions\ attributable\ to\ sector\ fromt\ Y1\ to\ Y2 = \frac{[Y2\ sector\ emssions\ (metric\ tons) - Y1\ sector\ emissions\ (metric\ tons)]}{[Y2\ total\ emissions\ (metric\ tons) - Y1\ total\ emissions\ (metric\ tons)]} * 100 \qquad [1]$$

NEI Vehicle Miles Traveled (VMT) for HDDVs and HDDV Emissions Normalization
To compare emissions reductions for HDDVs across all states, we normalized emissions by HDDV vehicle miles traveled (VMT). In recent reporting years (2014-2017), the NEI provides VMT data by vehicle category for each state (*95*). We combined the following vehicle categories to produce a composite HDDV VMT value for each state in 2014: intercity buses, transit buses, school buses, refuse trucks, single unit short-haul trucks, single unit long-haul trucks, combination short-haul trucks, and combination long haul-trucks. The NEI reports VMT in units of VMT per year, which we converted to billions of VMT. To normalize HDDV emissions data, we divided the HDDV emissions estimate (metric tons) by the VMT for that state (billions VMT). This normalization produces the ratio of HDDV emissions per HDDV VMT (metric tons/billion VMT) for each state, providing a valid basis for comparing state-by-state HDDV emissions in 2014. These data are provided in the Supplemental Data.

Data on diesel consumption, population and gross domestic product
To provide context for the DPM emissions data, we gathered data on diesel consumption, population growth and gross state product for all U.S. states, including the District of Columbia, during the period 1990-2014. For diesel consumption data, we used U.S. sales of distillate fuel oil by end use from the United States Energy Information Administration (EIA) Total-End Use Energy Consumption. Data from the EIA is available at the national and state levels for several categories, including total distillate sales/deliveries to vessel bunkering consumers, No. 2 diesel sales/deliveries to on-highway consumers, total distillate sales/deliveries to military consumers, No. 2 diesel sales/deliveries to off-highway consumers, and total

distillate sales/deliveries to other end users (*96*). We summed these five categories for a total consumption metric (in thousands of gallons) per year and calculated percent changes for California and the U.S. minus California.

We drew population data from the Centers for Disease Control and Prevention (CDC) WONDER online databases 1990-2014 bridged-race population estimates (*97*). Within the data request form, we specified group results by "Yearly July 1st Estimates," all ages, all races, all ethnicities, and all years. U.S. data were specified by selecting "All" and California was specified by selecting "06- California" in the request form. Data outputs give the number of estimated people per year in the U.S. and California, respectively. U.S. population estimates exclude California population estimates. We graphed the percent change in population for California and the rest of the U.S. indexed to 1990.

We obtained data on the Gross Domestic Product (GDP) from the United States Bureau of Economic Analysis (BEA). The BEA GDP and Personal Income data tool breaks down GDP data by region (*98*). We requested annual GDP by state in current U.S. dollars (millions) for 1990 through 2014. Within the data request form, we selected "All industry total," specified the years of interest, and requested data for the U.S. and California. Following these steps, the data tool returns GDP estimates for all industries for the specified years and locations. GDP is in current U.S. dollars and is not adjusted for inflation. We subtracted California GDP from the U.S. GDP to compare California GDP to the rest of the U.S. We graphed the percent change in GDP for California and the rest of the U.S. indexed to 1990.

Port of Los Angeles air quality monitoring data

We downloaded $PM_{2.5}$ emissions data directly from the Port of Los Angeles website (*99*) for the period 2005-2018. Specifically, we used the 12-month average for each year and each monitoring station, including Wilmington Community Site, Coastal Boundary site, San Pedro Community Site, and the Source-Dominated Site (denoted as "Source" in the "LA Ports" tab in Data S1). We took the average of all stations for each year and reported averages in the excel file (See Data S1).

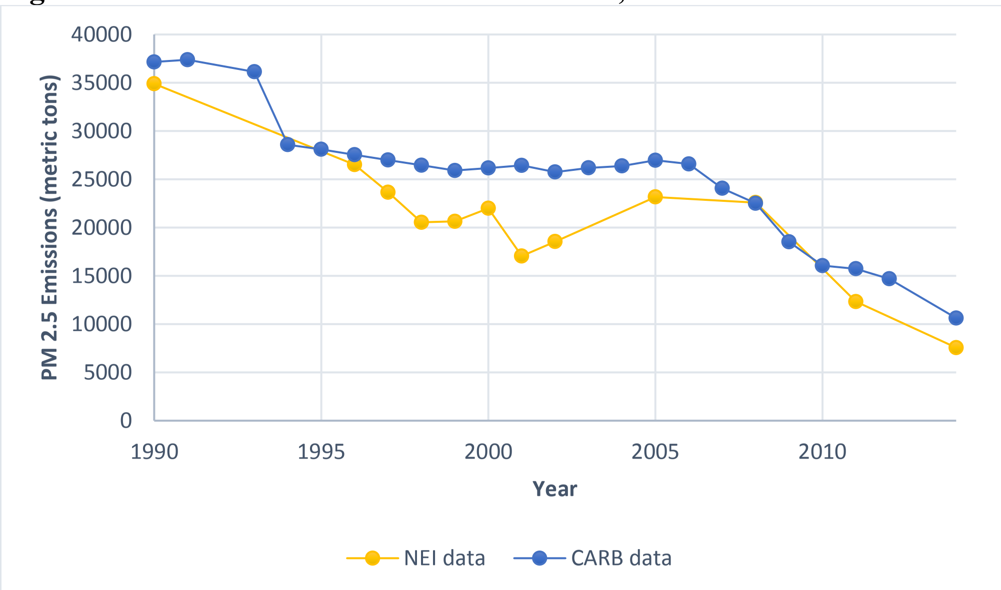
California share of U.S. container traffic

The American Association of Port Authorities maintains records of a variety of port-specific statistics. We downloaded "North American container traffic 1980-2018" from the AAPA website (*100*). By selecting ports located in California, we were able to calculate the portion of the U.S. total container traffic handled by California ports.

Comparing California DPM emissions data obtained from NEI and from CARB

The California Air Resources Board (CARB) conducts independent monitoring of air emissions in the state and reports those emissions data to the NEI. Given the gaps in NEI data, we obtained CARB emissions data to compare with the California data we downloaded from NEI. Mobile source emissions data are from CARB's California Emissions Projection Analysis Model (CEPAM) emissions inventory, and emissions for point sources are from the California Emissions Inventory Development and Reporting System (CEIDARS) database (CARB emission inventory web page) (*101*). For some sectors in some years, emission data collected by CARB and reported to NEI differ slightly from California emissions data downloaded directly from NEI. In some instances, discrepancies arise because EPA and CARB categorize emissions sources differently, which produces small discrepancies in sector-specific emissions, but not in total emissions. In other instances, jumps in NEI data for California reflect a change in NEI methodology, or a delay between transmission of CARB data to EPA and their incorporation into the NEI database. Given the overall correspondence between the two data sources on total emissions reductions and time trends (Figure S1), we concluded that the effect of using CARB data would be minimal and if anything would bias our analysis toward the null. We therefore used NEI data throughout the analysis to enable valid comparisons between emissions in California and the rest of the U.S.

Figure S1. California diesel PM 2.5 emissions, 1990 - 2014 based on CARB vs. NEI data.



Estimating cardiopulmonary mortality attributable to DPM in California

To calculate cardiopulmonary deaths attributable to DPM in California between 1990 and 2014, we used state-level mortality data and estimates of ambient DPM levels. We obtained compressed mortality files for the state of California for 1990-2014 from the Centers for Disease Control and Prevention's Wide-ranging Online Data for Epidemiologic Research (CDC WONDER) online database (*102*). These compressed mortality files categorize causes of death using the International Classification of Diseases (ICD)-9 codes (for the years from 1990 to 1998) and ICD-10 codes (for the years from 1999 to 2014). We selected the ICD codes corresponding to cardiopulmonary mortality: the ICD-9 codes are 390-459 (Diseases of the circulatory system) and 460-519 (Diseases of the respiratory system), and the ICD-10 codes are I00-I99 (Diseases of the circulatory system) and J00-J98 (Diseases of the respiratory system). The CDC WONDER dataset of the population and the number of deaths by age group and by county for each year was processed in R (see R Code).

To estimate ambient DPM levels, NOx concentrations for 1990-1991 and 1993-2014 were obtained from CARB's Air Quality and Meteorological Information System (CARB AQMIS (*103*), which contains data from a network of air quality monitors throughout California maintained by CARB and local air quality districts). We calculated annual average NOx concentrations for each monitor as follows: we obtained hourly NO and NO_2 data and added NO and NO_2 for each hour to obtain hourly NOx concentrations. We then computed daily means, omitting days for which fewer than 75% of the hourly concentrations were available. We then averaged daily means together to obtain annual averages, omitting years for which fewer than 75% of the daily means were available.

Annual average NOx concentrations at each monitor were multiplied by DPM/NOx emissions ratios to estimate ambient DPM concentrations, under the assumption that that atmospheric concentration ratios are approximately equal to emission ratios. Emission ratios are calculated separately for each year, for each air basin in California, as described in Propper et al. 2015 (*55*) and are included in the supplementary data file (Data S1). Emissions data were not available for 1992, so DPM was not estimated for that year. A spatial interpolation method, inverse distance-squared weighting, was then used to estimate DPM values for each of the 58 counties in California (see R Code).

To estimate the cardiopulmonary mortality impact of ambient DPM, we used the following concentration-response function:

$$mortality\ rate \times population \times (1 - e^{-\beta \times DPM}) \qquad [2]$$

where β is a coefficient value of 0.01293 for $PM_{2.5}$ cardiopulmonary mortality derived from the analyses performed by Krewski et al. (*104, Table 33 p.97*). Specifically, β was calculated by taking the natural log of the hazard ratio of cardiopulmonary mortality (1.138) provided in that study and dividing by the unit change in $PM_{2.5}$ exposure (10 $\mu g/m^3$). To ensure a conservative estimation, we selected this hazard ratio, which was derived from the study's third follow-up period using monitoring data from 1999-2000, adjusted for 44 individual and 7 ecological covariates (*104*).

In Krewski et al., the subjects included in their mortality analysis were all at least 30 years old. Thus, for our analyses, we focused on the following age groups: 35-44 years, 45-54 years, 55-64 years, 65-74 years, 75-84 years, and 85+ years. We were not able to include 30-34-year-olds in our analysis because the CDC Wonder mortality files aggregate the 25-34 age group, which could not then be split to isolate people aged 30-34. This means that our estimate is more conservative, potentially underestimating rather than overestimating the number of cardiopulmonary deaths attributable to DPM exposure. The total population of people aged 35+ for each county for each year of the analysis is presented in the "CA Population" tab of the Data S1 file.

We used Equation 2 to calculate the cardiopulmonary mortality impact of DPM for each age group in each county for each year from 1990-2014 (except for 1992) (see R Code). These values were then summed to arrive at the total cardiopulmonary mortality impact of ambient DPM for the state of California in each year ("DPM Mortality values" tab of Data S1).

Comparison of DPM-related cardiopulmonary mortality between California and the rest of the U.S.
As shown in Figure 1, from 1990-2014 DPM emissions trended down more in California than in the rest of the country. To understand how DPM-related cardiopulmonary mortality in California would have differed absent the State's more aggressive policy interventions, we first applied the percent changes in DPM emissions experienced by the rest of the country to California's emissions. For instance, if the rest of the U.S. saw an 80% decrease in emissions in 1997 compared to 1990, then we also calculated an 80% decline in California's emissions in 1997 compared to 1990. By performing these calculations between 1990-2014, we arrived at theoretical values for what California DPM emissions would have looked like had the state behaved like the rest of the country (Figure S2 and "Mortality Calculations" tab of Data S1). We repeated this analysis for state-by-state DPM emissions specific to the HDDV sector. This enabled us to see variation among states and to calculate a 95% confidence interval for our estimate of how much the emissions of California's HDDV sector would have been reduced if it had followed the same trajectory as other states ("HDDV state data" tab of Data S1 and R Code). Because the state-by-state data were not normally distributed, we used a bootstrapping method to calculate the confidence interval.

In order to estimate the cardiopulmonary mortality impact of DPM emissions for California, we divided the ambient DPM cardiopulmonary mortality by the statewide emissions data for each year (from the U.S. EPA NEI) to get ratios of mortality per DPM emissions. We then calculated the cardiopulmonary mortality for this "California like-the-U.S." by multiplying these ratios with the theoretical DPM emissions for "California like-the-US." Finally, we compared the difference in cardiopulmonary mortality between California and "California like-the-U.S." for the year 2014 ("Mortality Calculations" tab of Data S1). As 2014 is the latest year for which consistent, comparable data are available, the difference in emissions trends in that year reflects the cumulative impact of all CARB emissions policies implemented since 1990.

