THE NORTHWEST SEAPORT ALLIANCE
SEATTLE + TACOMA

Northwest Ports Clean Air Strategy

2021-2025 Implementation Plan

Produced by the Northwest Seaport Alliance

November 2021

Executive Summary

The 2020 Northwest Ports Clean Air Strategy (NWPCAS) -- unanimously adopted by the Managing Members of the Northwest Seaport Alliance (NWSA) in April 2021 – sets a bold new vision for clean air and climate action by the NWSA: "**phase out emissions from seaport-related activities by 2050.**" This implementation plan outlines the key actions the NWSA will take in the next five years to advance that vision, as well as our longer-term interim targets for greenhouse gas (GHG) emission reduction: 50% by 2030, and 70% by 2040.

The overarching goals of this implementation plan are as follows:

- ***Do our part to improve local air quality***, especially in places where environmental health disparities exist, according to the Washington Department of Public Health;
- ***Do our part to meet the global climate challenge*** – limit global temperature rise to 1.5°C to stave off what the International Panel on Climate Change (IPPC) calls "severe, widespread, and irreversible impacts"; and
- ***Sustain and strengthen our competitiveness*** in the cargo shipping industry to advance our core mission: facilitating international and domestic trade that supports more than 58,000 jobs and $12.4 billion in business activity in Pierce County and Washington state.

About 90% of the seaport-related diesel particulate matter and greenhouse gases in the Seattle-Tacoma airshed are associated with cargo shipping operations that the NWSA manages on behalf of the ports of Seattle and Tacoma. The NWSA's strategy for reducing and ultimately eliminating these emissions is two-pronged: continue and strengthen our work to reduce emissions from existing fleets of mostly diesel-powered vessels, vehicles, and equipment; and, at the same time, facilitate and accelerate the transition to zero-emission fuels and technologies, including the development of the necessary fueling and charging infrastructure.

Our approach is threefold: 1) take direct action where possible, such as the installation of shore power infrastructure on NWSA-managed terminals; 2) collaborate closely with tenants and industry partners – through lease agreements, pilot projects, and other means – to identify, finance, and implement emission-reduction initiatives, such as the purchase of cleaner or zero-emission vehicles and equipment; and 3) track, engage in, and influence international, federal, state and local policies and programs that support clean air and climate solutions in the NWSA gateway.

Key Milestones

To gauge success over next five years

Sector	Timeline	Key Milestones
Community Engagement and Partnerships	Q1 2022	Begin providing quarterly updates on NWPCAS progress.
	End 2022	Complete a Community Clean Air and Climate Resource Guide.
	End 2022	Develop and begin implementing a Tacoma community engagement and partnership program.
	End 2022	Develop and begin implementing a Seattle community engagement and partnership program.
Industry Engagement and Partnerships	Q2 2022	Develop and begin implementing a tenant engagement program.
	End 2022	Complete review of climate and sustainability programs and goals of major customers.
Policy Engagement and Advocacy	By 2023	The state Clean Fuel Standard and Climate Commitment Act contain funding mechanisms to support NWPCAS implementation.
	End 2025	Federal, state, and/or local/regional funding is secured to fill funding gaps for projects in this implementation plan.
	End 2025	Stronger emission standards for international shipping are developed.
Infrastructure Planning and Development	Q2 2023	Complete the South Harbor Electrification Roadmap.
	End 2022	Complete the Seattle Waterfront Clean Energy Strategic Plan.
	End 2023	Create gateway-wide infrastructure development plan.
Technology Assessment and Advancement	End 2022	Begin conducting technology assessments.
	End 2022	Begin conducting assessments on the availability and opportunities to increase use of renewable fuels.
OGVs	End 2023	Update planning analysis and cost estimates for WUT, PCT, and T-30 shore power systems.

Key Milestones

(Continued)

Sector	Timeline	Key Milestone
OGVs (continued)	End 2023	Update gateway shore power plan including costs and timelines.
	End 2024	Incorporate shore power projects planned between 2025 and 2029 into the five-year capital plan.
	End 2024	Bring in grant funds to support the T-18 shore power project by the end of 2024
	End 2023	Complete shore power installation at T-5.
	End 2023	Complete shore power installation at Husky Terminal.
	End 2023	Complete design of a shore power system at T-18.
	As infrastructure is installed	Incorporate lease requirement for shore power capable ships to use shore power.
		Ensure labor arrangements and billing procedures are in place to facilitate shore power connections.
	March each year	Compile data on shore power use and the fraction of shore power capable vessels calling at the major international container terminals during the previous year.
	End 2022	Complete vessel emission reduction study.
	End 2022	Establish and begin implementing an International Engagement Strategy for reducing vessel emissions.
Trucks	End 2023	Scrap 50 trucks through our scrap and replace program.
	End 2023	Assess levels of compliance and determine an appropriate method to ensure full compliance with the 2007 engine year standard at TOTE and West Sitcum.
	End 2023	Begin assessing the population of trucks calling at T-115.
	End 2024	Determine the appropriate mechanism to ensure compliance with the 2007 engine model year standard at T-115.
	End 2025	Implement compliance mechanism to enforce the 2007 model year standard at the domestic terminals.
	End 2022	The regional clean truck collaborative is formed.
	End 2025	A regional zero-emission truck infrastructure needs assessment is performed.
	End 2022	Complete a port truck parking and fleet and trip assessment.
	End 2022	Begin providing financial counseling support to the trucking community.

Key Milestones

(Continued)

Trucks (continued)	End 2025	At least 10 zero-emission trucks have been demonstrated in the gateway.
Cargo Handling Equipment	As leases are signed and amended	Include requirement for any new CHE purchases to be Tier 4 or better in any new or amended lease.
	End 2022	Develop and begin implementing a tenant engagement program.
	Q2 2022	Complete the SIM yard tractor project to bring 6 all electric yard tractors to the Tacoma SIM Yard.
	End 2025	At least 25 pieces of zero and/or near zero-emission CHE are operating in the gateway.
Locomotives	End 2025	Support at least 1 project to upgrade one or more locomotive engine(s) to Tier 3 or better.
	End 2022	Develop advocacy agenda related to locomotive funding and emission reductions.
Harbor craft	End 2025	Support the deployment of at least 1 hybrid or zero-emission tug in the gateway by the end of 2025.
	End 2022	Develop an advocacy agenda related to tug funding and emission reductions.
Administration: light duty fleets and facilities	End 2021	Complete the EB1 and NIM Yard LED lighting upgrade projects
	End 2022	Identify opportunities for energy efficiency upgrades at NWSA operated facilities.
	End 2025	Complete 3 additional energy efficiency projects.

The NWSA will track progress towards these milestones on an annual basis and produce an annual progress report that will be shared with the NWSA executive team, the Managing Members (Port of Seattle and Port of Tacoma commissions), and the public. This annual “NWSA Clean Air and Climate Digest” will outline progress towards our milestones, highlight implementation actions and achievements over the past year, and provide a preview of the year to come. To the extent practicable, this information will be organized by harbor (Seattle and Tacoma), to provide more specific information to near-port residents and communities in each harbor. In addition, an annual progress report on the overarching Northwest Ports Clean Air Strategy (NWPCAS) will be produced and published jointly by the four participating port entities. This joint report will outline progress toward the shared vision, objectives, and actions outlined in the 2020 NWPCAS.

The NWSA will take an adaptive management approach to monitoring, reporting, and reviewing this Implementation Plan. As advancements in technology, changes in policy, and funding opportunities occur, the NWSA will change course or advance action timelines and milestones as needed to maximize opportunities and remain on track to achieve the 2050 vision. Specifically, we will: 1) update our implementation plans on an annual basis; and 2) renew the overarching Northwest Ports Clean Air Strategy about every five years.

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1. Purpose

The Northwest Seaport Alliance (NWSA) is committed to reducing and ultimately eliminating the air and climate pollution – and related environmental health disparities – associated with the cargo shipping operations that we manage on behalf of the ports of Tacoma and Seattle. That is why the NWSA, at its inception in 2015, joined the Northwest Ports Clean Air Strategy (NWPCAS). The NWPCAS is a voluntary collaboration between the four largest port entities of the Pacific Northwest, the NWSA, Port of Tacoma (PoT), Port of Seattle (PoS), and Port of Vancouver (VFPA), to reduce air and climate pollution from their respective seaport activities throughout the Puget Sound – Georgia Basin Airshed. The NWPCAS constitutes a shared strategic framework for clean air and climate actions and investments that creates a "level playing field" across the four participating port entities, and helps them coordinate, collaborate, and hold each other accountable.

The participating ports updated and renewed the NWPCAS in 2020, strengthening their commitment to reducing air and climate pollution. The 2020 NWPCAS puts forth an ambitious, aspirational, joint vision to **phase out emissions from seaport activities by 2050**, and a suite of high-level joint objectives and actions to advance that vision.

In addition, each of the four participating port entities committed to developing a detailed implementation plan tailored to their particular policy environments, governance structures, lines of business, emissions profiles, and community priorities.

This is the NWPCAS Implementation Plan for the NWSA, outlining the NWSA's commitment to work towards the aspirational vision and objectives laid out in the NWPCAS. It describes the workplans for the NWSA's air quality and climate programs with a primary focus on actions to be taken over the next five years (2021-2025). The NWPCAS and this implementation plan will help to advance progress towards related commitments, such as the NWSA's Greenhouse Gas Resolution[1] and the Port of Seattle's Community Benefits Resolution (Port of Seattle Commission Resolution 3767).

1.1. Implementation Plan Applications

The NWSA's NWPCAS Implementation Plan is designed to document and communicate our air quality and climate action plan for the next five years. The following summarizes the intended audiences of the plan and how we intend for it to be used.

A. ***Staff of The NWSA*** – The Implementation Plan summarizes our workplan for the next five years. It includes a detailed summary of the air quality and climate actions and investments we plan to make and a suite of milestones for measuring success. The plan also includes an accountability framework that will guide us in tracking progress,

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[1] https://vecportal.blob.core.windows.net/nwseaportalliance/Documents/d58b3918c42038b22ffdeb8154458043/4A-RES-2017-02-GHG%20Policy-Cederberg.pdf

reporting out on that progress, and adjusting over time as new information becomes available and circumstances change.

B. ***NWPCAS Partner Ports*** – For our partner ports, the Implementation Plan transparently demonstrates our commitment to working towards the joint vision and objectives and feeds into our joint reporting.

C. ***Industry Partners*** – The Implementation Plan serves as both a mechanism to communicate our intentions and a call for collaboration, daylighting areas of joint interest where we can work together.

D. ***Government Partners*** – The Implementation Plan seeks to clearly communicate our near term workplan to partner governments. This provides transparency, daylights opportunities for partnerships, and highlights our funding needs. External funding will be vital if we and our industry partners are to be successful in achieving the NWPCAS vision. In addition, external funding can help accelerate action timelines in many areas.

E. ***Near Port Communities and the General Public*** – The NWSA is dedicated to clearly and transparently communicating our plans for reducing our contributions to air pollution and climate change and partnering with near-port communities on clean air and climate solutions. The Implementation Plan serves as our method for communicating our near term workplan and identifying partnership opportunities. We will report our progress via annual progress reports as defined later in the Implementation Plan.

2. NWPCAS Background

The NWPCAS was created in 2008 by the PoS, PoT, and VFPA to set joint aspirational goals to reduce air pollutant and GHG emissions from seaport related operations associated with the four ports. When it was formed in 2015, the NWSA joined the collaboration. The geographic and operational scope are described below.

2.1. Operational Scope:

The NWPCAS covers emissions from ocean-going vessels, harbor vessels, heavy duty trucks, locomotives, cargo-handling equipment, and port administration and tenant facilities (fleets and facilities). These sectors are explained in more detail in chapter 5.

2.2. Geographic Scope:

The geographic scope of the NWPCAS is the same as for the port emission inventories, shown in Figure 1. For the NWSA, this includes all truck, vessel, rail, and cargo handling equipment activities that are directly part of moving cargo to from and through facilities managed by the NWSA within the green shaded area. For example, an ocean-going vessel calling an NWSA terminal would be counted from when it enters the Strait of Juan de Fuca until it exits.

Figure 1. Geographic scope of the NWPCAS.

2.3. NWPCAS Vision

Responding to the urgent need to minimize environmental health impacts and disparities and address climate change, the 2020 NWPCAS sets a common vision among the participating ports to ultimately phase out air pollutant and GHG emissions. This vision is aligned with the latest guidance from the Intergovernmental Panel on Climate Change (IPCC)[2], which indicates that global carbon neutrality by 2050 is necessary to limit global temperature increase to 1.5 degrees C, thereby avoiding the most catastrophic impacts of climate change. Phasing out emissions also will help reduce regional environmental health impacts associated with diesel exhaust. The joint vision statement is:

"Phase out emissions from seaport-related activities by 2050, supporting cleaner air for our local communities and fulfilling our shared responsibility to help limit global temperature rise to 1.5 degrees."