Figure S2. California, and California like-the-U.S. diesel $PM_{2.5}$ emissions 1990 - 2014, based on NEI data.

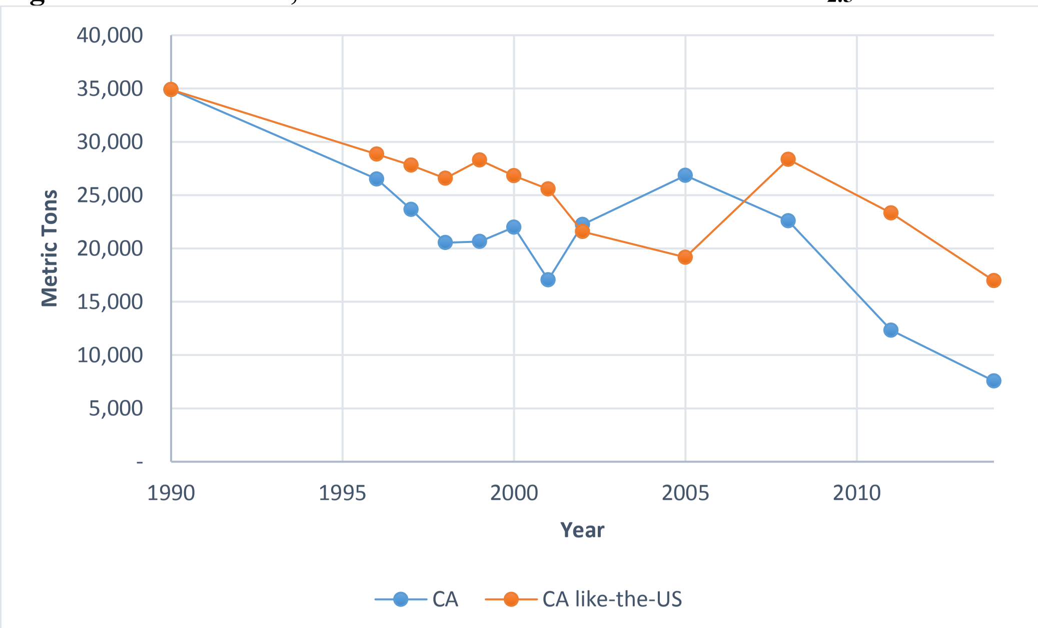
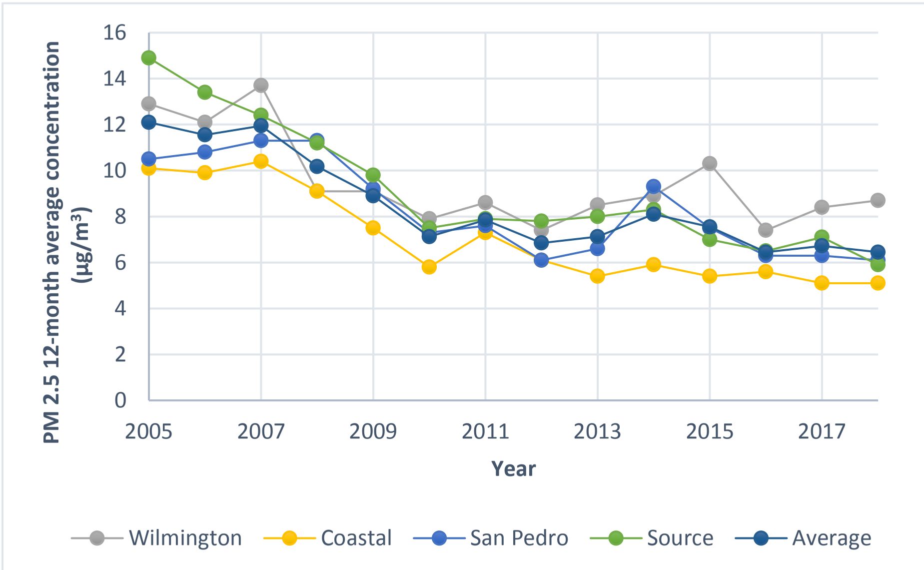
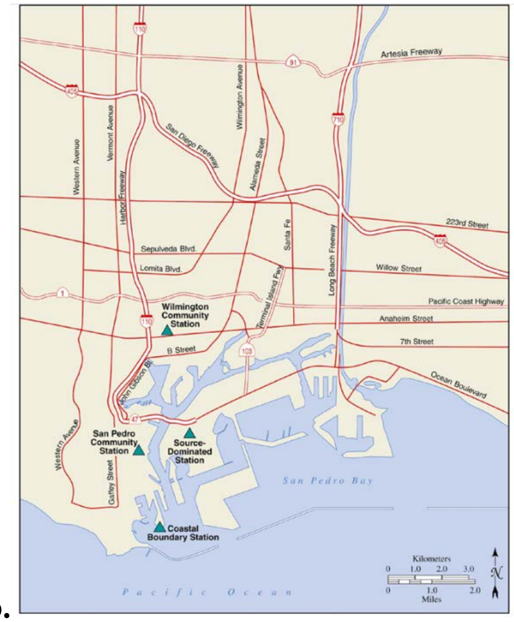


Figure S3a-b. (a) Port of Los Angeles $PM_{2.5}$ 12-month average concentrations in 2005 – 2018 for four monitoring stations, including the Wilmington, Coastal, San Pedro and Source stations, and their average of all four stations (b) Location of monitoring stations at the Port of LA.



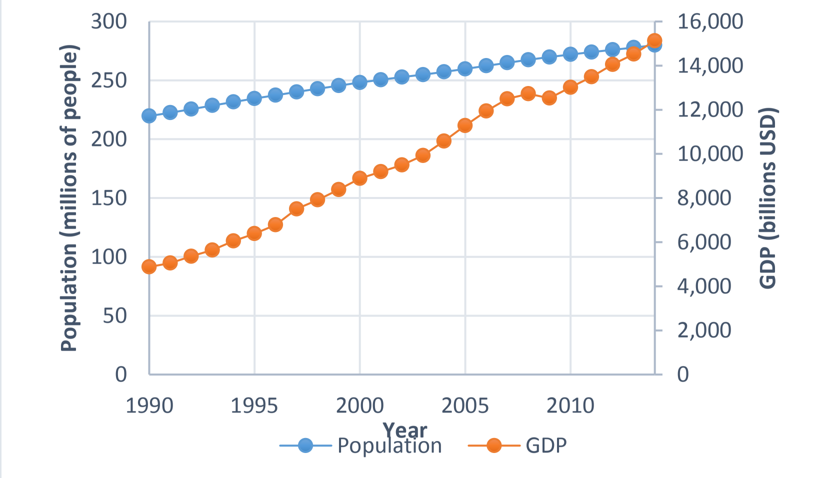
a.

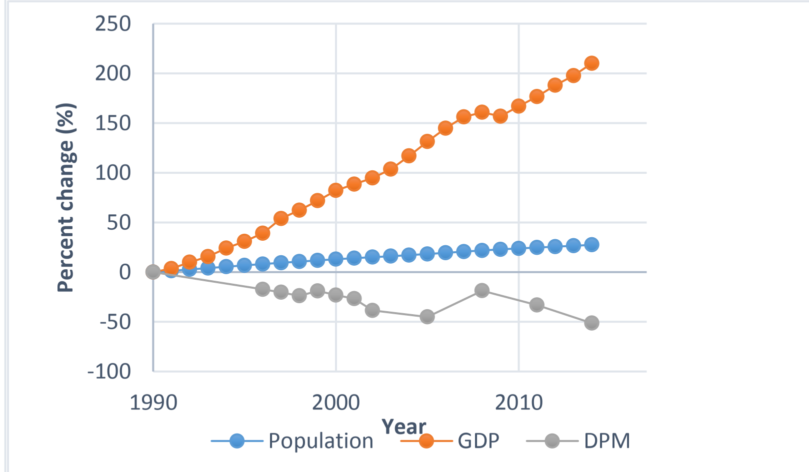


b.

Wilmington Community Station is generally downwind, and the Coastal Station is generally upwind from the Port of LA

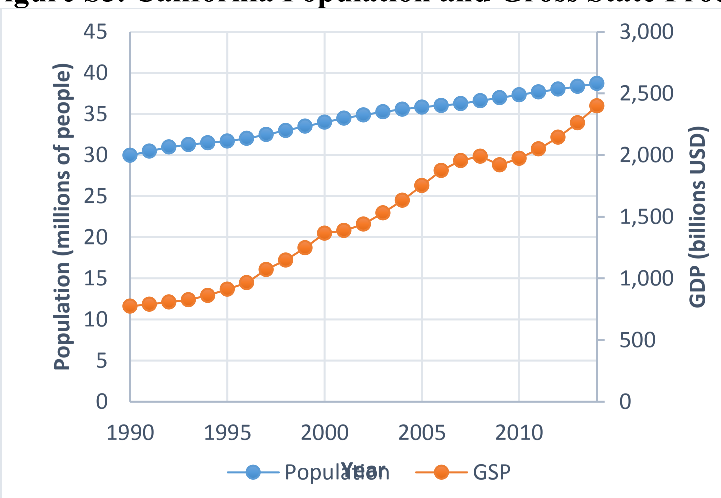
Figure S4. U.S. population and Gross Domestic Product (GDP), 1990 - 2014.

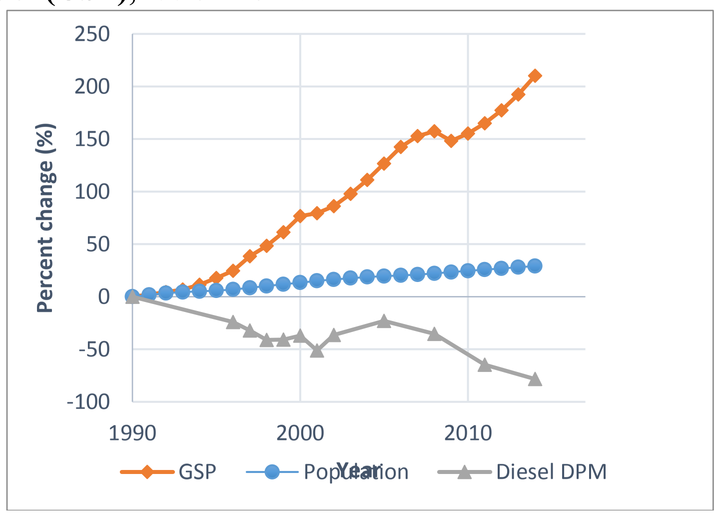




GDP is in current U.S. dollars and is not adjusted for inflation. Population is the estimated number of people in the United States on July 1st of each year. DPM is diesel $PM_{2.5}$ emissions percent change indexed to 1990.

Figure S5. California Population and Gross State Product (GSP), 1990 - 2014.





GSP is in current U.S. dollars and is not adjusted for inflation. Population is the estimated number of people in California on July 1st of each year. DPM is diesel $PM_{2.5}$ emissions percent change indexed to 1990.

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[We note that the comments herein are solely NRDC's and focus on the Zero Emission Vehicles portion of the program. For comments on the Advanced Clean Trucks provision of the regulatory proposal, please see above and the letter submitted by the DRCC.]

1. **Washington Department of Ecology has clear legal authority to adopt and amend its Clean Vehicles Program**

We support Ecology's efforts to update its Clean Vehicles Program as directed by the state legislature under Senate Bill 5811 as reflected under RWC 70A.30.010 requiring Ecology to adopt rules to implement California's vehicle emission standards including the ZEV program, and to amend the rules from time to time to maintain consistency with California's motor emission standards.

Washington also has clear authority under Section 177 of the Clean Air Act (42 U.S.C. Section 7507) to adopt and enforce California's vehicle standards so long as they are identical.

We also agree with Ecology that the current rules can be promulgated under the CR-102 process given the legislative directive to implement the program.

2. **The standards will increase availability and sales of zero-emission vehicles**

The adoption of a ZEV program will mean increased deliveries of zero-emission passenger vehicles in Washington, benefiting consumers who are interested in being able to test-drive and ultimately purchase zero-emission vehicles such as battery electrics, plug-in hybrids, and fuel cell vehicles.

The proposed rules will ensure that Washington consumers and fleets continue to have the latest electric vehicle product offerings and that a floor is established in terms of transitioning to pollution free cars, trucks and buses. Based on analysis in other ZEV states, automakers tend to prioritize - and in some cases limit - product offerings to states that have adopted ZEV.[1]

3. **A Clean Vehicles Washington Program will deliver air pollution and public health benefits to the state**

The clean vehicles package will also deliver public health benefits to the state in terms of reduced NOx and particulate matter as new zero emission vehicles displace combustion of diesel and gasoline.

The Department of Ecology's proposal to adopt California's ZEV program by reference before the end of the year ensures Washington starts experiencing the full benefits of the standards in 2025. This approach will:

[1] https://www.cleanenergytransition.org/post/zero-emission-vehicle-mandates-accelerate-evs

- Help Washington meet its greenhouse gas emissions reductions limits;[2]
- Improve air quality by reducing harmful pollutants from passenger vehicles;
- Accelerate clean transportation job growth in Washington from the existing 3,400 jobs in the sector;[3] and,
- Increase consumer choice by expanding zero-emission vehicle availability, increase used zero-emission vehicle availability, and increase access to fuel and maintenance cost savings.

4. The Department of Ecology should signal how it proposes to address issues related to the ZEV program in its ACC2 rulemaking, similar to recent developments in the Nevada ZEV adoption process

We support Ecology moving forward - without delay - to adopt the proposed Advanced Clean Cars 1 regulations. However, we ask that the Department make clear its intent regarding how it proposes to address concerns related to the ZEV initial credit bank in its future Advanced Clean Cars 2 rulemaking.

We appreciate that in past public meetings, the Department of Ecology has stated that for the Zero-Emission Vehicles Program, they intend to consider the issue of the credit banks as part of future updates to the program under an Advanced Clean Cars 2 rulemaking. We support the Department doing so, but recommend that the department provide greater specificity. Recent developments in the Nevada ZEV rulemaking, which resulted in a consensus approach across the state agency, environmental advocates, auto industry, and state auto dealers provide a good model for Washington to follow. In that process the state agency memorialized its intent in a statement inserted into the record.

This consensus approach, or a variation appropriate to the Washington administrative context, would ensure that the Washington ZEV program will have the same credit stringency, no more and no less, than California's program going forward taking into account any potential early and proportional credits. Memorializing Washington's intent now will provide greater certainty for clean vehicle supporters who want to ensure that surplus credits do not erode the impact of a future Advanced Clean Cars 2 ("ACC2") regulation in Washington, while also providing greater certainty to automakers planning to meet ACC2 trajectory and transition.

Comments on Proposed Rule Language

In order to realize the full benefits of the Clean Vehicles Program, we offer the following perspective and recommendations regarding the proposed rule language.

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[2] RCW 70A.45.020
[3] https://e2.org/wp-content/uploads/2020/11/E2-Clean-Jobs-Washington-2020.pdf

Zero Emission Vehicle Program Credits

The CR-102 states that "the rule does not provide credits for vehicles before model year 2025 that are sold in Washington," but as written, the proposed rule language allows for new zero emission vehicles from earlier model years that are delivered for sale in Washington in model year 2025 to count towards meeting the annual credit percentage requirement. In order to align the rule language with the stated intent, we recommend the following change.

> WAC 173-423-075 (1)(c) ZEV credits. *ZEV credits may only be earned by model year 2025 and subsequent vehicles*~~New vehicles delivered for sale in Washington before model year 2025 cannot earn ZEV credits~~.

Severability Clause

The ZEV and ACT regulations are combined into one new section (WAC 173-423-075 Zero-emission vehicle standards), which suggests the entire section is severable if part is held invalid. To ensure all valid portions are retained in such an instance, we suggest revisiting the structure.

Conclusion

Thank you for receiving our comments. We strongly support the adoption of the ZEV program and the ACT rule. These rules will help Washington achieve its statutory climate goals while reducing health-harming air pollution, providing Washingtonians with clean vehicle choices, and growing our local economy through good, green jobs. In order to ensure these rules are as strong as possible, we hope you consider our recommendations above, which do not change the intent of the rule language but add clarity and thus should be considered insignificant changes. We also look forward to supporting future rulemakings, including adoption of California's Advanced Clean Cars II rule at a parallel level of stringency with associated credit parameters, the Heavy-Duty Omnibus rule, and a fleet reporting requirement. All together, these rules represent significant progress toward a clean energy economy.

Sincerely,

Simon Mui
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Appendix

Washington Clean Trucks Program

An Analysis of the Impacts of Zero-Emission Medium- and Heavy-Duty Trucks on the Environment, Public Health, Industry, and the Economy

MJB & A

an ERM Group company

Acknowledgments

Lead Authors: Dana Lowell, Amlan Saha, Miranda Freeman, Doug MacNair, David Seamonds, and Ellen Robo.

This report summarizes the projected economic, climate, and public health benefits of actions that the state of New Jersey could take to increase the sale of low- and no-emission medium- and heavy-duty trucks in the state over the next 30 years.

This report was developed by M.J. Bradley & Associates for the Natural Resources Defense Council and the Union of Concerned Scientists.

About M.J. Bradley & Associates

MJB&A, an ERM Group company, provides strategic consulting services to address energy and environmental issues for the private, public, and nonprofit sectors. MJB&A creates value and addresses risks with a comprehensive approach to strategy and implementation, ensuring clients have timely access to information and the tools to use it to their advantage. Our approach fuses private sector strategy with public policy in air quality, energy, climate change, environmental markets, energy efficiency, renewable energy, transportation, and advanced technologies. Our international client base includes electric and natural gas utilities, major transportation fleet operators, investors, clean technology firms, environmental groups, and government agencies. Our seasoned team brings a multi-sector perspective, informed expertise, and creative solutions to each client, capitalizing on extensive experience in energy markets, environmental policy, law, engineering, economics, and business. For more information, we encourage you to visit our website, www.mjbradley.com.

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Contents

Introduction

M.J. Bradley & Associates was commissioned by the Natural Resources Defense Council and the Union of Concerned Scientists to evaluate the costs and benefits of state-level requirements for manufacturers that Washington could adopt to increase sales of no- and low-emission medium- and heavy-duty (M/HD) trucks and buses. The analysis examines all on-road vehicles registered in Washington with greater than 8,501 pounds gross vehicle weight, encompassing vehicle weight classes from Class 2b though Class 8. This is a diverse set of mostly commercial vehicles that includes heavy-duty pickups; school and shuttle buses; sanitation, construction, and other types of work trucks; and freight trucks ranging from local delivery vans to tractor-trailers that weigh up to 80,000 pounds when loaded.

Collectively the Washington M/HD fleet includes almost 540,000 vehicles that annually travel more than 8.56 billion miles and consume almost 1 billion gallons of petroleum-based fuels.

In Washington M/HD vehicles are currently responsible for an estimated 10.4 million metric tons (MMT) of greenhouse gas (GHG) emissions annually—approximately 30 percent of all GHGs from the on-road vehicle fleet.[1] In Washington M/HD vehicles are also responsible for 59 percent of the nitrogen oxide (NOx) and 53 percent of the particulate matter (PM[2]) emitted by on-road vehicles, both of which contribute to poor air quality and resulting negative health impacts in many urban areas, including low-income and disadvantaged communities that are often disproportionately affected by emissions from freight movement due to their proximity of transportation infrastructure to the communities.

Prior work by MJB&A conducted in consultation with the New Jersey Environmental Justice Alliance and members of the Coalition for Healthy Ports NY NJ demonstrated that emissions from diesel trucks and

1 The remainder of emissions are from passenger cars and light trucks. This includes tailpipe emissions and “upstream” emissions from fuel production and transport.

2 In this report all references to PM are particulate matter with mean aerodynamic diameter less than 2.5 microns ($PM_{2.5}$).

buses emit higher levels of air pollution, which can lead to even greater health concerns in populations more directly exposed to diesel emissions.[3] Communities located adjacent to ports and related goods-movement infrastructure (e.g., warehouses, logistics centers, rail yards, etc.) experience higher levels of truck traffic, both from surrounding thruways and on local streets, which exacerbates health concerns. Since these emissions are local in their effects, policies to reduce transportation emissions from medium- and heavy-duty vehicles can significantly improve the health and well-being of communities in urban areas or around transportation corridors, which are often home to people of color or low income or those who are otherwise vulnerable or disadvantaged.

For the study of Washington, MJB&A modeled three Clean Truck policy scenarios with increasing levels of ambition. Under the least aggressive scenario—state adoption of California's Advanced Clean Truck (ACT) rule (allowable under the Clean Air Act)—estimated cumulative net societal benefits total almost $24.9 billion (in constant 2020$) through 2050, compared with the baseline scenario.[4] These net societal benefits include the monetized value of climate and public health benefits resulting from reduced GHG, NOx, and PM emissions in the state, including up to 114 fewer premature deaths and 97 fewer hospital visits from breathing polluted air. Net societal benefits also include net cost savings to fleets from operating zero-emission trucks, and savings to all residential and commercial electricity customers due to lower electric rates made possible by the additional electricity sales for electric vehicle charging. Under the ACT scenario, by 2050 annual cost savings for Washington fleets are estimated to be more than $1.3 billion, and annual bill savings for electric utility customers in the state could reach an estimated $92 million.

The most aggressive policy scenario (100 x 40 ZEV + Clean Grid, discussed below) results in turnover of virtually the entire Washington M/HD fleet to zero-emission vehicles (ZEVs) by 2050, together with a shift to cleaner electricity generation sources. Cumulative net societal benefits through 2050 increase to more than $42.8 billion under this scenario, and there will be an estimated 288 fewer premature deaths and 242 fewer hospital visits. In 2050 estimated annual fleet cost savings also increase, to $2.4 billion, and electric customer annual bill savings increase to an estimated $148 million.

The modeling tools used for this analysis could not apportion these estimated benefits to individual communities within the state, but prior work indicates that emission reductions from M/HD trucks and buses would provide the greatest benefits in areas in close proximity to freight corridors and other transportation infrastructure. As such, communities that are currently disproportionately impacted by transportation are expected to receive a higher share of the public health benefits, as long as zero emission trucks and buses are deployed equivalently across the state.

Implementation of the modeled scenarios will require significant changes to the national economy, as manufacturing of internal combustion engine vehicles is replaced by manufacturing of electric and fuel cell vehicles, and production and sale of petroleum fuels is replaced by increased production and sale of electricity and hydrogen. This analysis indicates that this transition will have positive macroeconomic effects, including increased net jobs and gross domestic product (GDP), as well as increased wages for the new jobs that will be added, relative to the jobs that will be replaced.

Compared with the baseline scenario, net national job gains under the most aggressive policy scenario total 83 in 2035, though there is a net job loss by 2045 due to total fleet fuel and maintenance cost savings. Average wages for the new jobs created under the ZEV transition are expected to be, on average, almost 50% higher as average wages for the jobs that will be replaced.

3 MJB&A, *Newark Community Impacts of Mobile Source Emissions: A Community-Based Participatory Research Analysis*, November 2020, http://www.njeja.org/wp-content/uploads/2021/04/NewarkCommunityImpacts_MJBA.pdf.

4 All values cited in this report are in constant 2020$, unless otherwise stated.

Policy Scenarios

This report summarizes the projected environmental and economic effects of Washington adopting policies requiring manufacturers to sell a greater number of M/HDV low- and no-emission vehicles over the next 30 years. Three specific Clean Truck policy scenarios, representing increasing levels of ambition, were evaluated.

- **ACT Rule:** Washington adopts requirements analogous to those adopted by California under the Advanced Clean Trucks Rule, which requires an increasing percentage of new trucks purchased in the state to be ZEVs beginning in the 2025 model year. The percentage of new vehicles that must be ZEV varies by vehicle type, but for all vehicle types the required ZEV percentage increases each model year between 2025 and 2035 (see Figure 1).

- **ACT Rule plus NOx Omnibus Rule:** In addition to adopting the ACT Rule, Washington adopts requirements analogous to those adopted by California under the Heavy-Duty Omnibus Rule (referred to herein as the NOx Omnibus Rule). This rule requires an additional 75 percent reduction in nitrogen oxide (NOx) emissions from the engines in new gasoline and diesel trucks sold between model year 2025 and 2026, and a 90 percent reduction for trucks sold beginning in the 2027 model year.[5]

- **100 x 40 ZEV + Clean Grid:** In addition to adopting the ACT and NOx Omnibus Rules, Washington takes further actions to ensure more rapid and continued increases in new ZEV sales, such that virtually all new trucks are ZEV by 2040 (see Figure 1), with Class 2b–3 achieving 100 percent ZEV sales in 2038 and Class 4–8 (non-tractors) achieving 100 percent ZEV sales in 2035. In addition, an aggressive federal Clean Energy Standard is assumed to ensure that electricity generation in the state is virtually carbon free and 96 percent renewable by 2050. State-specific renewable portfolio standards that could increase the renewable electricity levels even more were not analyzed as part of this study.

All three of these Washington policy scenarios are compared with a baseline "business as usual" scenario in which all new trucks sold in the state continue to meet existing EPA NOx emission standards and ZEV sales increase only marginally, never reaching more than 1 percent of new vehicle sales each year.[6]

The analysis assumes that M/HD annual vehicle miles traveled (VMT) in Washington will continue to grow by approximately 0.8 percent annually through 2050, as projected by the Energy Information Administration (EIA), as the economy and population continue to grow. The modeled policy scenarios do not include freight system enhancements or mode shifting to slow the growth of, or reduce, M/HD truck miles; this would be expected to provide additional emission reductions.