This implementation plan defines how the NWSA will begin working towards achieving this joint vision and reducing emissions in the interim.

2.4. NWPCAS Objectives

Supporting the joint vision, the NWPCAS also puts forth a suite of objectives that outline the major action themes along the pathway to achieving zero-emissions. These objectives are:

1) *"Implement programs that improve efficiency, phase out old high emitting equipment, and increase use of lower emission fuels."*

   The ports will continue to play a central role in driving reductions of diesel emissions by incentivizing and/or requiring upgrading older equipment with newer models with modern emission controls and implementing programs to increase efficiency and reduce idling. This includes mechanisms like our Clean Truck Program, lease requirements for new cargo handling equipment purchases, grant funded projects to purchase hybrid equipment, and our gate queue management programs.

2) *"Facilitate collaboration among governments, utilities, fuel providers, and industry to ensure that infrastructure needed to enable zero-emission technologies is in place at the right time, addressing key constraints by 2030."*

   The ports have a key role to play as conveners and infrastructure providers in the transition to zero-emissions. Under this objective, the ports will work with other partners to ensure that the necessary infrastructure is in place to support zero-emission technology as it is needed. This means leading planning efforts for infrastructure needs on our own properties, partnering with tenants and other partners to make the necessary

[2] Global Warming of 1.5 ºC — (ipcc.ch)

investments on port properties, and bringing together coalitions to plan for and fund infrastructure investments needed to support the supply chain's transition outside of port property. The intent of this objective is not that all infrastructure will be in place by 2030, but that the right infrastructure investments will be made at the right time based on need.

3) *"Facilitate collaboration toward commercialization and drive adoption of zero-emission technology before 2050."*

   The ports also have a significant role to play in accelerating the development, commercialization, and deployment of zero-emission technologies. We will work as facilitators to help bring partnerships together to identify demonstration opportunities and align the funding needed to support deployment of zero-emission technologies that are not currently affordable.

2.5. NWPCAS Conditions for Success

Recognizing that most of the NWPCAS scope is out of the ports' direct operational control, the NWPCAS puts forth a suite of conditions for success that will need to be satisfied to reach zero-emissions. While the ports play an important role in working towards these conditions, significant action will be needed from others if they are to be satisfied. An abbreviated summary of the conditions for success is provided below, while a full description of the conditions is provided in the full NWPCAS strategy document. The ports will be active participants in promoting and advocating for funding and actions to achieve these conditions for success.

1. "Enabling policy is in place domestically and internationally to support investment in zero-emissions technology and infrastructure."

2. "Funding and/or access to capital [is available] to support adoption of zero-emission technology and infrastructure development where [the] business case is insufficient".

3. "Adequate electricity and/or fueling infrastructure is available when and where needed."

4. "Technology is commercially available and demonstrated for port applications, and total cost of ownership is competitive [with diesel] which may require enabling regulation and funding."

5. "Industry commitment [is made] to transition to zero-emission operations through investments and business planning."

6. "Workforce is trained to operate and maintain zero-emissions technology."

3. Northwest Seaport Alliance Background

The NWSA was formed in 2015 to manage the cargo shipping operations at the ports of Seattle and Tacoma. While the PoT and PoS rely on the NWSA to manage commercial relationships and agreements, the NWSA relies on the home ports to manage facilities development projects, fleet maintenance, facilities maintenance, and furnishment of administration office facilities, among others.

3.1. Description of the NWSA

The Northwest Seaport Alliance (NWSA) is a marine cargo operating partnership of the Ports of Seattle and Tacoma, which formed in 2015 to increase the competitiveness of the cargo operations at these ports. The NWSA is an independent port development authority that constructs, maintains, and operates marine terminals, and addresses related transportation and air quality issues.

The NWSA supports 58,400 jobs, produces more than $4 billion in labor income, and generates $135.9 million in state taxes (2017). Trade at the NWSA enables $5.9 billion in direct business revenue, $2.9 billion in indirect business revenue, and $3.7 billion in additional household spending[3]. Figure 2 further describes the NWSA's relationship to its home ports and how the emission sources are distributed between the three entities.

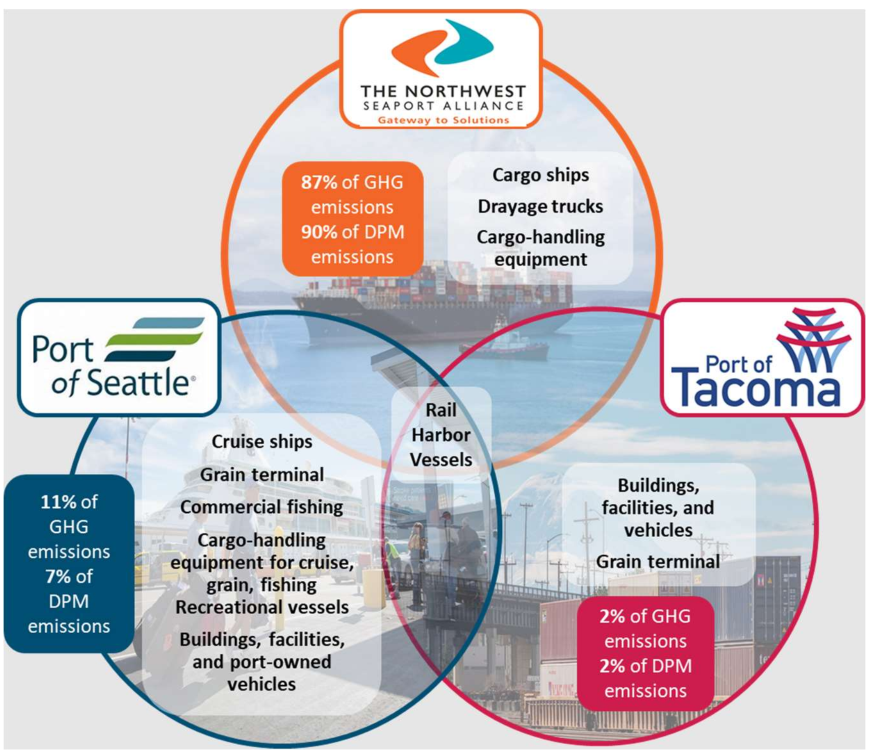

Figure 2. Sectors under Operational Control of the NWSA and its two "home ports".

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[3] CAI_NWSA_Marine_Cargo_Economic_Impacts_190122.pdf (portseattle.org)

3.2. Role of The NWSA and Operating Model

The NWSA is what is typically referred to as a “landlord” port, meaning that we do not directly operate the port terminals ourselves (in most cases). Instead, we lease the land to private operators who directly manage operations themselves, own the equipment and vehicles that operate on the terminals, and contract with shipping lines and trucking companies that pick up or drop off cargo at the terminal. Therefore, we do not have direct control of the day-to-day operations that occur on our properties, but instead, set the rules when lease agreements are signed, amended, and renewed. These long-term lease agreements – the terms of which are negotiated and agreed upon by the NWSA and the tenant – are our most direct opportunity to influence terminal operating practices.

It is important to note that the majority of the cargo coming through the NWSA gateway is discretionary cargo. Discretionary cargo is cargo that is not destined for local residents and businesses, which means it could be shipped through a number of different ports to reach its final destination. Discretionary cargo is particularly susceptible to potential diversion to other ports if costs through another gateway are comparatively lower. In addition to the economic impacts associated with our region losing cargo, diverting cargo to ports that are farther from Asia and/or have lower environmental standards could lead to increasing emissions. Because such a large percentage of the cargo coming through the NWSA gateway is discretionary, our ability to impose standards through leases without significant risk of cargo diversion, especially those that increase costs of operation, is limited.

These competitive pressures accentuate the importance of advocating at the federal and international levels for policies that advance air and climate emission standards in alignment with the vision of the 2020 NWPCAS while establishing a level playing field across ports.

In addition, the NWSA plays a critical facilitative leadership role in reducing air and climate pollution – fostering the collaboration needed among myriad stakeholders and partners to advance and accelerate the development, financing, and deployment of cleaner technologies, as well as the fueling and charging infrastructure necessary to enable the transition to those technologies.

3.2.1. NWSA Leases

As a landlord port, the NWSA and the home ports are long-term stewards of land in King and Pierce Counties for our constituents, to ensure the environmental and economic sustainability of the port for future generations. We operate this stewardship through long-term leases of land with terminal operators and port-related industries, where the ports do not operate the land ourselves, but we set the terms and conditions for use of the land and collect rent. Leases are typically long-term (around 20-30 years for terminal operators), allowing tenants security to establish and invest in a thriving business, creating jobs for our local communities. All leases are prepared by the NWSA’s real estate team, with input from all port departments, to tailor the requirements of each lease to that specific parcel of land

(I.e., permit requirements, historical contamination on-site, etc.). Every NWSA lease is posted on our website for review by the public and voted on by the Managing Members after two readings. Every NWSA lease has an Environmental Exhibit that details a list of environmental requirements for the tenant to comply with - this is where any lease requirements from the NWPCAS such as the Clean Truck Program are listed.

Although we sign 20–30-year leases with tenants, leases are reopened many times over their lifetimes, to update the lease with any changes in use of the land or additions to the property (I.e., installation of new lighting, fencing, additional land added to the lease, etc.). As with new leases, all lease amendments go through the same public review process and public vote by Managing Members at our regular public meetings. A lease amendment can be prompted by a change proposed by either the tenant or the NWSA. However, once the lease has been reopened to make the amendment, other updates can be made by either party to update the whole lease through a negotiation. As with new leases, all port departments can update sections of the lease to reflect new programs or requirements introduced since the previous amendment was voted on – this is where 2020 NWPCAS goals can be included.

3.3. Emissions and Impacts

Emission inventories have been the foundation of the NWPCAS since its inception, providing an analytical basis for how to prioritize emission reduction measures across the operational sectors to maximize benefits. Every five years, the NWSA participates in an emissions inventory study with other ports and maritime stakeholders in the region to produce the Puget Sound Maritime Air Emissions Inventory (PSEI)[4]. The most recent inventory was completed for activity occurring in calendar year 2016 and the next one will be conducted for activity occurring in calendar year 2021. Because the NWSA implemented its Clean Truck Program requirement for drayage trucks calling its international container terminals after the most recent PSEI (January 1, 2019), NWSA staff have modelled estimated diesel particulate matter emission reductions associated with this policy and incorporated them into the emissions data shown in this section. In addition to the PSEI, the NWSA conducted a supplemental GHG inventory to understand the GHG emissions associated with activities not covered by the PSEI such as facility energy use and corporate emissions (like business travel and employee commuting). Data from the supplemental GHG Inventory has been included for completeness.

While we track a full suite of criteria air pollutants as part of the PSEI, we generally focus on diesel particulate matter (DPM) as an indicator of air pollutant burden, as it carries the biggest human health risk of air pollutants that we track. In addition, we focus on aggregated GHG emissions (in units of carbon dioxide equivalents (CO_2e); which includes emissions of carbon dioxide, methane, and nitrous oxide emissions) as the metric for our contribution to climate change. In total, operations connected to cargo and corporate activities of the NWSA resulted in the emissions of 171 tons of diesel particulate matter based on our most current

[4] https://pugetsoundmaritimeairforum.org/

calculations (incorporating Clean Truck Program requirement reductions into the 2016 PSEI) and 657,719 tons of GHG emissions. This includes all emissions throughout the airshed shown in Figure 1 above.

Emissions from NWSA's operational scope have decreased significantly since the first 2005 emissions inventory - DPM emissions have been reduced by 80% and GHG emissions have been reduced by 16%. These reductions are the result of a combination of policy changes, fleet turnover, and port programs. For example, the North American Emissions Control Area[5], enacted by the International Maritime Organization in 2015, requires that ships burn fuel with a 0.1% sulfur content, greatly reducing emissions of DPM and oxides of sulfur. Additionally, the EPA has enacted several policies to increase emission standards for new on-road[6] and nonroad[7] engines and decrease allowable fuel sulfur contents of diesel fuel[8]. The NWSA, along with industry partners, have implemented a number of projects and programs to reduce emissions such as clean truck requirements[9] and installing shore power at TOTE Terminal[10].

Figure 3 and Figure 4 show the distribution of DPM and GHG emissions respectively across the airshed depicted in Figure 1 for activities associated with NWSA business in the Tacoma and Seattle harbors combined. Ocean Going Vessels (OGVs) are clearly the largest source of both DPM and GHG emissions, especially the transiting segment. For DPM emissions, locomotives are the second largest source and the other sources are similar in magnitude, while trucks are the second largest source of GHG emissions, followed by locomotives, cargo-handling equipment (CHE), and then harbor vessels.

[5] Designation of the North American Emission Control Area for Marine Vessels | US EPA
[6] Heavy-Duty Highway Compression-Ignition Engines and Urban Buses: Exhaust Emission Standards (EPA-420-B-16-018, March 2016)
[7] Nonroad Compression-Ignition Engines: Exhaust Emission Standards (EPA-420-B-16-022, March 2016)
[8] Diesel Fuel Standards and Rulemakings | US EPA
[9] Clean Truck Program | Northwest Seaport - Port of Tacoma (nwseaportalliance.com)
[10] First cargo ship in Pacific Northwest plugs into shore power at Port of Tacoma | Port of Tacoma

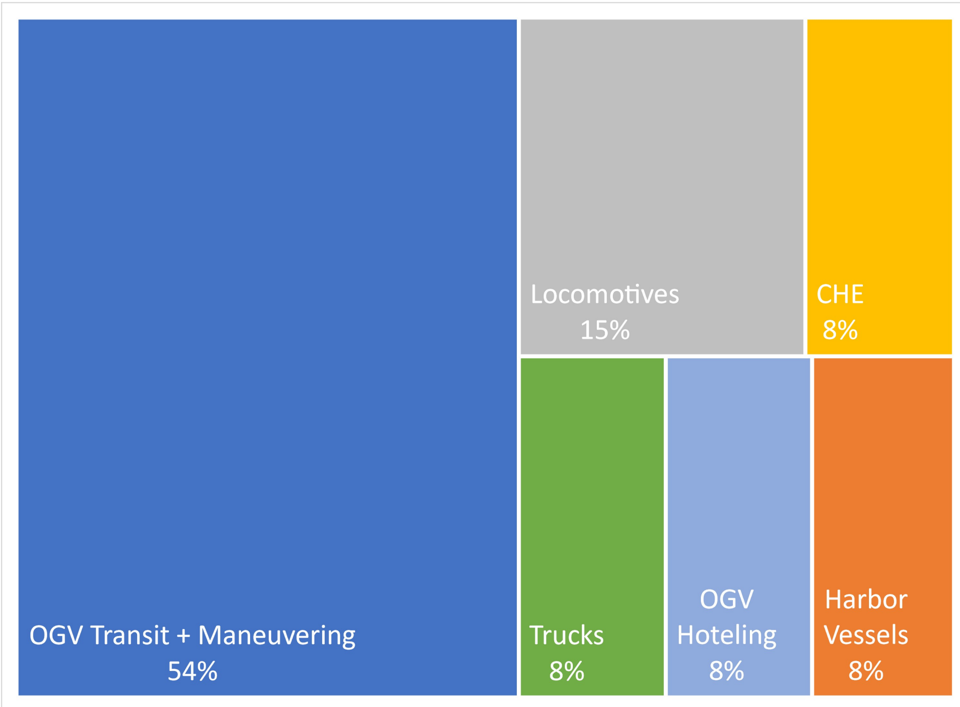

Figure 3 NWSA DPM emissions by sector.

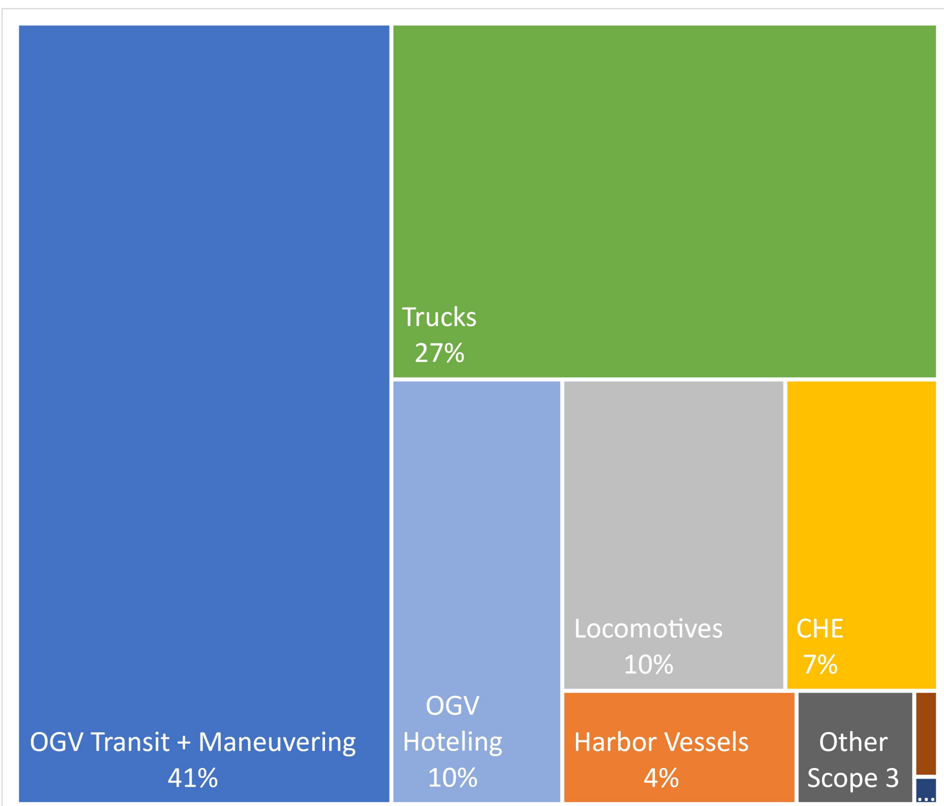

Figure 4. NWSA GHG emissions by sector. The red rectangle represents tenant facility energy use (less than 1% of total emissions) and the purple rectangle represents light duty fleets (less than 1% of total emissions).

3.3.1. Emissions in the Tacoma Harbor

The following figures detail the emission distributions for port related sources associated with port business in the NWSA's Tacoma Harbor that occur across the airshed. This includes more than just the emissions that physically occur in the Tacoma Harbor. For example, vessel emissions are tracked from when they enter the Strait of Juan de Fuca to the berth in Tacoma and back out. Truck trips are included from the port terminal to its destination or the airshed boundary, which may be outside of Pierce County. Because our corporate GHG Inventory was not broken out by harbor, only cargo transport emissions are included here. In total, cargo transport activities associated with NWSA business in the Tacoma Harbor emit 110 tons per year of DPM and 395,195 tons per year of GHGs. This includes only emissions from NWSA related maritime activities, excluding Port of Tacoma managed activities not associated with the NWSA.

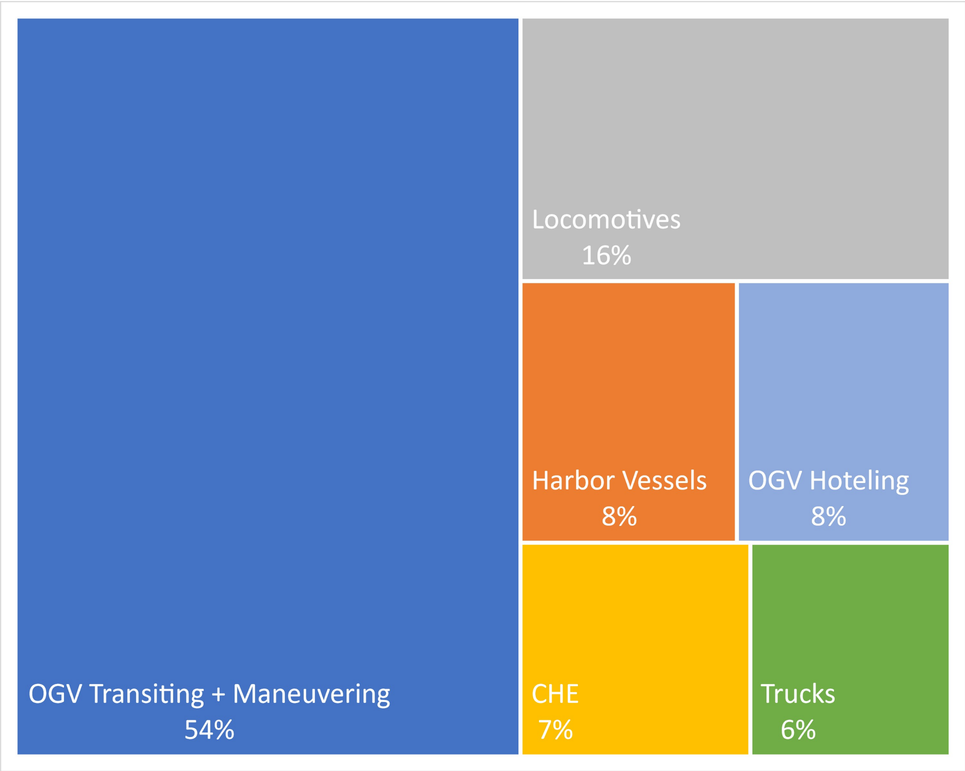

Figure 5. DPM emissions by sector associated with Tacoma Harbor NWSA business.

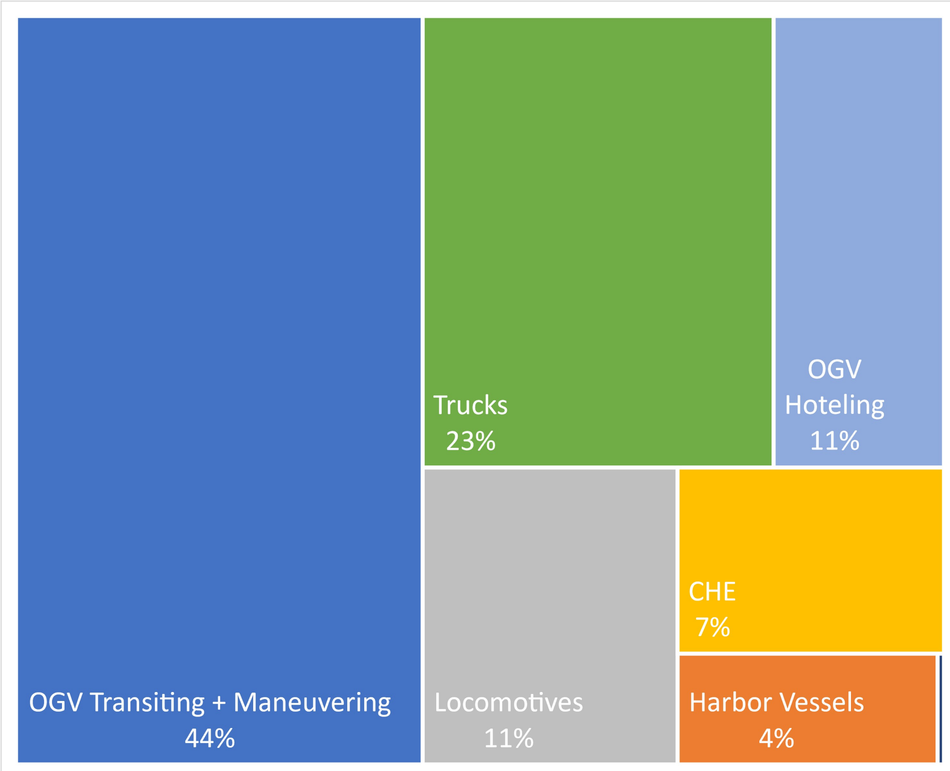

Figure 6. GHG emissions by sector associated with Tacoma Harbor NWSA business. The purple rectangle represents light duty fleets (less than 1% of total).

3.3.2. Emissions in the Seattle Harbor

The following figures detail the emission distributions for port related sources associated with the NWSA's business in the NWSA's Seattle Harbor that occur across the airshed. This includes more than just the emissions that physically occur in the Seattle Harbor. For example, vessel emissions are tracked from when they enter the Strait of Juan de Fuca to the berth in Seattle and back out. Truck trips are included from the port terminal to its destination or the airshed boundary, which may be outside of King County. Because our corporate GHG Inventory was not broken out by harbor, only cargo transport emissions are included here. In total, activities associated with NWSA business in the Seattle Harbor emit 61 tons per year of DPM and 248,316 tons per year of GHGs. This includes only emissions from NWSA related maritime activities, excluding Port of Seattle managed activities not associated with the NWSA.