The analysis was conducted using MJB&A's STate Emission Pathways (STEP) Tool. The climate and air quality impacts of each policy scenario were estimated on the basis of changes in M/HD fleet fuel use and include both tailpipe emissions and "upstream" emissions from production of the transportation fuels used in each scenario. These include petroleum fuels used by conventional internal combustion engine vehicles (gasoline, diesel, natural gas) and electricity and hydrogen used by ZEVs, which are assumed to include both battery electric (EV) and hydrogen fuel cell electric (FCV) vehicles.

5 Reductions are relative to current federal EPA new engine emission standards. This rule does not require additional PM reductions but includes anti-backsliding provisions to ensure that PM emissions do not increase compared with engines designed to meet current federal standards.

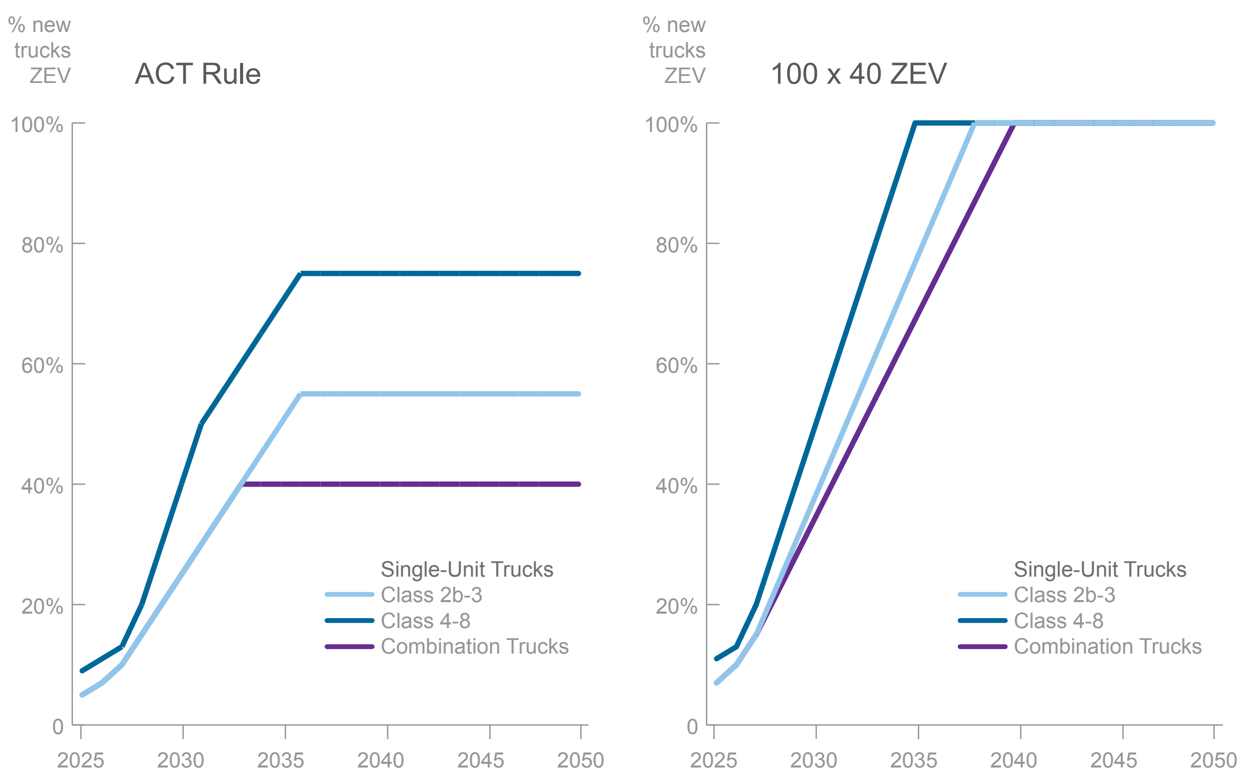
6 The baseline ZEV sales assumptions are consistent with projections in the Energy Information Administration's Annual Energy Outlook 2021.

To evaluate climate impacts, the analysis estimated changes in all combustion related GHGs, including carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O). To evaluate air quality impacts, the analysis estimated changes in total nitrogen oxide (NOx) and particulate matter (PM) emissions and resulting changes in ambient air quality and health metrics such as premature deaths, hospital visits, and lost workdays.

The economic analysis estimated the change in annual M/HD fleet-wide spending on vehicle purchase, charging/fueling infrastructure to support ZEVs, vehicle fuel, and vehicle and infrastructure maintenance under each scenario. Currently ZEVs are more expensive to purchase than equivalent gasoline and diesel vehicles, but they have lower fuel and maintenance costs. Over time the incremental purchase cost of ZEVs is also projected to fall. Technologies required to meet the more stringent NOx standards of the NOx Omnibus Rule are also projected to increase purchase costs for compliant vehicles.

On the basis of estimated changes in fleet spending, the analysis estimated the macroeconomic effects of each scenario on national jobs, wages, and gross domestic product (GDP).

Figure 1 Annual Zero-Emission Vehicle Sales in Clean Truck Policy Scenarios



The analysis also estimated the impact of each scenario on Washington's electric utilities, including the total statewide change in power demand (kW) and energy consumption (kWh) for M/HD EV charging, as well as the additional revenue and net revenue that would be received by the state's electric utilities for providing this power. On the basis of projected utility net revenue, the analysis estimates the potential effect on state electricity rates for residential and commercial customers.

In addition, the analysis estimated the total number of vehicle chargers that will be required to support the increase in M/HD EVs under each scenario—both depot-based chargers and shared public chargers—compared with the existing charging network in the state.

For a full description of the modeling approach and sources of assumptions used for this analysis, see the report: *Clean Trucks Analysis: Costs & Benefits of State-Level Policies to Require No- and Low-Emission Trucks, Technical Report—Methodologies and Assumptions*, May 2021 (https://mjbradley.com/clean-trucks-analysis).

The Washington electric grid mix and energy cost assumptions used can also be found in the Appendix to this report.

Washington Results

The sections below detail the results of the Washington Clean Trucks analysis, beginning with a description of the current Washington M/HDV fleet and the projected fleet under each modeled policy scenario. This is followed by a summary of the environmental and public health benefits of each scenario and the economic impacts of the modeled fleet transitions.

Washington M/HD Vehicle Fleet

Table 1 summarizes the current M/HD fleet in Washington State, broken down by the four major vehicle types used to frame the Clean Trucks analysis.

Table 1 Current Washington M/HD Fleet

Vehicle Type		No. of Vehicles	Annual VMT (billion miles)	Annual Fuel (million gallons)
Heavy-Duty Pickup and Van **Class 2b**		283,257	3.19	170.3
Bus **Class 3–8**		11,908	0.22	27.0
Single-Unit Work and Freight Truck **Class 3–8**		199,343	2.45	302.0
Combination Truck **Class 7–8**		45,109	2.70	397.2
TOTAL		**539,617**	**8.556**	**896.6**

Approximately 52 percent of the in-use M/HD fleet are Class 2b vehicles (8,500–10,000 in gross vehicle weight rating, GVWR), which are mostly heavy-duty pickup trucks and vans.[7] These vehicles account for 37 percent of annual M/HD miles and 19 percent of annual fuel use. Approximately 2 percent of the fleet are buses, which account for 3 percent of annual VMT and 3 percent of annual fuel use. This includes relatively small shuttle buses (class 3–5) as well as school buses, transit buses, and intercity/charter coach buses.[8] Thirty-seven percent of the fleet are single-unit freight and work trucks, which account for 29 percent of annual VMT and 34 percent of annual fuel use. These vehicles come in a wide variety of sizes (Class 3–8) and have a wide variety of uses, from vans and box trucks used to deliver freight, to sanitation and construction trucks, to boom-equipped utility trucks. Only 8 percent of the fleet are combination truck-tractors, but these vehicles account for 32 percent of annual VMT and 44 percent of annual fuel use, since approximately two-thirds of these vehicles are used primarily for long-distance freight hauling and typically log many more daily and annual miles than other M/HD vehicles.

Today less than 1 percent of the national M/HD fleet is powered by electricity or alternative fuels (natural gas and propane). Approximately 64 percent of the fleet have diesel engines and 36 percent use gasoline.[9] The largest Class 7 and 8 vehicles are almost all diesel, while almost 50 percent of the smaller Class 2b–5 trucks have gasoline engines, with most of the remainder diesel.

Figure 2 summarizes the modeled turnover of the Washington in-use fleet to zero-emission and low-NOx trucks under the three Clean Truck policy scenarios. Fleet turnover to new trucks is based on historical average turnover rates and projected fleet growth rates, along with the new vehicle ZEV purchase percentages shown in Figure 1. Approximately 6.1 percent of existing Class 2b trucks and 4.7 percent of Class 3–8 trucks and buses are retired each year and replaced with new vehicles.[10] The ACT + NOx Omnibus scenario and the 100 x 40 ZEV + Clean Grid scenario further assume that all new vehicles purchased in 2024 and later years that are not ZEV will have low-NOx engines compliant with the NOx Omnibus standards.

As shown, under the ACT Rule policy scenario, 34.6 percent of the in-use M/HD fleet will turn over to ZEV by 2040, and 59.9 percent are ZEV by 2050; all of these ZEVs are assumed to be electric vehicles. Under the ACT + NOx Omnibus policy scenario, the same percentage of the fleet turns over to ZEV, but the remaining internal combustion engine vehicles in the fleet turn over to low-NOx engines by 2044. Under the 100 x 40 ZEV + Clean Grid policy scenario, 54.5 percent of the in-use fleet turns over to ZEV by 2040 and 97.1 percent do so by 2050. This scenario assumes that new ZEVs will include both EV and fuel cell vehicles powered by hydrogen. In 2050, 5.2 percent of in-use ZEVs are assumed to be FCV and 91.9 percent are EV.

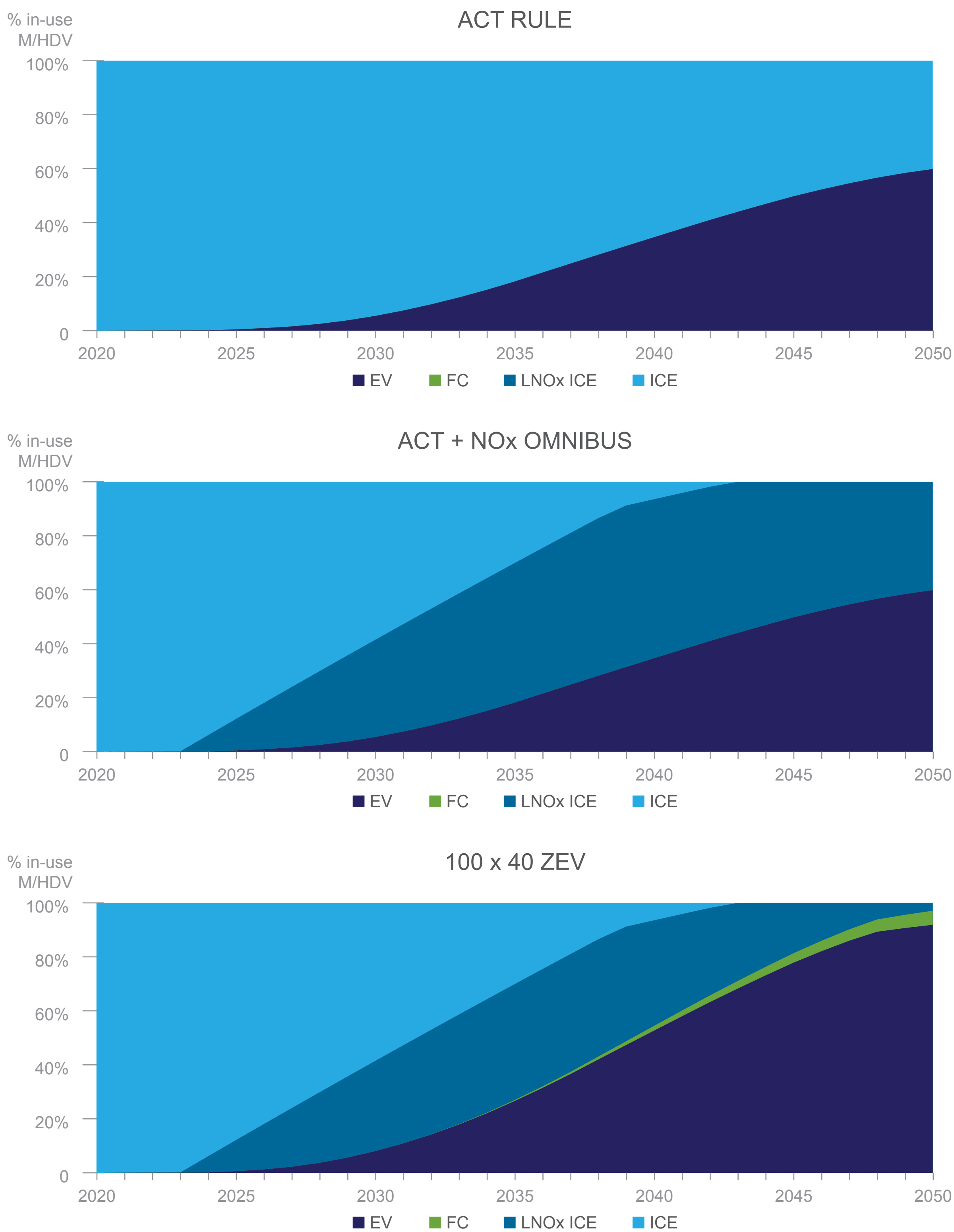
7 A very small percentage of these vehicles are large SUVs.