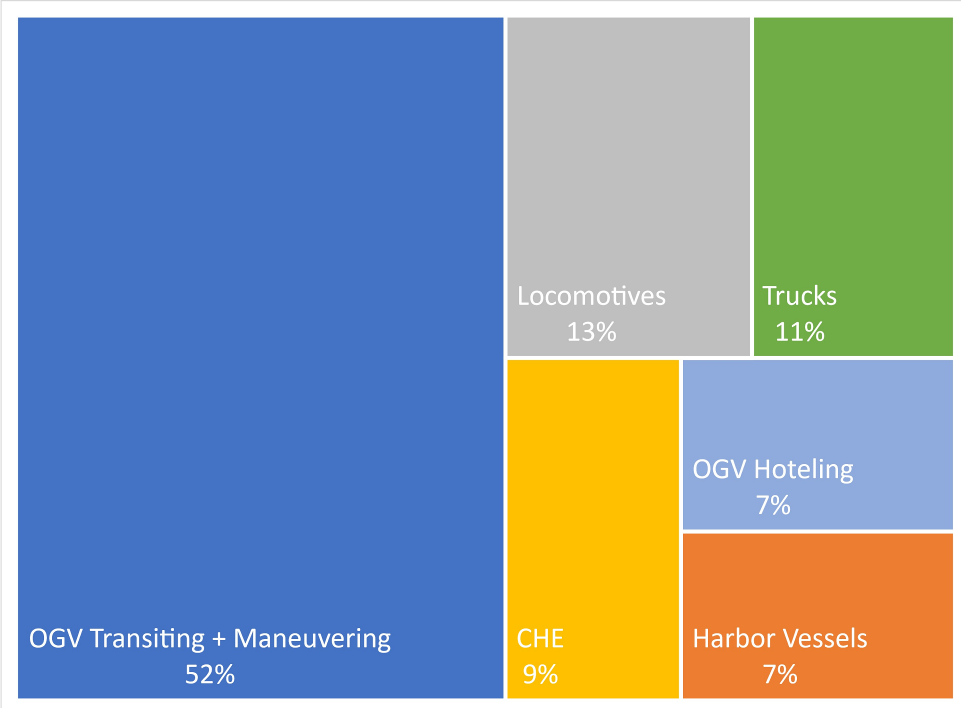

Figure 7. DPM emissions by sector associated with Seattle Harbor NWSA business.

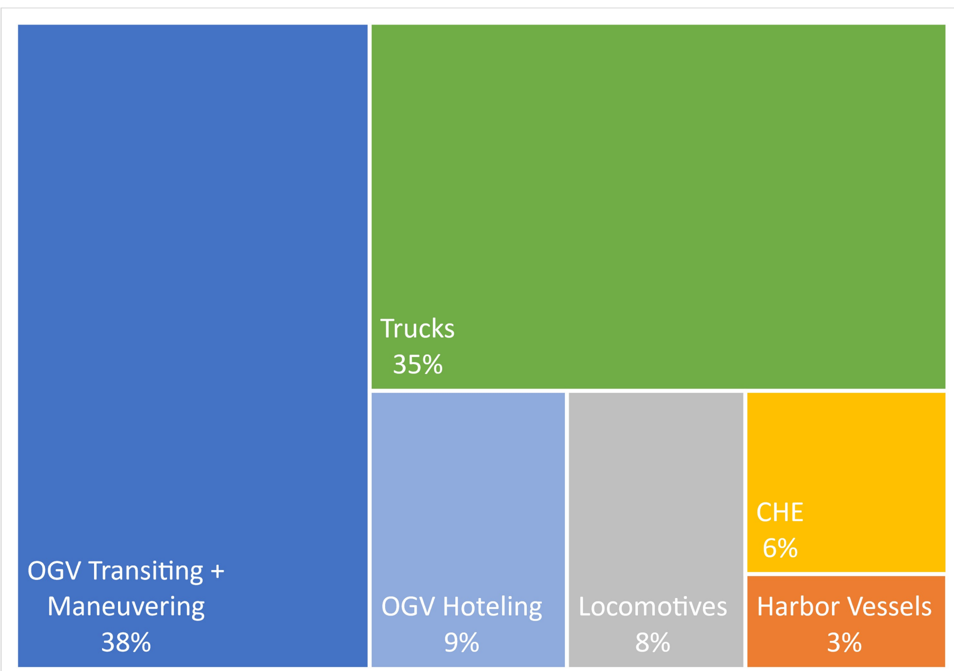

Figure 8. GHG emissions by sector associated with Seattle Harbor NWSA business.

3.4. Exposure Modeling

Recognizing that the location and dispersion of emissions play a significant role in determining their impacts, we commissioned an air quality modeling study with the

Washington State University (WSU) Laboratory for Atmospheric Research. This study modeled the dispersion of particulate matter emissions associated with key port related sources using a special adaptation of WSU's AIRPACT5[11] model, focused on the Puget Sound region. Modeling the dispersion of pollutants means estimating the concentrations that result from emissions, accounting for wind and other meteorological variables and atmospheric chemistry. The study, which used data from the PSEI to isolate port-related sources, concluded that – when dispersion patterns and population data are factored in – reducing emissions from cargo-handling equipment, drayage trucks, and vessels-at-berth are the NWSA's best opportunities for reducing port-related impacts on air quality. The full technical report can be found in Appendix 1.

4. Accountability Framework

The accountability framework is the process by which the NWSA will evaluate progress towards meeting the NWPCAS vision and advancing environmental equity. The framework includes our emission targets, a suite of milestones by which we will track our progress, a reporting framework for transparently reporting on our progress, and an adaptive management framework for updating our plans.

4.1. Emission Reduction Goals

The NWSA is committed to working towards the emission reduction goals in the 2020 NWPCAS vision and our 2017 Greenhouse Gas Resolution (Resolution 2017-02[12]). The NWPCAS puts forward the goal to get to zero-emissions by 2050 and the GHG Resolution adds an interim goal to reduce emissions to 50% of 2005 levels by 2030. The GHG Resolution also contains 2050 goals, but these have been replaced by the new NWPCAS vision, as they are less aggressive.

In addition, we recognize that we share responsibility with the rest of Washington's economy to meet the state's GHG reduction goals of 45% by 2030, 70% by 2040, and 95% by 2050 and achieving net-zero-emissions, all relative to a 1990 baseline. Combining the NWPCAS vision, the NWSA's GHG Resolution, and the state's goals, the NWSA will track its emission reductions against the goals summarized below in Table 2. Because our inventories only go back as far as 2005, we have chosen 2005 as our baseline year. Progress towards meeting these goals will be assessed every five years, at a minimum, through our Puget Sound Maritime Air Emissions Inventory. We will incorporate the latest science to include lifecycle GHG emissions as analytically feasible in our future emission inventories, with a preference for data and methods from the Intergovernmental Panel on Climate Change (IPCC).

[11] AIRPACT Air-Quality Forecasting for the PNW (wsu.edu)
[12] https://vecportal.blob.core.windows.net/nwseaportalliance/Documents/650149a89db8aa4946977df4ace6635f/4A-RES-2017-02-GHG%20Policy-Cederberg-10-03-17.pdf

Table 2. GHG Emission Reduction Goals (relative to the 2005 baseline)

Year	Emission Reduction Goal
2030	50%
2040	70%
2050	100%

DPM emissions from NWSA's operational scope have been reduced by 80% between our 2005 and 2016 inventories. However, there is still significant work to be done to reduce and ultimately eliminate air pollutant emissions. We will be working towards getting to zero air pollutant emissions by 2050 and implementing cleaner technologies to reduce emissions in the interim, as we wait for zero-emission technologies to be available and affordable. Implementing zero-emission technologies reduces both GHG and DPM emissions.

4.2. Milestones

The milestones in Table 3 below are how we will measure success, on everything from reducing emissions from ocean going vessels to engaging effectively with near-port communities.

Table 3. Key Five-Year Milestones

Sector	Timeline	Key Milestones
Community Engagement and Partnerships	Q1 2022	Begin providing quarterly updates on NWPCAS progress.
	End 2022	Complete a Community Clean Air and Climate Resource Guide.
	End 2022	Develop and begin implementing a Tacoma community engagement and partnership program.
	End 2022	Develop and begin implementing a Seattle community engagement and partnership program.
Industry Engagement and Partnerships	Q2 2022	Develop and begin implementing a tenant engagement program.
	End 2022	Complete review of climate and sustainability programs and goals of major customers.
Policy Engagement and Advocacy	By 2023	The state Clean Fuel Standard and Climate Commitment Act contain funding mechanisms to support NWPCAS implementation.
	End 2025	Federal, state, and/or local/regional funding is secured to fill funding gaps for projects in this implementation plan.
	End 2025	Stronger emission standards for international shipping are developed.
Infrastructure Planning and Development	Q2 2023	Complete the South Harbor Electrification Roadmap.
	End 2022	Complete the Seattle Waterfront Clean Energy Strategic Plan.
	End 2023	Create gateway-wide infrastructure development plan.

Technology Assessment and Advancement	End 2022	Begin conducting technology assessments.
	End 2022	Begin conducting assessments on the availability and opportunities to increase use of renewable fuels.
OGVs	End 2023	Update planning analysis and cost estimates for WUT, PCT, and T-30 shore power systems.
	End 2023	Update gateway shore power plan including costs and timelines.
	End 2024	Incorporate shore power projects planned between 2025 and 2029 into the five-year capital plan.
	End 2024	Bring in grant funds to support the T-18 shore power project by the end of 2024
	End 2023	Complete shore power installation at T-5.
	End 2023	Complete shore power installation at Husky Terminal.
	End 2023	Complete design of a shore power system at T-18.
	As infrastructure is installed	Incorporate lease requirement for shore power capable ships to use shore power.
		Ensure labor arrangements and billing procedures are in place to facilitate shore power connections.
	March each year	Compile data on shore power use and the fraction of shore power capable vessels calling at the major international container terminals during the previous year.
	End 2022	Complete vessel emission reduction study.
	End 2022	Establish and begin implementing an International Engagement Strategy for reducing vessel emissions.
Trucks	End 2023	Scrap 50 trucks through our scrap and replace program.
	End 2023	Assess levels of compliance and determine an appropriate method to ensure full compliance with the 2007 engine year standard at TOTE and West Sitcum.
	End 2023	Begin assessing the population of trucks calling at T-115.
	End 2024	Determine the appropriate mechanism to ensure compliance with the 2007 engine model year standard at T-115.
	End 2025	Implement compliance mechanism to enforce the 2007 model year standard at the domestic terminals.
	End 2022	The regional clean truck collaborative is formed.
	End 2025	A regional zero-emission truck infrastructure needs assessment is performed.
	End 2022	Complete a port truck parking and fleet and trip assessment.
	End 2022	Begin providing financial counseling support to the trucking community.
	End 2025	At least 10 zero-emission trucks have been demonstrated in the gateway.
CHE	As leases are signed and amended	Include requirement for any new CHE purchases to be Tier 4 or better in any new or amended lease.

	End 2022	Develop and begin implementing a tenant engagement program.
	Q2 2022	Complete the SIM yard tractor project to bring 6 all electric yard tractors to the Tacoma SIM Yard.
	End 2025	At least 25 pieces of zero and/or near zero-emission CHE are operating in the gateway.
Locomotives	End 2025	Support at least 1 project to upgrade one or more locomotive engine(s) to Tier 3 or better.
	End 2022	Develop advocacy agenda related to locomotive funding and emission reductions.
Harbor craft	End 2025	Support the deployment of at least 1 hybrid or zero-emission tug in the gateway by the end of 2025.
	End 2022	Develop an advocacy agenda related to tug funding and emission reductions.
Administration: light duty fleets and facilities	End 2021	Complete the EB1 and NIM Yard LED lighting upgrade projects
	End 2022	Identify opportunities for energy efficiency upgrades at NWSA operated facilities.
	End 2025	Complete 3 additional energy efficiency projects.

4.3. Reporting

We will track progress towards these milestones on an annual basis and produce an annual progress report that will be shared with the NWSA executive team, the Managing Members (Port of Seattle and Port of Tacoma commissions), and the public. This annual "NWSA Clean Air and Climate Digest" will outline progress towards our milestones, highlight implementation actions and achievements over the past year, and provide a preview of the year to come. To the extent practicable, this information will be organized by harbor (Seattle and Tacoma), to provide more specific information to near-port residents and communities in each harbor. In addition, an annual progress report on the overarching Northwest Ports Clean Air Strategy (NWPCAS) will be produced and published jointly by the four participating port entities. This joint report will outline progress toward the shared vision, objectives, and actions outlined in the 2020 NWPCAS.

4.4. Adaptive Management

The NWSA will take an adaptive management approach to monitoring, reporting, and reviewing the Implementation Plan. As advancements in technology, changes in policy, and funding opportunities occur, the NWSA will change course or advance action timelines and milestones as needed to maximize opportunities and remain on track to achieve the 2050 vision. Specifically, we will: 1) update our implementation plans on an annual basis; and 2) renew the overarching Northwest Ports Clean Air Strategy about every five years.

- **Annual Implementation Plan Updates**: Annual updates will focus on revising priorities and annual workplans and budgets based on progress to date and the changing political, funding, commercial, and technology landscapes. The primary goal of the annual review and update is to create the workplan and budget for the coming year. This will be done as part of the NWSA's budget process in late fall of each year, before public approval by our Managing Members, allowing the workplan to be in place before the start of the next year. As part of the Implementation Plan update, new actions may be added that support the existing milestones and timelines for existing actions may be adjusted. Industry, government, community, and NGO partners will be engaged in annual implementation plan updates through the engagement programs outlined in section 5.3.

- **Five-Year NW Ports Clean Air Strategy Renewals:** Every five years the four-port collaborative will renew the NWPCAS, revisiting the shared vision, objectives, and actions based on individual and collective progress to date, changing circumstances, and updates of the Puget Sound Emissions Inventory. As was the case in the development of the 2020 NWPCAS, industry, government, tribal, community and NGO partners will be systematically and significantly engaged in the Strategy renewal process.

5. NWSA Sector Action Plans

This section lays out the five-year action plan in each activity sector for working towards the NWPCAS vision and joint objectives as well as major implementation plan milestones.

5.1. Action Plan Development Process

The development of this implementation plan has been led by the NWSA's Air Quality and Sustainable Practice team, with the goal of developing a plan with actions and milestones that are aggressive yet achievable, will have significant impact, and are rooted in the interests of our local communities, industry partners, governments, and other non-government partners. The implementation plan development has been guided by a rigorous multi-stakeholder external engagement process, public engagement (including webinars and an online survey)[13], and an internal working group that brought in expertise from across business units at the NWSA. Additionally, a two-year, three-stage engagement process was undertaken to develop the 2020 NWPCAS update, which also provided direction for development of this implementation plan.

Our actions and milestones were created based on what we heard throughout the external engagement process, the expertise of our interdepartmental working group, and the technical work and expertise of our air quality and sustainable practices team. Building the action plans and milestones was a complex process that considered a range of prioritization criteria to both determine the actions we should select as well as how we prioritize work between the sector areas. These criteria are listed below.

- ***GHG emission reductions*** – Achieving our vision will require that we achieve carbon neutrality by 2050, critical for doing our part to limit climate change.

- ***Air pollution impacts*** – Air pollutant emissions, especially those from diesel engines, result in negative health impacts for those exposed. Our actions will strive to reduce air pollutant emissions, prioritizing emissions of diesel particulate matter, which are thought to have the most significant health implications of port related air pollutant emissions. We will prioritize air pollutant emission reductions based on results of the WSU air modeling study described in section 3.3.3., placing more emphasis on sources that have more relative impact on populations.

- ***Address environmental health disparities*** – We will continue to refine our understanding of the NWSA's relationship to environmental health disparities and prioritize air emission reduction efforts in areas that are disproportionately impacted.

- ***Alignment with community priorities*** – Aligning our work with the priorities of our near port communities is a central priority of this implementation plan.

[13] Northwest Ports Clean Air Strategy Implementation: Get Involved | Port of Seattle (portseattle.org)

- ***Alignment with customer plans and priorities*** – We will work to align the actions in this plan with our tenants' and other business partners' plans to implement cleaner technologies, to ensure we are supporting those efforts.

- ***Level of influence*** – We will prioritize actions for which the NWSA has more influence over success.

- ***Technical feasibility*** – It is important that technologies can "do the job" and can be reasonably integrated into operations.

- ***Cost*** – The cost of the action and funding available to offset those costs will be a critical consideration both for the NWSA and our industry partners. We will seek to prioritize actions that get the largest benefit for the lowest cost to maximize our limited resources.

- ***Alignment with commercial goals*** – We will prioritize actions that increase, or at least maintain the competitive position of the Puget Sound cargo gateway in the global marketplace. This means we will need to be conscientious about adding additional costs and prioritizing actions that cargo owners find desirable.

- ***Advancement of the pathway to zero*** – Our ultimate goal is to transition to zero-emissions across all of the sector areas. We will prioritize actions that push us farther down the path towards achieving the desired end state.

5.2. Benefits and Costs

The benefits of this implementation plan are multifaceted, including both tangible and intangible aspects. While many of the actions in the plan directly reduce emissions, there are several actions that do not directly reduce emissions but are nevertheless critical to our short- and long-term success. For example, there are a number of planning and partnership building actions that enable future emission reduction projects by identifying and planning for infrastructure investments needed to support zero-emission technologies, preparing for future grant applications, and daylighting opportunities where we can work with our tenants, the trucking community, and other partners to move emission reduction initiatives forward. In addition, demonstration projects of zero-emission technology may produce relatively small emission reduction benefits when compared with the capital cost but provide significant benefits in demonstrating that the technologies can do the work required in a port environment, giving operators experience with the new technologies, and providing important lessons learned for future deployments. They also help create a market for the technology, giving equipment manufacturers more reason to develop the technologies and improve their production processes, driving costs down over time. Finally, community engagement and partnership building activities will further community understanding of the

NWSA and its clean air and climate programs, as well as fostering mutually beneficial partnerships.

5.2.1. Emission Reduction Benefits

The quantifiable emission reduction benefits associated with actions projected over this five-year implementation period are summarized below in Table 4. It should be noted that the emission reductions summarized below do not account for many emission reductions that are harder to quantify, such as the expected modernization of vessel, truck, cargo handling equipment, and light duty vehicle fleets that would occur through natural attrition and initiatives of the shipping and logistics industries to increase efficiency or otherwise reduce emissions. Additionally, actions to be taken beyond the five-year time horizon, such as shore power installations at other terminals, are not included. These emission reduction estimates are calculated using methods from the PSEI as well as the EPA's Diesel Emission Quantifier[14]. It should be noted that, because specific commitments have not been made, the cargo handling equipment demonstration project emission reduction benefits may change depending on the types of equipment demonstrated.

On the way to achieving zero-emissions by 2050, we expect the trajectory of emissions to be nonlinear. That is to say, the adoption of zero-emission technologies will be slower at first, as planning and demonstrations take place, and will ramp up as the technologies are broadly demonstrated and the costs come down. The magnitude of the emission reductions projected below reflect the state of technology and this implementation plan's focus on planning and demonstration, to enable adoption of zero-emission technologies over time.

Table 4. Direct Emission Reductions of Key Actions

	Action	**GHG Emission Reductions (tons/yr)**	**Percentage of Sector GHG Emissions**	**DPM Emission reductions (tons/yr)**	**Percentage of Sector DPM Emissions**
OGVs at Berth	T-5 Shore Power[a]	1,666	2.5%	0.55	4.1%
	Husky Shore Power	3,660	5.5%	1.20	9.0%
Trucks	Scrap and replace 50 pre-2007 trucks	0	0.0%	1.76	13.1%
	Demonstrate 10 zero-emission trucks	838	0.5%	0.36	2.7%
Cargo-handling equipment	SIM Yard electric terminal tractor project	670	1.5%	0.33	2.4%
	Seattle ZE/NZE CHE demonstration	1,741	4.0%	1.35	10.0%
	Tacoma ZE/NZE CHE Demonstration	743	1.7%	0.99	7.3%

[14] Diesel Emissions Quantifier (DEQ) | Clean Diesel and DERA Funding | US EPA

Harbor craft	Hybrid tug demonstration	351	1.5%	0.12	0.9%
Locomotives	Switching locomotive repower	0	0.0%	0.11	0.4%
	Total[b]	9,669	1.5%	6.77	4.0%

[a] The emission reductions follow assumptions made in the T-5 Modernization project's Environmental Impact Statement. If actual vessel traffic is greater than projected and connection rate is greater than 30%, then emission reductions could be larger.
[b] The percentages in the total line are of all of NWSA's emissions across all sectors.

5.2.2. Costs

A summary of the projected costs of implementing the actions in this implementation plan is provided below in Table 5. The cost estimates below are preliminary in most cases and are expected to be refined over time. The table also highlights where funding from industry partners and external funders will be necessary to accomplish our goals. A deeper discussion of the costs on a project-by-project basis, the associated funding needs, and our funding strategy is provided in section 6.

Table 5. Estimated Implementation Plan Costs

	Total Cost	NWSA Funding	Industry Partner Funding Needed	Industry Partner Funding Secured	External Funding Needed	External Funding Secured	Combined Funding Gap
Crosscutting	$2,075k	$1,625k	$0	$0	$450k	$250k	$200k
OGV[a]	$38,890k	$14,010k	$0	$0	$24,880k	$5,100k	$19,780k
Trucks	$10,835k	$1,110k	$1,700k	$0	$8,025k	$850k	$8,875k
CHE	$34,200k	$4,500k	$6,290k	$1,290k	$23,410k	$910k	$27,500k
Fleets and Facilities	$3,790k	$1,400k	$750k	$0	$1,640k	$140k	$2,250k
Total	**$89,790**	**$22,645k**	**$8,740k**	**$1,290k**	**$58,405k**	**$7,250k**	**$58,605k**

[a]Includes costs for the T-18 shore power project, which is not projected to be completed within the five-year implementation period.

5.3. Strategy-Wide Actions

Strategy-wide actions are those that apply broadly across more than one operational sector. These include community engagement and partnerships, industry engagement and partnerships, public policy engagement, infrastructure planning and development, and technology assessment and advancement.

5.3.1. Community Engagement and Partnerships

Improving air quality for port workers and near-port communities through reduced emissions from port-related sources is a central priority of the NWPCAS and this implementation plan. Communicating, engaging, and partnering with our near-port residents and community groups is an essential component of this work. The NWSA, working closely with the ports of Seattle and Tacoma, will continue and strengthen our efforts to engage and partner with near-port residents and communities in both the Tacoma and Seattle harbors, to ensure that our clean air and climate actions and investments incorporate community experience, perspectives, priorities, and ideas.

Based on the Washington State Department of Health's Environmental Health Disparities Map[15], significant environmental health disparities exist along the I-5 corridor and in and around the Tacoma and Seattle industrial centers, of which the ports are a part. Quantifying environmental health is a complicated exercise - the Washington State Department of Health uses 19 indicators including environmental exposures; proximity to certain activities that are thought to elevate risk to human health; population sensitivity; and socioeconomic factors[16]. Diesel emissions from port activities is one of many contributors to these long-standing environmental health disparities that will need to be addressed by a wide consortium of stakeholders. The NWPCAS and the actions in this Implementation Plan are the NWSA's effort to reduce our diesel exhaust contributions to these disparities.

As part of our efforts to reduce our impacts we will work with communities and appropriate government agencies to refine and expand our understanding of how port related air emissions contribute to environmental health disparities and identify the highest impact strategies for reducing and over time eliminating those contributions.

The main programmatic priorities for our air quality and climate community engagement programs over the next five years are:

1. Increase mutual understanding of port related air quality and climate opportunities and challenges in the Tacoma and Seattle harbors.
2. Continue to build mutual trust and capacity for collaboration.
3. Better understand the NWSA's relationship to air quality related environmental health disparities experienced by near port communities in the Tacoma and Seattle harbors.
4. Collaborate on the development and implementation of port related air quality and climate solutions.

Based on these priorities, the actions to be taken are summarized in Table 6 below.

[15] Information by Location | Washington Tracking Network (WTN)
[16] Washington Environmental Health Disparities Map :: Washington State Department of Health

Table 6. Community Engagement and Partnerships Action Plan

Action	Milestones
1. Gateway-Wide: a. Rely on targeted analytical work and community consultations to better understand and address port-related air quality impacts in near port communities. b. Develop a "Community Guide to Clean Air & Climate Solutions" to increase understanding of port operations, air quality and climate issues related to ports, and the Northwest Ports Clean Air Strategy. c. Develop and implement a mechanism for providing quarterly updates on NWPCAS implementation.	- Begin providing quarterly updates on NWPCAS implementation by Q1 of 2022. - Complete the Resource Guide by the end of 2022
2. Tacoma Harbor: a. Work with near-port residents and community groups to develop an ongoing community engagement and partnership program. b. Collaborate with Port of Tacoma staff to expand the network of near port residents and community groups with whom we communicate, engage, and partner. c. Collaborate with Port of Tacoma staff to identify and implement partnership opportunities that advance near port community priorities and the NWPCAS in the Tacoma Harbor.	- Develop and launch a community engagement and partnership program by the end of 2022.
3. Seattle Harbor: a. Continue to participate actively in the development and implementation of the Duwamish Valley Clean Air Program. b. Support implementation of Port of Seattle Duwamish Valley Community Equity Program, supporting implementation of the Port of Seattle's Duwamish Valley Community Benefits Agreement (Port of Seattle Commission Resolution 3767). c. Work with near-port residents and community groups to develop an ongoing community engagement and partnership program. d. Collaborate with Port of Seattle staff to expand the network of near port residents and community groups with whom we communicate, engage, and partner. e. Collaborate with Port of Seattle staff to identify and implement partnership opportunities that advance near port community priorities and the NWPCAS in the Seattle Harbor.	- Develop and launch a community engagement and partnership program by the end of 2022.

5.3.2. Industry Engagement and Partnerships

Achieving the 2020 NWPCAS vision will require action across all industry stakeholders in the port network including terminal operators, ocean carriers, 3PLs, tug operators, rail operators, and truck owners and operators. The NWSA will play an important role as a convenor and strategic leader in identifying opportunities and helping to identify and bring in funding for projects. The NWSA will continue and strengthen its efforts to engage and partner with its industry partners by providing information, assistance, and facilitating incentives to facilitate and encourage the transition to zero-emission technologies.