8 Note that the ACT Rule does not include ZEV requirements for transit buses, as these vehicles are covered by a separate Innovative Clean Transit regulation in California.

9 These figures are based on state registration data collected by IHS Markit.

10 This is a long-term average. Actual annual turnover is highly correlated to economic conditions and can vary widely from year to year.

Figure 2	Fleet Turnover to Low-NOx and Zero-Emission Vehicles in Clean Truck Policy Scenarios



EV (battery electric vehicle); FC (fuel cell vehicle); LNOx ICE (low-NOx internal combustion engine vehicle); ICE (conventional internal combustion engine vehicle)

Changes in Fleet Fuel Use

Under all modeled Clean Truck policy scenarios, a significant portion of the Washington M/HD fleet is assumed to turn over to EV and FCV trucks and buses. This will result in replacement of petroleum fuels—primarily gasoline and diesel fuel—with electricity and hydrogen.[11]

Under the baseline scenario, total petroleum fuel use by the Washington M/HD fleet in 2050 is projected to be 780 million gallons. Under the ACT Rule policy scenario, petroleum fuel use in 2050 falls to an estimated 380 million gallons (–51 percent), and cumulative reductions in diesel and gasoline use by the M/HD fleet total 5.0 billion gallons between 2020 and 2050. This petroleum fuel is replaced by 90.5 million megawatt-hours (MWh) of electricity between 2020 and 2050. Electricity use for M/HD EV charging in 2050 is estimated to be 7.8 million MWh, a 11 percent increase to estimated baseline electricity use by Oregon residential and commercial customers that year (70 million MWh).

Adding the NOx Omnibus Rule to the ACT Rule does not result in additional reductions in petroleum fuel use.

Under the 100 x 40 ZEV + Clean Grid scenario, estimated petroleum fuel use by the M/HD fleet in 2050 falls to 4.7 million gallons (–94 percent), and cumulative reductions in diesel and gasoline use by the M/HD fleet total 8.4 billion gallons between 2020 and 2050. This petroleum fuel is replaced by 134.8 million MWh of electricity and 1.1 billion kilograms of hydrogen between 2020 and 2050. Electricity use for M/HD EV charging in 2050 is estimated to be 11.9 million MWh, a 17 percent increase to estimated baseline electricity use by Washington residential and commercial customers that year.

Public Health and the Environment

The modeled Clean Trucks policy scenarios produce significant reductions in NOx, PM, and GHG emissions from the M/HD fleet, even after accounting for the emissions from producing the electricity and hydrogen needed to power ZEVs. NOx and PM reductions will improve local air quality, particularly in urban areas, resulting in public health benefits from reduced mortality and hospital visits. As noted earlier, low-income and disadvantaged communities are often disproportionately impacted by emissions from freight movement, due to the proximity of the transportation infrastructure to many of these communities.[12]

Air Quality Impacts

Figures 3 and 4 show estimated annual M/HD fleet NOx and PM emissions, respectively, under the baseline scenario and the modeled Clean Truck policy scenarios. Under the baseline scenario, annual M/HD fleet NOx emissions are projected to fall by 47 percent and annual fleet PM emissions are projected to fall 73 percent through 2045, as the current fleet turns over to new gasoline and diesel trucks with cleaner engines that meet more stringent EPA new engine emissions standards. After 2045 baseline annual NOx and PM emissions are then projected to start rising again as annual fleet VMT continues to grow.

11 A small number of M/HD trucks and buses in Washington currently use natural gas.

12 MJB&A, *Newark Community Impacts*.

Figure 3 Projected M/HD Fleet NOx Emissions

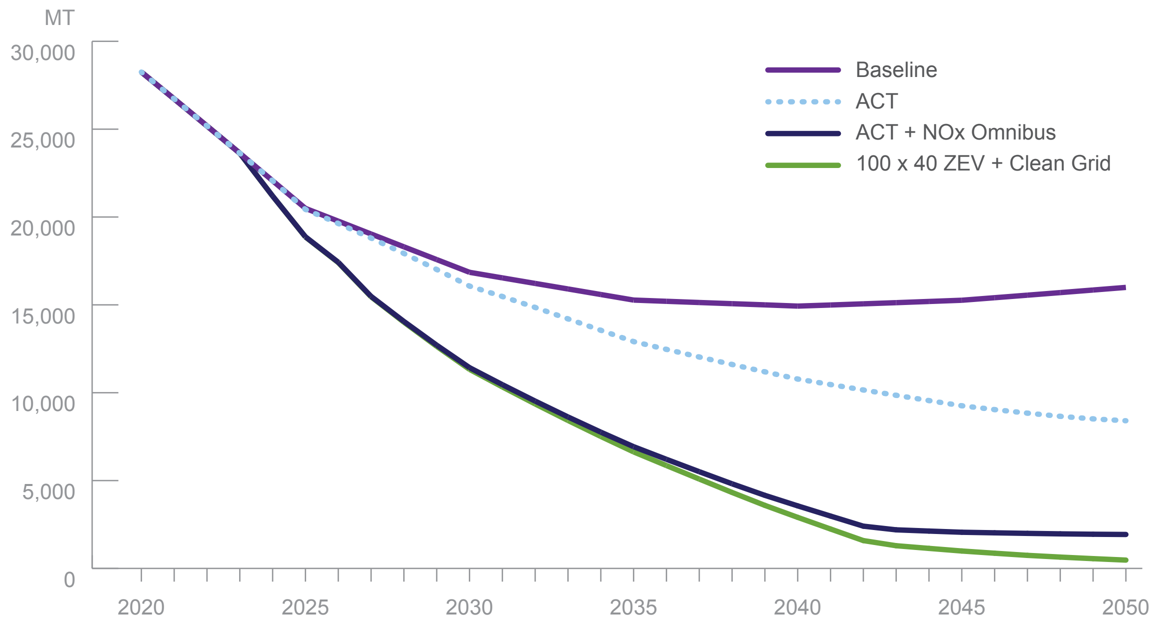
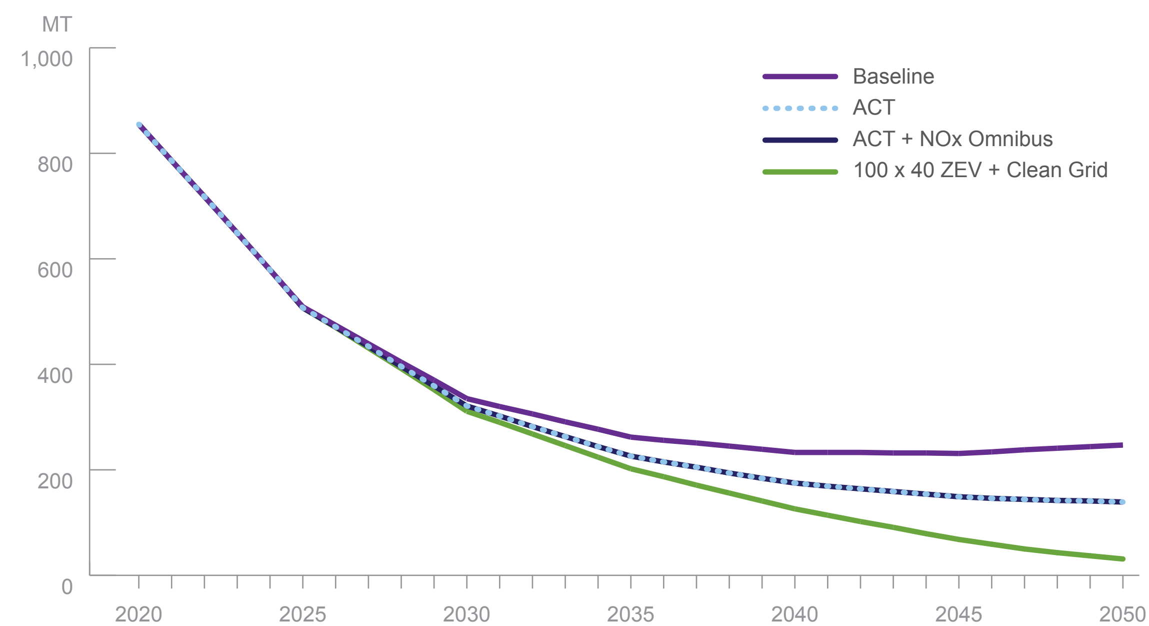


Figure 4 Projected M/HD Fleet PM Emissions



Compared with the baseline, by 2050 the ACT rule is estimated to reduce annual fleet NOx and PM emissions by 47 percent and 43 percent, respectively, as diesel and gasoline trucks are replaced with electric vehicles. Adding the NOx Omnibus Rule will further reduce annual fleet NOx emissions due to turnover of the diesel and gasoline portion of the fleet to new vehicles with low-NOx engines; by 2050 annual NOx emissions are projected to be 88 percent lower than under the baseline if both the ACT and NOx Omnibus Rules are implemented.

The 100 x 40 ZEV + Clean Grid scenario has the lowest fleet emissions due to replacement of virtually all gasoline and diesel trucks and buses with EVs and FCVs by 2050, when annual NOx and PM emissions are estimated to be 97 percent and 87 percent lower, respectively, than baseline emissions.

Over the next 30 years, cumulative NOx and PM emission reductions from the ACT Rule (compared with the baseline scenario) total 89,340 metric tons (MT) and 1,289 MT, respectively. Additional cumulative NOx reductions from the NOx Omnibus Rule are estimated at 153,400 MT over the same time. Cumulative NOx and PM emission reductions from the 100 x 40 ZEV + Clean Grid scenario (compared with the baseline) are projected to total 257,700 MT and 2,440 MT, respectively.

Public Health Benefits

The reduced annual NOx and PM emissions under the Clean Truck policy scenarios will reduce ambient particulate levels in the air, which will reduce the negative health effects on Washington residents breathing in these airborne particles.[13] Estimated public health impacts include reductions in premature mortality and fewer hospital admissions and emergency room visits for asthma. There will also be reduced cases of acute bronchitis, exacerbated asthma, and other respiratory symptoms, and fewer restricted activity days and lost workdays. Cumulative estimated reductions in these health outcomes in Washington under the modeled Clean Truck policy scenarios are shown in Table 2; these benefits were estimated using the U.S. Environmental Protection Agency's CO-Benefits Risk Assessment (COBRA) Health Impacts Screening and Mapping Tool. While this analysis did not apportion estimated public health benefits to specific communities within the state, they are expected to disproportionately accrue to those communities in close proximity to freight infrastructure, since these communities are disproportionately impacted by current emissions from M/HD truck traffic.

Table 2 Cumulative Public Health Benefits of Clean Truck Policy Scenarios, 2020–2050

Health Metric	ACT Rule	ACT + NOx Omnibus	100 x 40 ZEV + Clean Grid
Avoided Premature Deaths	114	246	288
Avoided Hospital Visits[a]	97	205	242
Avoided Minor Cases[b]	69,553	152,909	177,576
Monetized Value, 2020$ (millions)	$1,329	$2,878	$3,364

a Includes hospital admissions and emergency room visits.

b Includes reduced cases of acute bronchitis, exacerbated asthma, and other respiratory symptoms, and reduced restricted activity days and lost workdays.

13 PM is directly emitted to the atmosphere from combustion sources as solid particles. NOx is emitted from combustion sources as a gas but contributes to the formation of secondary particles via chemical reactions in the atmosphere. Both direct and secondary particles have negative health effects when taken into the lungs.

The monetized value of cumulative public health benefits from the ACT Rule over the next 30 years totals more than $1.3 billion. Adding the NOx Omnibus Rule would increase the monetized value of cumulative net public health benefits to nearly $2.9 billion. The monetized value of cumulative public health benefits under the 100 x 40 ZEV + Clean Grid policy scenario totals nearly $3.4 billion through 2050.

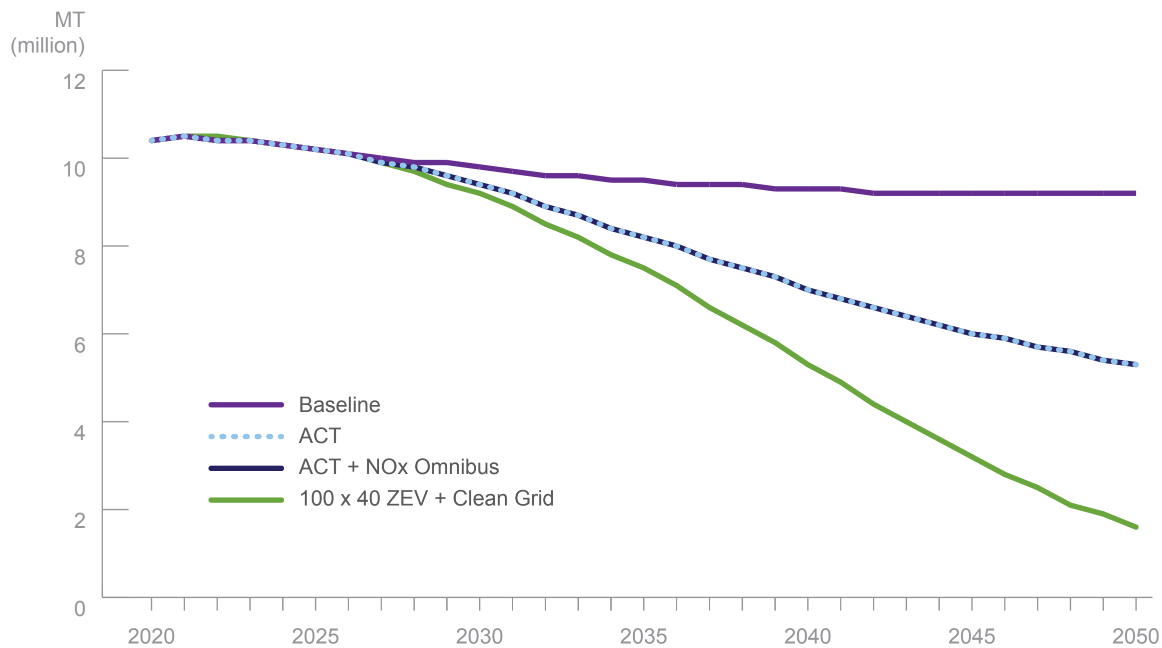
Climate Benefits

Figure 5 illustrates estimated annual M/HD fleet GHG emissions under the baseline scenario and the modeled Clean Truck policy scenarios. As shown, under the baseline scenario annual M/HD fleet GHG emissions are projected to fall by 12 percent through 2050 as the current fleet turns over to new, more efficient gasoline and diesel trucks that meet more stringent EPA new engine and vehicle emission standards.

Compared with the baseline, by 2050 the ACT rule is estimated to further reduce annual fleet GHG emissions by 42 percent, as diesel and gasoline trucks are replaced with electric vehicles; adding the NOx Omnibus Rule does not produce additional fleet GHG emissions beyond those achieved by the ACT Rule.

The 100 x 40 ZEV + Clean Grid scenario has the lowest fleet emissions due to replacement of virtually all gasoline and diesel trucks and buses with EV and FCV by 2050, when annual fleet GHG emissions are estimated to be 83 percent lower than baseline emissions.

Figure 5 Projected M/HD Fleet GHG Emissions



Over the next 30 years, cumulative GHG emission reductions from the ACT Rule (compared with the baseline scenario) total 46.9 million MT. Cumulative GHG emission reductions from the 100 x 40 ZEV + Clean Grid scenario (compared with the baseline) are projected to total 85.3 million MT. These estimates of GHG reductions from each policy scenario account for reductions in petroleum fuel use (gasoline, diesel fuel) by the M/HD fleet as well as increased emissions from electricity and hydrogen production to fuel the EVs and FCVs that will replace gasoline and diesel trucks and buses.

Using the social cost of greenhouse gases as estimated by the federal government's Interagency Working Group, these estimated cumulative GHG reductions have a monetized value of $8.6 billion for the ACT Rule policy scenario and $14.9 billion for the 100 x 40 ZEV + Clean Grid policy scenario.[14] The social value of GHG reductions represents potential societal cost savings from avoiding the negative effects of climate change, if GHG emissions are reduced enough to keep long-term warming below 2 degrees Celsius from preindustrial levels.[15]

The assumed Washington grid mix for electricity production each year is shown in the Appendix. For the baseline, ACT Rule, and ACT+ NOx Omnibus scenarios, this analysis conservatively uses a business-as-usual (BAU) grid mix, while the 100 x 40 ZEV + Clean Grid scenario assumes a "decarbonized" grid mix. In 2020 the BAU grid mix is 0.3 percent coal-fired generation, 11.1 percent natural gas–fired generation, and 88.6 percent "zero-emitting" generation sources.[16] By 2050 the zero-emitting portion of the BAU grid mix increases to 89.9 percent while the coal stays nearly steady at 0.4 percent and natural gas falls to 9.7 percent. Considering just renewable resources, the percentages are 80.9 percent in 2030, 81.5 percent in 2040, and 83.1 percent in 2050.

Under the 100 x 40 ZEV + Clean Grid scenario, zero-emitting generation increases to 98.0 percent in 2030, 99.2 percent in 2040, and 100 percent in 2050. Considering just renewable resources, the percentages are 91.0 percent in 2030, 93.8 percent in 2040, and 96.1 percent in 2050. It is noted that additional state policies, such as Renewable Portfolio Standards, could potentially increase the renewable percentages even higher, but these were not considered in this analysis.

Economic Impacts

This section summarizes projected economic impacts of the modeled Clean Truck policy scenarios, including changes in annual operating costs for Washington fleets; impacts to Washington electric utilities and their customers; net societal benefits; and macroeconomic effects on jobs, wages, and gross domestic product from the transition to low-NOx and zero-emission trucks and buses. This section also estimates the required public and private investment in electric vehicle charging infrastructure to support the electric M/HD fleet under each scenario.

Costs and Benefits to Fleets

For all the modeled Clean Truck policy scenarios, this analysis estimated annual incremental costs associated with purchase and use of M/HD ZEVs compared with baseline conventional vehicles with combustion engines that operate on petroleum fuels (gasoline, diesel). These costs include the incremental purchase cost of the new ZEVs added each year (instead of new combustion vehicles), the cost of installing the charging and hydrogen fueling infrastructure required by these new ZEVs, and net fuel and maintenance costs for all ZEVs in the fleet, both those newly purchased each year and those purchased in prior years and still in use.

Net fuel costs include reductions in purchases of diesel fuel and gasoline (due to fewer combustion vehicles), offset by the increased purchase of electricity and hydrogen to power ZEVs. Net maintenance costs include net savings in annual vehicle maintenance for the ZEVs in the fleet compared with combustion vehicles, offset by annual costs to maintain the charging and hydrogen fueling infrastructure needed to support in-use ZEVs.

14 For the social cost values used, see MJB&A, *Clean Trucks Analysis: Costs & Benefits of State-Level Policies to Require No- and Low-Emission Trucks, Technical Report—Methodologies & Assumptions*, May 2021, https://mjbradley.com/clean-trucks-analysis.

15 The Interagency Working Group developed GHG social cost estimates using a range of discount rates. These values are based on the 95th percentile results using a 3 percent discount rate, which is in the middle of the range of estimated values. The monetized value of cumulative GHG reductions under each policy scenario would be 72 percent lower if using the lowest published social cost values, and three times greater if using the highest published values.

16 For this analysis, coal-fired generation includes oil and biomass. Zero-emitting sources include nuclear and renewable sources such as wind, solar, and hydropower.

Figure 6 Projected Lifetime Incremental Costs for Washington ZEVs Compared With Combustion Vehicles

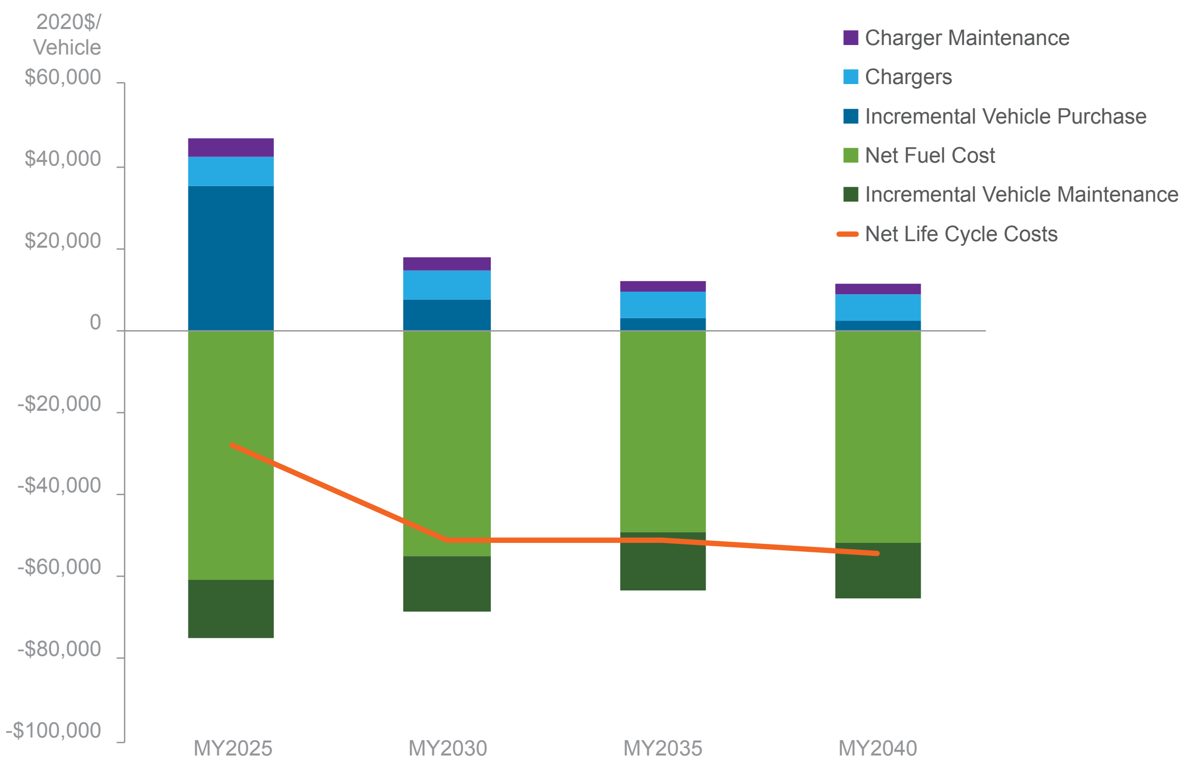


Figure 6 shows projected average lifetime incremental costs for new ZEVs purchased in Washington compared with lifetime costs for combustion vehicles purchased in the same model year; the bars show fleet average values for all Class 2b–8 ZEVs purchased each year under the 100 x 40 ZEV scenario. Incremental fuel and maintenance costs are discounted lifetime costs, assuming 21-year vehicle life, and 6 percent annual discount rate. Vehicle financing, which is often used by fleets when purchasing vehicles, was not considered in this analysis.

As shown, the average M/HD ZEV in Washington is projected to produce more than $65,000 in discounted fuel and maintenance cost savings over its lifetime. For ZEVs purchased in the very near term, this savings may not be enough to offset the projected incremental cost of vehicle purchase and fueling infrastructure for some ZEVs, resulting in net increased lifetime costs compared with those of combustion vehicles. However, by 2030 incremental ZEV purchase costs are projected to fall significantly, such that the average ZEV will reach lifetime cost parity with combustion vehicles, when discounted lifetime fuel and maintenance savings are considered. By 2040, the average ZEV purchased that year is projected to produce over $54,000 in discounted lifetime net savings (2020$) compared with the costs of an equivalent combustion vehicle.

It is important to reiterate that the values in Figure 6 are fleet average values, which mask a significant amount of variability across vehicle types and among different fleets of the same vehicle type. Also note that the utility impact analysis (in the next section) indicates that the cost of providing power to charge M/HD EVs is lower than expected utility revenue under current rate structures. This suggests that Washington could consider changes to rates that would not only be fairer for fleets, but also lower electricity costs for M/HD EV charging, thus reducing net fleet operating costs further than estimated here. However, this would reduce the potential benefits that would accrue to other ratepayers from M/HD vehicle charging (see discussion below).