The main programmatic priorities for air quality and climate industry engagement over the next five years are:

1. Inspire, enable and empower our industry partners to implement cleaner technology, especially zero-emission technology.
2. Identify partnerships through which the NWSA can enable implementation of zero and near zero-emission technology by facilitating external funding.
3. Maximize the use of zero-emission infrastructure installed by the NWSA, especially shore power infrastructure.

Based on these priorities, the actions to be taken are summarized in Table 7 below.

Table 7. Industry Engagement and Partnerships Action Plan

Action	Milestones
1. **Strengthen tenant engagement and support:** Develop a robust tenant engagement and support program to: - Share information about infrastructure and technology developments; - Communicate grant and other funding opportunities; - Identify project and partnership opportunities; and - Provide technical support to tenants related to clean air/climate efforts and/or zero-emission technology.	- Develop framework: Q4 2021 - Implement tenant engagement program: 2022 onwards
2. **Partner with tenants and industry partners on funding applications:** Lead grant applications and other efforts to secure external funding to support tenant and other industry led projects to implement clean technology.	- Supports milestones throughout the plan related to implementing clean technology
3. **Identify and pursue additional clean air/climate partnership opportunities with key industry partners:** Conduct a thorough review of the climate and sustainability goals and programs of major customers (e.g., BCOs, 3PLs, ocean carriers, etc.) and identify additional industry partnership opportunities to be pursued.	- Complete review by end of 2022 - Engage industry partners and act on partnership opportunities: 2022 onwards
4. **Strengthen ocean carrier engagement and partnerships:** As needed, engage with major ocean carriers and the PMSA on	*- Supports milestones in the OGV sector*

air pollution reduction programs like shore power and potential new programs for reducing emissions while underway.	
5. Strengthen rail operator engagement: Partner with PSCAA in the Western Clean Rail Collaborative to engage with Tacoma Rail and the Class 1 rail lines to identify opportunities for emission reduction projects and partnerships like repowers.	*- Supports milestone in the locomotive sector*

5.3.3. Public Policy Engagement and Advocacy

Supportive public policy at the local, state, federal, and international levels will be critical to achieving the 2020 NWPCAS vision, for example by establishing appropriate market signals, creating new revenue streams and funding pathways for emission-reduction projects at the NWSA, and creating a level playing field for air quality and climate action across ports. For example, we know that transitioning to zero-emissions will come at significant cost beyond "business as usual". To accelerate the transition, it will be critical to continue and strengthen our efforts to offset these incremental costs with external funding. Similarly, achieving the vison of zero-emission cargo ships calling on NWSA terminals will require stronger action by the International Maritime Organization (IMO), which sets emissions standards and efficiency requirements for international ships.

The NWSA will increase its efforts under the 2020 NWPCAS, in partnership with the other participating ports and government, industry, and community partners, to promote policies that enable emission reductions and the transition to zero-emissions while maintaining a competitive cargo gateway. The following are the main programmatic priorities for the NWSA's air quality and climate policy engagement program.

1. Advocate for increased funding opportunities for implementation of zero and near zero-emission technologies in the port and maritime sectors and direct as much of that funding as possible to the Tacoma-Seattle gateway.
2. Advocate for international and federal policies that increase ambition on air pollutant and greenhouse gas emissions in ways that create a level playing field across ports.
3. Build relationships with local, state, federal, and international agencies and policy makers to advance deployment of lower emission technologies and direct funding towards these projects in the Tacoma-Seattle gateway.

Based on these priorities, the actions to be taken are summarized in Table 8 below.

Table 8. Policy Engagement Action Plan

Action	Milestones
1. Strengthen International Engagement a. Continue to implement and refine our international engagement program, advocating for more aggressive action on air quality and climate in international shipping. More specific details are provided in the OGV section below (Table 8). b. Strengthen cross-port collaboration on international engagement with the other NWPCAS partner ports.	- Supports milestones in the OGV section (Establish and begin implementing International Engagement Strategy by the end of 2022)
2. Strengthen Federal Engagement a. Continue to implement and refine our federal engagement program, advocating for strengthened air quality and climate policies that create a level playing field for ports across the US, and for more funding for the NWSA's emission reduction efforts. b. Maintain and strengthen working relationships with key Federal agencies. i. Continue partnership with EPA through the Ports Initiative and DERA program. ii. Strengthen relationship with US DOE, PNNL, and US DOT.	- Funding is secured to support NWPCAS implementation, filling funding gaps by 2025
3. Strengthen State Engagement a. Continue to implement and refine our state engagement program, advocating for policies that create increased funding opportunities for port related emission reduction efforts. b. Engage in key state rule-making processes – in particular those related to the Clean Fuel Standard and the WA Climate Commitment Act – to advocate for support for NWSA emission-reduction activities c. Maintain and strengthen relationships with state agencies. i. Department of Ecology through the Clean Diesel Program, VW Settlement Program, Preventing Nonattainment Program, etc. ii. Department of Commerce through the Clean Energy Fund; Electrification of Transportation program, energy efficiency program, etc. iii. Strengthen relationships with the Puget Sound Regional Council (PSRC) and the Washington State Department of Transportation (WSDOT).	- By the time rulemakings are completed in 2023: the state Clean Fuel Standard and Climate Commitment Act contain funding mechanisms to support NWPCAS implementation - Funding is secured to support NWPCAS implementation, filling funding gaps by 2025
4. Strengthen Local Engagement: a. Puget Sound Clean Air Agency: support Western Clean Rail Collaborative program, partner on clean truck initiatives, serve on Advisory Council, and others. b. Utilities: Seattle City Light and Tacoma Public Utilities. Collaborate on energy planning and deployment of infrastructure to support zero-emission operations.	- Supports milestones across other sectors and our funding strategy

c. City of Seattle: Engage with Office of Sustainability and Environment, for example on the Seattle Zero-emission Truck Corridor Assessment and other “clean truck” initiatives d. City of Tacoma: Continue partnership with Office of Sustainability and Sustainable Tacoma Commission and participate in development and implementation of the City’s Climate Action Plan. e. Pierce County: Track Sustainability 2030 Pierce County and look for partnership opportunities. f. King County: Strengthen relationship with the sustainability and climate programs and staff. g. Regional freight flow strategy: Work with local and regional partners, via infrastructure investments and/or traffic flow strategies to reduce congestion and improve freight flow regionally, with a focus on near port.	

5.3.4. Infrastructure Planning and Development

The transition to zero-emission vehicles and equipment will require charging and fueling infrastructure that is accessible and affordable to a wide range of owners and operators including ocean carriers, truck owners, marine terminal operators, railyard operators, rail companies, and tug companies. Facilitating the planning and installation of this infrastructure is one of the most important roles that port authorities will play in NWPCAS implementation. It also is one of the most challenging given the monumental cost, likely constraints of the power distribution grids, and uncertain trajectory of zero-emission technology advancement and affordability.

The following are the main priorities for infrastructure planning and deployment.

1. Plan for and aggressively seek funding to overcome the high cost of the infrastructure needed to support zero-emission operations.
2. Facilitate installation of infrastructure as needed to support adoption of zero-emission technologies.

Based on these priorities, the actions to be taken are summarized in Table 9 below.

Table 9. Infrastructure Planning and Development Action Plan

Action	Milestones
1. Develop the South Harbor Electrification Roadmap In partnership with Tacoma Power, evaluate infrastructure needs to support zero-emission cargo handling equipment, shore power, drayage trucks, and rail in the Tacoma harbor. This study will take a	- Begin the study by the end of 2021 - Complete by Q2 2023

detailed look at the infrastructure needed on port property as well as in the distribution networks as well as investigating innovative solutions.	
2. Support the Seattle Waterfront Clean Energy Strategic Plan Evaluate infrastructure needs to support zero-emission cargo handling equipment, shore power, drayage trucks, and rail. The study will be performed in close partnership with Seattle City Light to address the complicated constraints that exist in the grid near the NWSA's facilities in the Seattle harbor.	- Begin in 2021 - Complete by end of 2022
3. Infrastructure development plan Create an infrastructure development plan that combines the recommendations of the infrastructure planning studies outlined in the first two actions and creates a gateway-wide plan of finance. The timelines and specifics of this action will depend on the outcome of the studies and will need to be adaptable based on the state of technology and tenant needs.	- Complete infrastructure development plan by the end of 2023

5.3.5. Technology Assessment and Advancement:

Achieving the 2020 NWPCAS vision will require a transition to zero-emission technologies that are in varying stages of development, and in some cases don't yet exist. For example, zero-emission class 8 tractor trucks (heavy-duty trucks that haul port cargo along public roads) exist, but still are in the early stages of commercialization and are approximately three times as expensive as their diesel counterparts as of 2021. Another example is that zero-emission cargo ships on the scale of those currently serving the Pacific trade do not yet exist. The Getting to Zero Coalition[17] has a goal of getting the first commercially viable deep sea zero-emission vessel powered by carbon neutral fuels into operation by 2030. Additionally, a coalition of major retailers has pledged to only use shippers that use carbon neutral fuels by 2040[18]. The NWSA's role in advancing these new, zero-emission technologies focuses primarily on tracking the development and total cost of ownership of relevant technologies in the PNW region, keeping the owners and operators of vehicles and equipment with whom we partner informed about these developments, and looking for strategic opportunities for "early adoption" of zero-emission technologies as they are commercialized and as funding becomes available. Demonstration projects are discussed in the sections on each operational sector below.

The following are our main priorities for technology assessment and advancement:

1. Track the state of zero and near zero-emission technology in each operational sector including purchase price and total cost of ownership.

[17] Getting to Zero Coalition (globalmaritimeforum.org)
[18] Amazon, Ikea and other big companies commit to zero-emission shipping by 2040 - The Washington Post

2. Facilitate demonstration and early adoption of zero-emission technologies across our gateway.

Based on these priorities, the actions to be taken are summarized in Table 10 below.

Table 10. Technology Assessment and Advancement Action Plan

Action	Milestones
1. Collaborate with partner ports to assess zero-emission technology feasibility and readiness a. In collaboration with other NWPCAS ports, determine the appropriate breadth, depth and frequency for technology assessment in each sector. Assemble a framework for jointly delivering and sharing these technology assessments. b. Perform technology assessments to analyze the cost and state of commercialization of zero-emission technologies in the PNW market.	- Begin assessments in 2022
2. Collaborate with partners to assess innovative energy technologies such as on-site solar, energy storage, hydrogen fueling, microgrids, etc. a. PNNL port microgrids study b. PNNL H2 @ Scale Study c. Pursue, advocate, and support other energy innovation assessments.	- Supports milestones in the energy planning sector
3. Actively explore increased use of renewable fuels a. Track the availability of renewable and biodiesel in the Puget Sound region and compile results annually. b. Annually, consider methods to encourage use of renewable and biodiesel across all sectors depending on policy landscape, cost, and availability.	- Begin annual assessment of renewable fuel opportunities in 2022

5.4. Ocean-going Vessels (OGVs)

The OGV source category typically consists of cargo carrying vessels equipped with large marine propulsion engines, auxiliary engines, and boilers. The most common origins and destinations of ships calling the NWSA are Asia and Alaska. The ocean-going vessel types most frequently calling the NWSA are: articulated tug barge, auto carriers, bulk vessels, container vessels, and roll on/roll off (ro/ro) vessels. A summary of vessel call that occurred in 2020 by type is provided in Table 11 below.

Table 11. 2020 Vessel Calls by Type

Vessel Type	Seattle Harbor	Tacoma Harbor	Total
Autos	0	121	121
Barge	101	99	200
Bulk	221	0	221
Containers	531	524	1055
RoRo/Breakbulk	0	66	66
Total	853	810	1663

5.4.1. Emissions from OGVs

OGVs are the NWSA's largest source of emissions for both DPM and GHGs. The majority of emissions occur when vessels are in transit (i.e., traveling between the airshed boundary and the port terminals), but the at dock (hoteling) segment also makes up a significant fraction of NWSA's emissions. The maneuvering segment, i.e., when vessels transition between transit and hoteling, often under tug assist, results in the least emissions of the three, given the relatively short time vessels spend maneuvering. Of NWSA's total emissions, OGVs make up 51% of the GHG emissions (40% transiting, 10% hoteling, and 1% maneuvering) and 62% of DPM emissions (52% transiting, 8% hoteling, and 2% maneuvering).

5.4.2. Level of Influence

The NWSA's ability to influence emissions from OGVs depends greatly on the segment of operation. We have greatest influence over operational practices of vessels while they are at berth, since they have a direct business agreement with the terminal operating tenant, who use port owned facilities to load and unload cargo. Therefore, the NWSA can work with the terminal operators and shipping lines to encourage cleaner operating practices and install infrastructure (such as shore power) to enable cleaner practices.