M/HD ZEVs in some fleets will likely achieve lifetime cost parity with combustion vehicles much earlier than 2030, while others may lag. In addition, this analysis, and the values shown in Figure 6, assume no government incentives for vehicle purchase or development of fueling infrastructure. If existing and potential incentives are considered, or policies such as improved electricity rates for fleets, then actual net costs to fleets will be lower, resulting in cost parity sooner.

Electric Utility Impacts

Current annual electricity sales to residential and commercial customers in Washington total 65.5 million MWh and are projected to grow to 70.0 million MWh in 2050.[17]

Under the ACT Rule policy scenario, additional annual electricity sales for M/HD EV charging are estimated to total 0.7 MWh in 2030, rising to 7.8 million MWh in 2050. This incremental load represents 1.0 percent and 11.9 percent of the total electricity demand in 2030 and 2050, respectively. Incremental monthly peak charging demand under this scenario is estimated at 164 MW in 2030, rising to 2,165 MW in 2050.

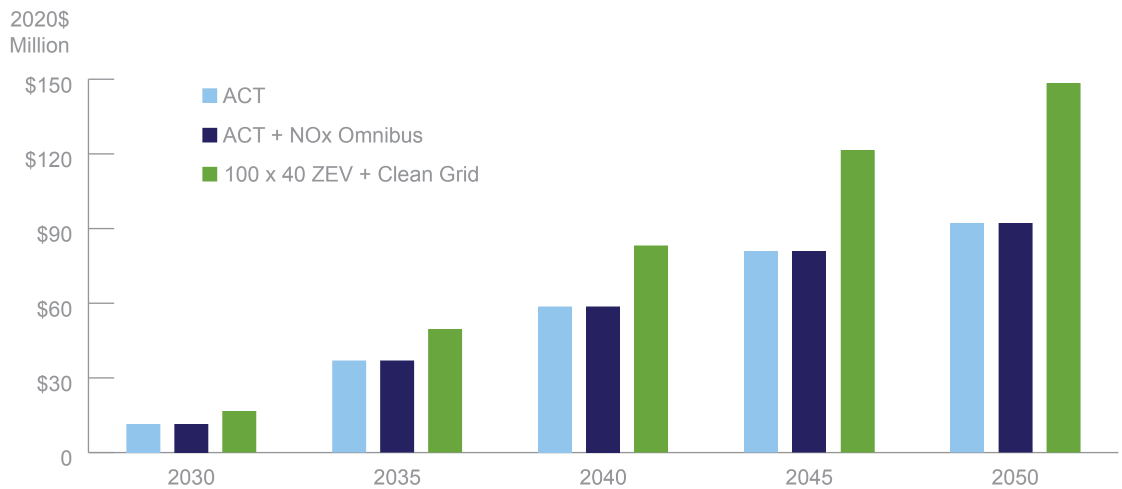
Under the 100 x 40 ZEV policy scenario, incremental peak charging demand is estimated at 245 MW in 2030, rising to 3,193 MW in 2050, and annual incremental electricity sales are estimated to be 1.0 million MWh in 2030, rising to 11.9 million MWh in 2050 (1.4 percent and 17.0 percent of the total electricity demand, respectively).

This analysis estimated the revenue that Washington electric utilities would receive from these incremental electricity sales, the marginal generation and transmission costs of providing this power, and the net revenue that utilities would earn (net revenue = revenue – marginal cost). The estimated marginal cost includes costs associated with procuring the necessary additional peak generation and transmission capacity to serve the load ($/MW) as well as marginal generation and transmission energy costs ($/MWh).

Figure 7 summarizes estimated annual utility net revenue from M/HD EV charging under the modeled Clean Truck policy scenarios. Under the ACT Rule scenario, annual utility net revenue is projected to be $11.5 million in 2030, rising to $58.7 million in 2040 and $92.1 million in 2050. Under the 100 x 40 ZEV scenario, utility net revenue is projected to be $16.6 million in 2030, rising to $83.1 million in 2040 and $148.4 million in 2050.

17 This growth assumption is from the EIA 2021 Annual Energy Outlook. It does not include sales to large industrial customers.

Figure 7 Projected Annual Utility Net Revenue From M/HD EV Charging



In general, a utility's costs to maintain its distribution infrastructure increase each year with inflation, and these costs are passed on to utility customers in accordance with rules established by the Washington Utilities and Transportation Commission via periodic increases in residential and commercial electric rates. However, projected utility net revenue from increased electricity sales for M/HD EV charging would lower distribution rates ($/kWh), since fixed annual distribution system costs would be spread over a larger base of energy sales.

This analysis indicates that under the 100 x 40 ZEV scenario, by 2050 incremental utility net revenue from M/HD EV charging could potentially reduce average residential and commercial electricity rates in Washington by as much as 1.52 percent ($0.0041/kWh in 2020$). This could save the average Washington household $48 per year and the average commercial customer $309 per year on their electricity bills (2020$).[18]

Jobs, Wages, and GDP

The transition from gasoline and diesel M/HD vehicles to ZEVs will have significant impacts on the U.S. economy, with substantial job gains in many industries (e.g., battery and electric component manufacturing, charging infrastructure construction, electricity generation), accompanied by fewer jobs in other industries (e.g., engine manufacturing, oil exploration and refining, gas stations, auto repair shops).

This analysis used the IMPLAN model to estimate these macroeconomic effects of the modeled Washington Clean Truck policy scenarios based on estimated changes in spending in various industries (relative to the baseline scenario). These estimates of spending changes by industry were developed from the fleet cost analysis. For example, under the modeled Clean Truck policy scenarios, more money will be spent to manufacture batteries and electric drive components for ZEVs, but less will be spent to manufacture gasoline and diesel engines, and transmissions. Similarly, less money will be spent by fleets to purchase petroleum fuels, but more will be spent to purchase electricity and hydrogen.

18 Figures are based on average annual electricity use of 11,680 kWh per housing unit and 74,620 kWh per commercial customer in Washington.

The IMPLAN analysis also includes the effects of induced economic activity due to consumers having more money to spend, thanks to return of utility net revenue in the form of lower electric rates, and net fleet cost savings returned as lower shipping costs for goods, resulting in lower consumer prices for those goods.

The IMPLAN analysis was run at the national level, but assuming only the industry spending changes (from application of the policy scenarios) occurring due to M/HD vehicle purchase and use in Washington. Estimated national effects would be significantly greater if the modeled policy scenarios were applied to the entire U.S. M/HD fleet.

Table 3 offers a summary of estimated macroeconomic effects of the modeled Clean Truck scenarios on jobs, GDP, and wages.

Compared with the baseline scenario, adoption of the ACT + NOx Omnibus policy or 100 x 40 ZEV + Clean Grid scenarios in Washington will increase national net jobs through 2035. The ACT + NOx Omnibus policy scenario will also increase annual GDP through 2035. The job and GDP loss for both policies in 2045 is due to total fleet fuel and maintenance cost savings. For both scenarios in all years, the average wages for new jobs added to the economy are more than 45% higher as the average wages for jobs that are replaced. This is because the largest number of added jobs are in electrical component manufacturing and in construction of charging infrastructure, requiring many well-paid electricians and electrical engineers, while the largest job losses are in vehicle repair—due to lower maintenance required by ZEVs—as well as relatively low-paid retail workers at gas stations.

Table 3 Macroeconomic Effects of Washington Clean Truck Policy Scenarios

Metric		ACT + NOx Omnibus		100 x 40 ZEV + Clean Grid	
		2035	2045	2035	2045
Net Change in Jobs		263	(1,469)	83	(3,230)
Net Change in GDP 2020$ (million)		$17	($207)	($9)	($449)
Average Annual Compensation	Added Jobs	$82,618	$77,872	$82,611	$77,718
	Replaced Jobs	$47,113	$52,007	$47,898	$52,902

Today many components used in electric and fuel cell vehicles—most notably batteries, but also many electric drivetrain components—are manufactured outside the United States and imported for final vehicle assembly. The percentage of imported content is higher for ZEV drivetrains today than for conventional drivetrains (gasoline and diesel engines, and transmissions). The scale of U.S. macroeconomic effects from the modeled Clean Truck policy scenarios will depend on how the nascent M/HD ZEV industry develops; for this analysis, MJB&A assumed that all incremental spending on ZEV batteries and electric drivetrain components would be in the United States, with no imported content. As such, the results summarized in Table 3 represent a high-end estimate of what is possible from the ZEV transition, with the right federal and state policy supports in place to incentivize development of U.S.-based ZEV component manufacturing. If vehicle manufacturers continue to rely primarily on imported batteries and electric drivetrain components, the net job and GDP gains will be lower than those summarized here.

This macroeconomic analysis only includes direct, indirect, and induced impacts from changes in M/HD vehicle manufacturing and use, and from consumer re-spending of net utility revenue and fleet cost savings returned as lower prices for electricity and shipped goods. It does not include any effects on freight industry growth and investment due to lower operating costs, or any macroeconomic effects associated with the estimated climate and air quality (health) benefits of the modeled Clean Truck policy scenarios.

Required Public and Private Investments

On the basis of a detailed charging model that considers typical daily usage patterns for different vehicle types, this analysis assumes that most M/HD ZEVs in Washington will use overnight charging at their place of business, though about 10 percent will need to rely on a publicly accessible network of higher-power chargers.[19] The exception are combination trucks, 70 percent of which are assumed to require high-power public chargers since they are used primarily for long-haul freight operations.

Table 4 summarizes estimated charging infrastructure required to support M/HD electric trucks and buses under the Clean Truck policy scenarios.

Table 4 Projected Charging Infrastructure Required for Clean Truck Policy Scenarios

Metric		ACT Rule			100 x 40 ZEV		
		2035	2045	2050	2035	2045	2050
Cumulative Charge Ports	Depot	81,956	246,762	306,058	124,208	404,961	481,770
	Public 150 kW	1,005	2,999	3,755	1,489	4,739	5,792
	Public 500 kW	696	1,858	2,354	1,018	3,758	5,156
Cumulative Investment, 2020$ (million)	Depot	$404	$1,148	$1,536	$600	$1,894	$2,590
	Public	$293	$773	$1,030	$428	$1,445	$2,020

Depot chargers will need to be 10–50 kW per port depending on vehicle type. The smaller 150 kW public chargers are needed primarily to support single-unit freight trucks, while the higher-capacity 500 kW public chargers are needed mostly for combination trucks.

As of May 2021, there were 194 publicly accessible charging stations in the state of Washington with a total of 665 direct current fast-charging (DCFC) ports (>50 kW).[20] More than 50 percent of these DCFC ports are Tesla superchargers that can be used only by Tesla owners. Statewide, there are only 330 DCFC ports fully available to any vehicle.

Under the ACT Rule policy scenario, Washington's fleet owners will have to invest an average of $61.4 million per year (2020$) between 2025 and 2050 to purchase and install depot-based charging infrastructure. The government and private investors will need to invest an average of $41.2 million per year over the same time period to build out a publicly accessible charging network across the state to serve the EV M/HD truck fleet.

19 See the methodology report for a detailed discussion of M/HD EV charging needs.

20 These numbers are from the U.S. Department of Energy's Alternative Fuel Data Center public charger database.

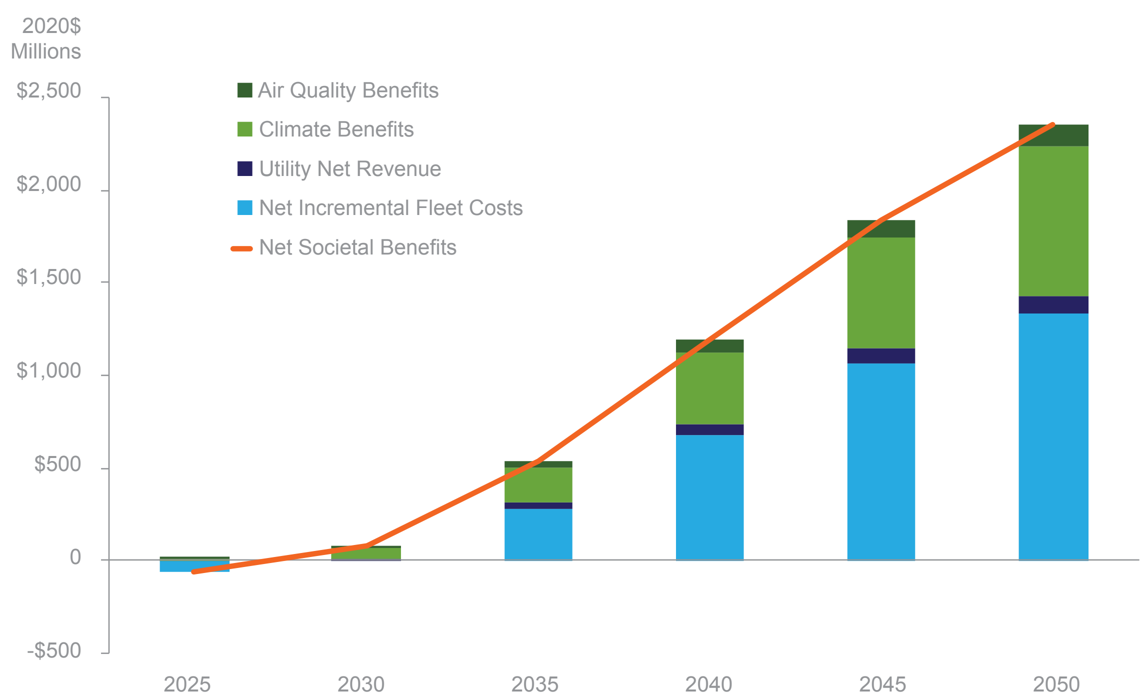
Under the 100 x 40 ZEV scenario, fleet investments in depot charging infrastructure from 2025 to 2050 will need to increase to an average of $103.6 million per year, and public and private investments in the public charging network will need to rise to an average of $80.8 million per year.

Net Societal Benefits

The net societal benefits from the modeled Washington Clean Truck policy scenarios include the monetized value of public health and climate benefits, net cost savings for fleets, and net utility revenue from electricity sales for EV charging.

Figures 8–10 present projected annual net societal benefits under the ACT Rule, ACT + NOx Omnibus Rule, and 100 x 40 ZEV + Clean Grid scenarios, respectively. Under all three Clean Truck policy scenarios, near-term fleet costs are higher than fleet costs under the baseline.[21] However, after approximately 2030 all policy scenarios show annual net societal benefits, despite net fleet costs, due to growing utility net revenue in addition to public health and climate benefits. After approximately 2035 there is an annual net savings in fleet costs from operating ZEVs instead of diesel and gasoline trucks, and net societal benefits grow quickly.[22]

Figure 8 Projected Annual Net Societal Benefits From ACT Rule Policy Scenario



21 If an individual truck owner finances a vehicle, it would better equalize payments for increased vehicle price and fuel savings, resulting in a better balancing of cash flow. On a net fleet-wide basis, however, the cost of financing reduces total net fleet savings.

22 Note that fleet-wide annual net savings under the Clean Truck policy scenarios lag average ZEV life-cycle cost parity to combustion vehicles by about 5 years. This is because even after life-cycle cost parity is achieved, most ZEVs will still have higher up-front purchase costs (vehicle plus charger) than combustion vehicles; these higher costs are then paid back over the next few years via fuel and maintenance cost savings.

Figure 9 Projected Annual Net Societal Benefits From ACT + NOx Omnibus Policy Scenario

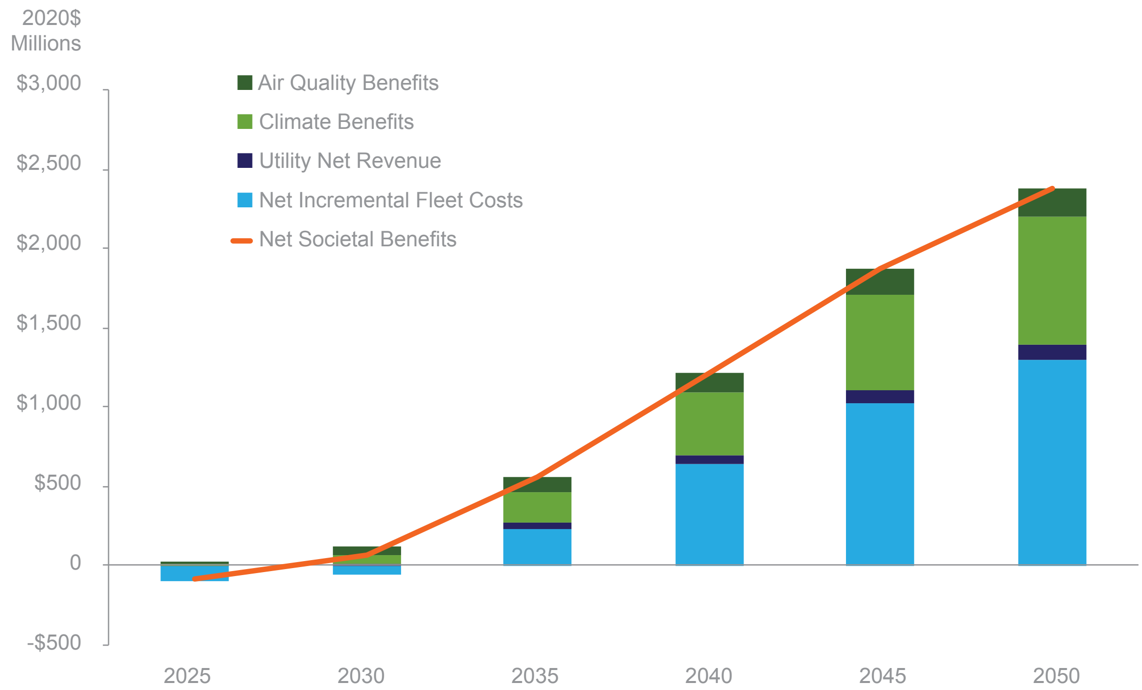
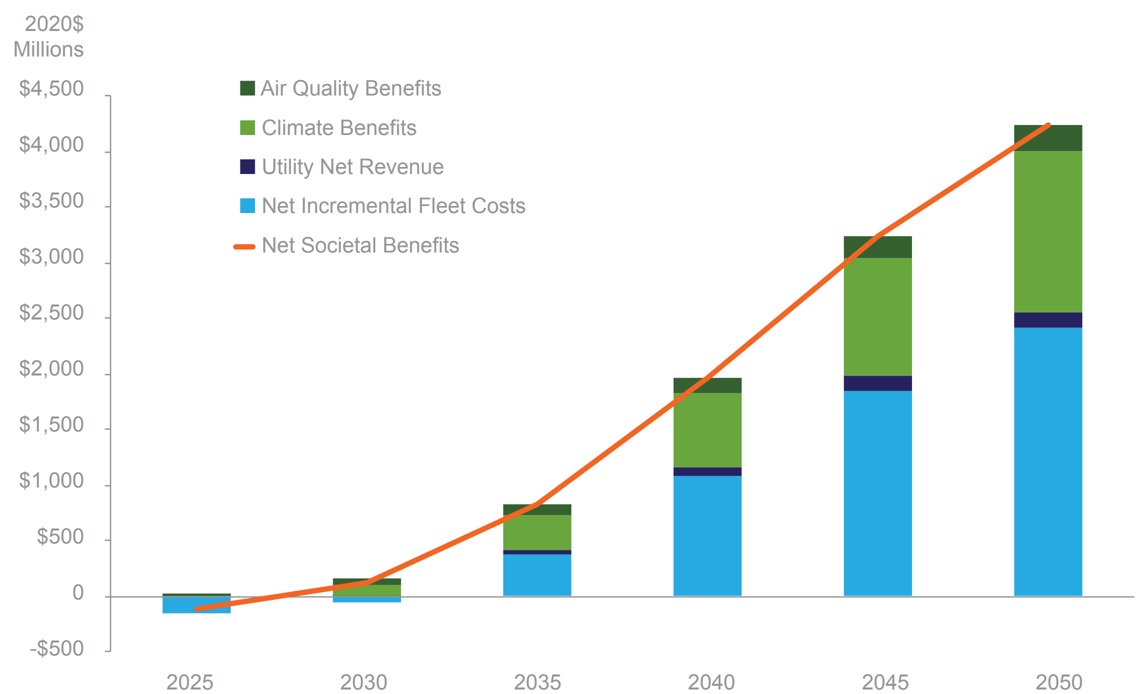


Figure 10 Projected Annual Net Societal Benefits From 100 x 40 ZEV + Clean Grid Policy Scenario



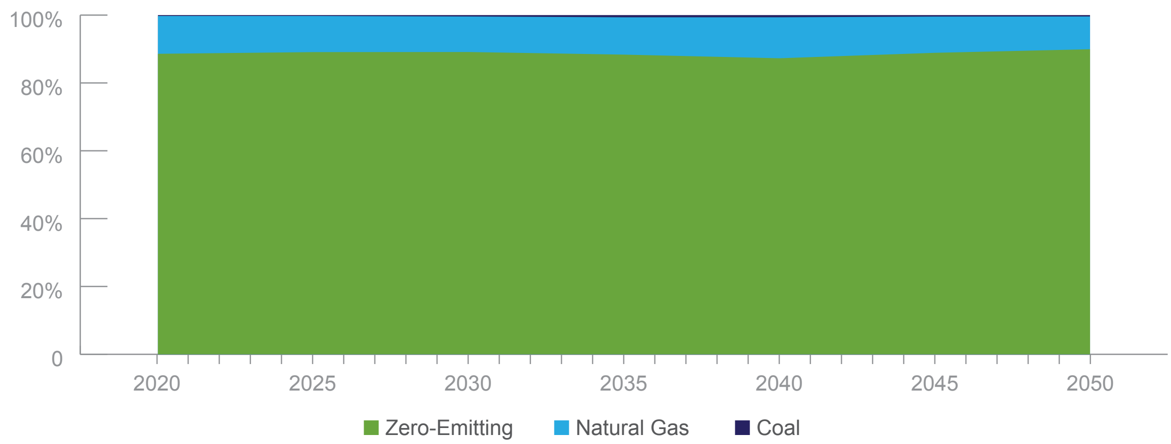
Under the ACT Rule scenario, by 2050 annual net societal benefits are estimated to be $2.4 billion, including $1.3 billion in net fleet savings and $92 million in utility net revenue. Cumulative estimated societal net benefits under this scenario total $5.9 billion between 2020 and 2050.

Under the ACT + NOx Omnibus scenario, by 2050 annual net societal benefits are estimated to be $2.4 billion, including $1.3billion in net fleet savings and $92 million in utility net revenue. Cumulative estimated societal net benefits under this scenario total $6.0 billion between 2020 and 2050.

Under the 100 x 40 ZEV + Clean Grid scenario, by 2050 annual net societal benefits are estimated to be $4.2 billion, including $2.4 billion in net fleet savings and $148 million in utility net revenue. Cumulative estimated societal net benefits under this scenario total $10.3 billion between 2020 and 2050.

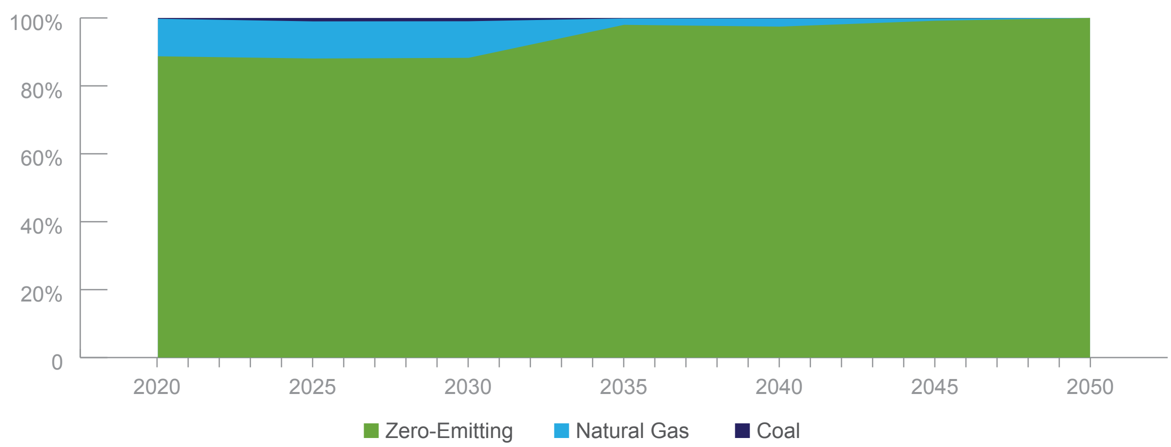
APPENDIX
Washington Grid and Energy Cost Assumptions

Figure A1 Washington Business as Usual Grid Mix Assumptions



These business-as-usual grid mix assumptions were applied to the baseline, ACT Rule, and ACT + NOx Omnibus policy scenarios.

Figure A2 Washington Decarbonized Grid Mix Assumptions



These Decarbonized grid mix assumptions were applied to the 100 x 40 ZEV + Clean Grid policy scenario.

For simplicity, results from EPA's Integrated Planning Model for coal, oil, and biomass were combined under "coal," as noted in the accompanying methodology report. The zero-emitting category includes nuclear and renewable resources such as wind, solar, and hydropower. Analysis of new, state-specific electricity policies, such as from more stringent Renewable Portfolio Standards, was beyond the scope of this study but would be expected to increase the usage of these renewable resources.

Figure A3 Washington Average Fuel Costs