The NWSA has much less influence when vessels are in transit and when maneuvering, as the NWSA has no jurisdictional control over vessels as they transit through Puget Sound and the Strait of Juan de Fuca. State, Federal, and international regulations govern the operation of vessels in transit. The NWSA does have indirect commercial relationships with the shipping lines and therefore is limited to influencing them through incentives and voluntary programs. However, even these avenues are limited because in most cases the terminal operators, not the NWSA, make berthing arrangements and collect fees with the shipping lines. Unlike other ports, the NWSA does not charge dockage fees and therefore does not have a direct financial avenue through which to offer incentives. Most other ports that have incentive programs operate them by charging dirtier vessels more and cleaner vessels less on their dockage fees, thereby creating a revenue neutral program.

The NWSA can also advocate internationally for policies that advance emission standards and goals for ships, particularly with the International Maritime Organizations (IMO) that sets these policies and other organizations that influence the IMO, such as the International Association of Ports and Harbors (IAPH). While we are just one of many voices, this international engagement targets what has been the most significant driver of change in the industry and the one that will best maintain a level playing field while doing so.

5.4.3. State of Technology and Outlook

The state of zero-emission technology is significantly different depending on operational mode and type of improvements targeted.

For vessels at berth, shore power technology has been robustly demonstrated at other ports in the Pacific trade, specifically at California ports and some ports in China. Shore power is the provision of electricity to a vessel from the local distribution grid, that allows the vessel to shut down its engines while at berth, greatly reducing emissions. It is important to note that for a ship to be able to use shore power, it must have infrastructure installed onboard to accept shore side power. Installing this infrastructure costs hundreds of thousands to over a million dollars per vessel. Installation of shore power systems on port terminals can cost tens of millions of dollars per terminal; cost is a significant barrier to ports making these investments. Though implementing shore power is challenging, a growing number of container vessels have been installing capacity to accept shore side power, indicating an opportunity to leverage this infrastructure in the Pacific Northwest. It should be noted that non-container vessels have generally not yet begun being equipped with shore power capabilities. The one exception is that TOTE Maritime has installed shore power infrastructure on its two vessels dedicated to the Tacoma to Alaska route, which transport roll-on-roll-off containerized cargo.

Emission capture and treatment systems ("bonnet" or "hood" systems) have also been under development in recent years and are an option for reducing air pollutant emissions from OGVs while at berth. The upside to these types of systems is that the vessel does not need special onboard infrastructure to use it, which makes it an option for vessels that aren't shore power capable[19]. However, shore power is generally favored because the emission capture systems don't reduce GHG emissions, and emission capture and treatment systems have not been demonstrated as broadly. Additionally, the operational cost of emission capture and treatment systems will likely be higher than shore power, as vessel operators may even save money by plugging in in Tacoma and Seattle. Fuel cell and battery energy storage systems are also being evaluated within the industry[20] that could allow vessels to operate with zero-emissions while at dock but have not yet been demonstrated or commercialized on large international container ships to our knowledge.

The best targets for installing shore power systems in the NWSA gateway are the major international container terminals (Husky, WUT, PCT, T-5, T-18, and T-30), where the greatest number of shore power capable ships call and where the container business is expected to remain long into the future, minimizing the possibility of stranded assets. Table 12 summarizes the number of vessel calls by shore power capable ships and the shore power capable vessel hoteling hours at each of these facilities in 2020. It is important to note that Terminal 5 in the Seattle harbor is not yet operational and will most likely see a subset of the vessel traffic that is currently calling Terminal 18 and Terminal 30.

Table 12. 2020 Shore Power Capable Stats at NWSA Major International Container Terminals

	Total Calls	Shore Power Capable Calls	Percent Shore Power Capable Calls	Hours per Shore Power capable call	Shore Power Capable Hours
Husky	86	67	78%	68	4,574
PCT	103	72	70%	35	2,497
WUT	83	39	47%	53	2,061
Tacoma Harbor	***272***	***178***	***65%***	***51***	***9,132***
T-18	398	197	49%	32	6,393
T-30	97	47	48%	30	1,395
Seattle Harbor	***495***	***244***	***49%***	***32***	***7,788***
Gateway Total	**767**	**422**	**55%**	**40**	**16,919**

While significant research and development is underway within the industry, the technology for zero-emission vessels capable of trans-pacific transits remains nascent. Given the large

[19] https://shipandbunker.com/news/am/985727-long-beach-backs-sock-on-a-stack-emissions-reduction-technology#:~:text=ACTI%20say%20it%20works%20by%20first%20sealing%20a,Oxide%2C%20Sulfur%20Oxides%2C%20and%20Particulate%20Matter%2C%20are%20removed.
[20] https://www.seatrade-maritime.com/technology/energy-storage-solutions-are-future-suppliers-must-do-more

energy requirements of the trans-pacific transit, liquid fuels such as hydrogen, ammonia, biofuels, and synthetic renewable fuels, are most likely to be part of the suite of solutions. However, to date there has not been a single zero-emission trans-pacific transit, nor is there consensus in the industry on what the fuel or fuels of the future will be. While this uncertainty exists, some of the major ocean carriers are making commitments to decarbonize by 2050 taking strides towards developing and deploying lower emission and carbon neutral vessels. For example, Maersk has committed to being fully carbon neutral by 2050 and will be piloting a small container ship that is capable of carbon neutral operations in 2023[21]. CMA-CGM has made a similar commitment to carbon neutrality by 2050 and has been aggressively adding LNG vessels to their fleet[22]. Notably, a coalition of retailers has pledged to only use ocean shippers that use carbon neutral fuels by 2040[18].

While zero-emission vessels are not likely to be fully commercialized for some time, the shipping industry has made important strides to improve efficiency and thereby reduce emissions in recent years and will continue to do so. These include but are not limited to: increasing vessel size which reduces the total number of vessel trips required to move the same cargo, upgrading propellors, engines, and hull coatings to improve vessels efficiency, and slow steaming, among others. More cutting edge measures some ocean carriers are taking include piloting rotor sails to reduce fuel consumption, and piloting use of biofuel and/or renewable fuel blends to reduce carbon emissions.

International policy, driven by the IMO, is likely to continue to advance through the IMO's Initial Strategy to Reduce Emissions from Ships[23], by which the IMO seeks to achieve a goal of reducing the carbon intensity of international shipping by 75% and the absolute emissions by 50% by 2050. Implementation plans for achieving these goals are still in progress. While a step in the right direction, these targets are not as aggressive as our vision to phase out emissions completely by 2050.

To reduce air pollution, the IMO enacted the North American Emissions Control Area in 2015, which requires vessels to burn fuel with sulfur content of 0.1% when within 200 miles of shore in North America[24]. This policy has greatly reduced air pollutant emissions, particularly sulfur oxides and DPM. Additionally, the IMO enacted a global limit on fuel sulfur content in 2020[25], lowering the standard from 3.5% to 0.5%, greatly reducing emissions of sulfur oxides and particulate matter.

5.4.4. OGV Sector Action Plan

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[21] World's first carbon neutral liner vessel by 2023 | Maersk
[22] CMA CGM Group Targets Carbon Neutrality by 2050 (maritime-executive.com)
[23] https://www.imo.org/en/MediaCentre/HotTopics/Pages/Reducing-greenhouse-gas-emissions-from-ships.aspx
[24] Designation of the North American Emission Control Area for Marine Vessels | Regulations for Emissions from Vehicles and Engines | US EPA
[25] https://www.imo.org/en/MediaCentre/HotTopics/Pages/Sulphur-2020.aspx#:~:text=Known%20as%20%E2%80%9CIMO%202020%E2%80%9D%2C%20the%20rule%20limits%20the,control%20areas%20the%20limits%20were%20already%20stricter%20%280.10%25%29.

Container ship shore power is the most significant effort the ports can make towards zero-emission operations today, as the technology has been robustly demonstrated elsewhere and connecting container ships to shore power significantly reduces emissions. We have shore power installation projects currently underway at Terminal 5 in Seattle and Husky Terminal in Tacoma, which will allow vessels to connect at our gateway's "big ship ready" terminals and TOTE Maritime has been successfully using shore power at their Tacoma operation since 2010.

In addition to installing the infrastructure on the terminals, there will be a significant and challenging body of work associated with coordinating the operational and commercial aspects of connecting shore power capable ships to shore power. The NWSA will need to work with the terminal operators, and our labor partners to organize the labor required to execute the shore power connection. We will also need to work with the ocean carriers, utilities, and terminal operators to create billing procedures for passing electricity costs to the ocean carriers. If shore power is eligible to generate credits under the new low carbon fuel standard that was enacted in Washington during the 2021 legislative session, we will need to determine how the revenue will be shared. Finally, the NWSA will work to incorporate requirements to use shore power in the marine terminal operating leases, as shore power systems are installed.

To implement shore power beyond the two projects currently underway, it is vital that we update planning work to assess the costs and impacts of installing shore power at our major international container terminals. A critical component of this planning effort is to work with the utilities to understand network capacity and needs for upgrades, which will be accomplished via the energy planning studies described in section 5.A. In addition, securing substantial external funding is a necessity.

In addition to shore power, it is also important that we maximize our influence to reduce emissions from vessels while not at our docks, particularly through engagement on the international level and by implementing voluntary emission reduction measures as practicable within our airshed.

The main programmatic priorities in the OGV sector over the next five years are:

1. Complete shore power installations at Terminal 5 and Husky Terminal.
2. Incorporate requirement for capable ships to use shore power into the relevant leases.
3. Update our shore power planning work for WUT, PCT, and T-30.
4. Aggressively pursue external funding to support the updated shore power plan.
5. Engage internationally to advance environmental standards for vessels and support the industry as it develops zero-emission fuels.
6. Explore methods to encourage vessels to reduce emissions in our airshed while transiting.

Based on these priorities, the actions to be taken in the next five years are summarized in Table 13 below.

Table 13. Actions to be taken by 2025 to reduce emissions from OGVs.

Action	Milestones
Shore Power Planning	
1. Update planning work and cost estimates for container terminal shore power projects a. Hire engineering consultants to develop detailed cost estimates for the WUT, PCT, and T-30 shore power projects based on site exploration and existing conditions. b. Include timeline to design and construct c. To the extent possible, combine with electrification planning studies	- Complete by the end of 2023
2. Update our shore power plan with new timelines based on results of planning efforts a. Projects will be prioritized based on cost, projected project timelines, emission reduction benefits, commercial strategy, and other factors. b. Prepare capital plan that can be incorporated into the five-year capital investment plan. c. Consider incorporation of domestic terminals that do not already have shore power infrastructure installed based on the potential usage and commercial considerations.	- Complete by the end of 2023
3. Apply for grants and pursue other funding mechanisms to support the updated shore power plan a. Work shore power into other large redevelopments and funding asks.	- Secure funding to support the T-18 project by the end of 2024
4. Capital planning a. Integrate the shore power projects into the five-year capital investment plan, aligning and integrating with major redevelopment efforts.	- Complete by the end of 2024
Shore power infrastructure installation	
5. Install shore power infrastructure at two berths at T-5 as part of the redevelopment project.	- Complete installation by the end of 2023
6. Install shore power at two berths at Husky Terminal	- Complete construction by the end of 2023
7. Complete design of shore power infrastructure at T-18	- Complete design by the end of 2023
Shore power implementation and tracking	

8. Work with terminal operators and labor to organize labor arrangement for connecting and disconnecting vessels from shore power. a. Begin a year before each shore power system is operational to ensure labor arrangements are in place when the system is complete.	- Complete at each terminal by the time shore power infrastructure is installed
9. Work with terminal operators, ocean carriers, and the utilities to ensure that billing procedures are in place to pass power costs to the ocean carriers. a. Begin a year before each shore power system is operational to ensure billing arrangements are in place when the system is complete.	
10. Work with the terminal operators to incorporate requirement for shore power capable ships to connect to shore power.	
11. Annually analyze the vessel fleet at major international and domestic container terminals to assess the fraction of calls shore power capable	- Compile shore power data for each year by March of the following year.
12. Track shore power usage. a. Track shore power usage. b. Track reasons that vessels do not connect and seek to mitigate factors that prevent shore power connections.	
Develop program to reduce emissions from transiting vessels	
13. Perform a study to identify voluntary and/or incentive-based initiatives that would increase fuel efficiency and/or reduce air emissions from cargo ships transiting through the Puget Sound to NWSA and PoT terminals. a. Survey of what other ports do and the estimated effectiveness of each action b. Analysis of co-benefits from “quiet-sound” underwater noise program c. Analysis to slow steaming efficacy in Puget Sound d. Analysis of NWSA governance structure to analyze possibility for incentives e. Analysis of shore power incentives and LCFS revenue f. Program recommendations	- Complete study by end of 2022
14. In 2022 and beyond, implement recommendations from study a. Create program(s) b. Develop activity metric(s)	TBD
Strengthen international engagement and advocacy	

15. Advocate for policies to reduce emissions from international vessels a. Closely track the IMO's Marine Environment Policy Committee (MEPC) and Intersessional Working Group (ISWG) on GHG Emission Reduction, and look for strategic opportunities to influence IMO climate policy (e.g. strategically timed letters to the US delegation and/or the IMO Secretariat). b. Participate in IAPH Climate and Energy Committee c. Collaborate more closely with the Ports of Tacoma, Seattle, and Vancouver BC – and, potentially, California ports as well – to bolster influence with the IMO and IAPH.	- Establish and begin implementing International Engagement Strategy by the end of 2022
16. Support industry efforts to develop and demonstrate cleaner fuels including zero and near zero-emission options a. IMO Green Voyage 2050 project b. IAPH/WPSP/WPCAP Clean Marine Fuels Working Group	

5.5. Trucks

The port trucking sector is made up of heavy duty (class 8) combination tractors that move cargo to and from port marine terminals and railyards. Trucks that serve the port exist within a much broader regional trucking "ecosystem" and serve many functions within the regional economy, many of which are not directly involved with hauling cargo to and from the port specifically. These trucks are owned by many different trucking companies that vary in size from small, independent owner-operators with fleets as small as one truck to large logistics companies with expansive fleets. Many of the owner operators are new Americans and people of color. It is also important to note that many of the trucks calling the port are purchased second or third-hand and have little residual value, especially those owned by smaller fleets. As larger companies generally have much more access to capital than the smaller owner operators, we must take extra care to ensure that our programs in the trucking sector are developed and implemented equitably.

When the ports estimate emissions from these trucks, we isolate the truck trips that are made to and from port terminals, as they move on the terminals and on public roads. We do not estimate emissions or other impacts from non-port related truck trips.

Though the actual number fluctuates month to month depending on volume of containers at the terminals, there are roughly 4000-4500 unique trucks doing business at the NWSA's international container terminals in a given year. Since implementation of the NWSA's Clean Truck Program requirement on January 1, 2019 all of these trucks meet EPA engine year 2007 emission standards, meaning that they are equipped with diesel particulate filters, which remove up to 90% of the DPM compared to pre-2007 trucks. The NWSA's terminal operators enforce this requirement at their gates, turning away trucks that do not comply, using radio frequency identification (RFID) technology that the NWSA installed in 2018. RFID technology uses a "tag" on each truck to identify each truck when it pulls up to a terminal gate with RFID readers installed. The RFID tag information is crossed referenced with the NWSA's truck registry, which determines whether the truck complies with the Clean Truck Program requirements and gives the gate guard a red light or a green light, indicating whether the truck may enter the terminal.

There is also a fleet of about 500-600 trucks that do business at the TOTE and West Sitcum domestic container terminals in Tacoma. Roughly half of this fleet also call the international terminals, while the other half are separate and only serve these domestic terminals. Of this separate domestic fleet, approximately 80 trucks do not meet the model year 2007 standard. The NWSA is able to monitor the age of this fleet by using optical character recognition (OCR) camera data at TOTE and SSA-West Sitcum terminals. In addition to TOTE and West Sitcum, the NWSA also manages T-115 in Seattle which moves domestic containerized cargo from barges. As this is a barge operation that experiences less traffic than the other two domestic container terminals, the focus of the next phase of the Clean Truck Program has been on the other domestic container terminals, which have a different business model than T-115. Neither RFID nor OCR infrastructure are installed at T-115, meaning the NWSA currently does not have any data on the age of trucks entering this terminal. The NWSA's emissions inventory also includes truck calls at railyards, and other non-container cargo facilities in Tacoma and Seattle, but currently we do not have the ability to collect data on these fleets.

To our knowledge, there are currently no zero-emission trucks calling the NWSA gateway.

5.5.1. Emissions from Trucks

Trucks are the second largest source of GHG emissions in the NWSA's airshed and are tied for the third largest source of DPM (with CHE and harbor vessels). The majority of truck emissions occur off port property, on the regional road network. This has implications for exposure, as trucks driving near residential areas are more likely to expose communities to air pollution. However, The NWSA has much less influence over operational and routing decisions that occur away from our property.

It should be noted that the NWSA's DPM emissions from trucks reported in the 2016 Puget Sound Maritime Air Emissions Inventory were much greater than reported here, as the inventory occurred before implementation of the Clean Truck Program requirement in 2019. We have re-estimated the DPM emissions from trucks to incorporate expected emission reductions from this high impact program, which resulted in reducing the DPM emissions estimate for trucks by 71% from what was reported in 2016. The Puget Sound Maritime Air Emissions Inventory will be conducted again in 2022 on 2021 annual emissions, where these emissions will be updated.

5.5.2. Level of Influence

The NWSA has influence over the trucks that enter the terminal gates through lease agreements and can play a facilitative role by aligning funding needed for deployment of cleaner technologies and by bringing trucking stakeholders together to plan for and address issues associated with deploying zero-emission trucks. The NWSA does not have any direct operational control over trucks, nor does the NWSA have direct business relationships with trucking companies, but we do have an ability to influence emissions from them while on port property through our lease agreements with terminal operators. For example, in order to implement the Clean Truck Program requirement in 2019, the NWSA re-negotiated lease agreements with the operators of the international container terminals to insert a requirement to enforce the 2007 engine year standard and turn away those that don't comply. The NWSA is also able to physically install RFID technology on terminals and on port property in both harbors to collect data on individual truck information, turn times, and queue lengths.

The majority of emissions from trucks in our airshed occur off port property, on the regional road network. The NWSA's programs that facilitate the replacement of older dirtier trucks with newer cleaner diesel ones will reduce emissions both on and off port property, since the newer engines and emission controls are permanent installations on these newer trucks. In addition, the NWSA can partner with agencies and private partners across the region to increase freight flow efficiency. For example, the NWSA is currently working on several projects with government partners to improve freight flow through major freight corridors near our terminals by installing closed circuit cameras and connecting traffic signals to each other and partner agencies' traffic centers. In addition, we are working with the Seattle Area Joint Operations Group to implement a Virtual Command Center that is designed to improve cooperation, coordination, and communication among partner agencies and with the public (including truck drivers) to minimize the impact of incidents on the roadway system. The NWSA and the home ports can also use their joint voice to advocate for improvements to the regional road network, such as the Port of Tacoma Road - I-5 interchange redevelopment, improving traffic flow and road safety. In the future, the NWSA can play a similar role to help facilitate the deployment of zero-emission truck technologies.

5.5.3. State of Technology

Culminating in 2010, clean diesel emission standards for new engines were phased in by the EPA[26]. The most notable of these standards for the NWSA's efforts to reduce emissions in the trucking sector are the engine year 2007 particulate matter standards, which reduce emissions 90% when compared with the prior standard, and the 2007 NO_x standard (phased in completely by 2010), which reduces NO_x emissions by 95% when compared with the prior standard. Meeting these standards required use of emission control technology that was new at the time but is now industry standard, specifically diesel particulate filters (DPF) to address particulate emissions, and selective catalytic reduction to address NO_x. Since 2010, there has not been significant advancement in federal new engine emission standards, save for incremental fuel efficiency requirements[27] that require a 3% increase in engine fuel efficiency between model year 2014 and 2017. Therefore, there is much greater emissions benefit from upgrading pre-2007 trucks, ideally to 2010 or newer, than for upgrading post 2007 trucks to newer models.

Renewable diesel is a drop-in fuel that is chemically equivalent to petroleum diesel, but is produced from renewable sources of carbon such as waste oils and greases and in most cases results in substantially lower net GHG emissions. Substituting renewable diesel for conventional diesel in trucks could significantly reduce GHG emissions, but is not currently broadly available in the Puget Sound Region[28]. However, renewable diesel is likely to be much more available and affordable in Washington State in the future following the implementation of the Low Carbon Fuel Standard in 2023.

Zero-emission trucks are beginning to become commercially available and we expect their availability to continue to expand in the coming years, in part due to the California Advanced Clean Truck Rule[29] which requires dealers and manufacturers to make an increasing

[26] https://nepis.epa.gov/Exe/ZyPDF.cgi?Dockey=P100O9ZZ.pdf
[27] https://www.govinfo.gov/content/pkg/FR-2011-09-15/pdf/2011-20740.pdf
[28] https://www.wwcleancities.org/alternative-fuels/renewable-diesel
[29] Advanced Clean Trucks Fact Sheet (ca.gov)

proportion of their trucks available for sale zero-emission models. Washington State adopted California's Advanced Clean Truck Rule in 2021[30]. Relevant to port trucking, the rule will require 40% of new class 8 tractor sales to be zero-emission by 2035, although it remains to be seen how this will impact the second and third-hand truck markets our drivers use. Regional haul is projected to be a viable use case for zero-emission trucks according to the CARB Advanced Clean Truck Rule Market Assessment[31]. The primary technologies emerging for class 8 tractors are battery electric and hydrogen fuel cell, each of which has its own advantages and disadvantages. Battery electric trucks are generally cheaper to purchase and operate, but have more range limitations, take longer to fuel, and are significantly heavier. Hydrogen fuel cell trucks are more expensive to purchase and fuel, but do not have the time to fuel constraints that battery electric trucks do. Neither battery electric nor hydrogen fuel cell trucks have an established regional fueling/charging network to support them in Washington State.

Currently, zero-emission trucks are much more expensive than new diesel trucks to purchase and by total cost of ownership, but battery electric trucks are projected to have a lower total cost of ownership by 2030 than diesel, and hydrogen trucks are projected to be close to parity[32]. While CARB predicts cost parity with new diesel trucks by 2030, many of the trucks calling NWSA terminals are purchased as second or third-hand models, as opposed to brand new. This means that cost parity with used diesel trucks is unlikely to be achieved for trucks that call the NWSA on this predicted timeline and will likely only occur when a robust used zero-emission truck market develops. There is still tremendous uncertainty as to when used zero-emission trucks will be available and when their cost will allow them to be competitive in short to regional haul. Given the constraints posed by the purchase price of zero-emission trucks and the potential for lower operating costs, some companies are exploring "pay per use" business models to defray the purchase costs and risks associated with purchasing a new technology[33].

5.5.4. Action Plan

Given that zero-emission trucks are not likely to be cost effective in the five-year term of this Implementation Plan, especially for NWSA drayage operators, it is important that we continue our work to clean up the existing diesel truck fleet in the short term to reduced DPM and air pollutants, with a focus on those remaining trucks that are engine year 2007 and older. The existing NWSA Clean Truck Program is currently enforced at the international container terminals. Included in this five-year Action Plan are a number of actions to expand the Program to the domestic container terminals and focusing our efforts to scrap and replace older diesel trucks serving these domestic terminals.

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30 WAC 173-423-400 - Washington State Department of Ecology
31 https://ww3.arb.ca.gov/regact/2019/act2019/appe.pdf
32 https://ww3.arb.ca.gov/regact/2019/act2019/apph.pdf
33 Nikola Plans a Different Truck Ownership Model for its Hydrogen-Electric Trucks - Fuel Smarts - Trucking Info

Looking towards the adoption of zero-emission trucks in our gateway, it is clear that transition of the fleets that call the NWSA must happen within a broader regional, state-wide, and national transition to be successful. At a minimum it will be essential that a renewable fueling/charging network is built out across the region, zero-emission truck technology is commercialized and cost effective, and policies are in place to incentivize adoption of zero-emission trucks. Therefore, a collaboration between all agency and trucking partners must be established to address these issues that are much bigger than just the NWSA.

Demonstrating zero-emission truck technology in the Pacific Northwest is on the critical path to getting the entire fleet to zero-emissions by 2050. As the port does not own or operate drayage trucks itself, this technology demonstration will need to be a collaboration between the port, a trucking company and a manufacturer. The NWSA will seek to encourage and facilitate demonstration projects of zero-emission truck technology as soon as possible.

The main programmatic priorities in the trucking sector over the next five years are:

1. Implement the NWSA Clean Truck Program at our domestic container terminals.
2. Reduce the number of pre-2007 trucks calling our domestic terminals through grant funded scrap and replace incentives.
3. Improve operational efficiency and reduce idling.
4. Influence partners to establish a statewide collaboration for advancing commercialization of zero-emission trucks and installing an infrastructure network to support them.
5. Support partners in demonstrating zero-emission trucks in our region.

Based on these priorities, the actions to be taken in the next five years are summarized in Table 14 below.

Table 14. Actions to be taken by 2025 to reduce emissions from Trucks.

Action	Milestone
Cleaning up the diesel fleet	
1. Expand scrap and replace programs using grant funds targeting non-compliant trucks at the domestic terminals a. In 2021-2022, scrap and replace 20 trucks using City of Seattle grant funds and Department of Ecology Clean Diesel grant funding. b. In 2022 – 2023, scrap at least 30 trucks using DERA grant funds **2. Explore potential for increased use of renewable diesel**	- Scrap and replace 50 by the end of 2023

Action	Milestone
Existing Clean Truck Program standards	
3. Continue enforcing the 2007 engine year standard at international terminals. a. Work with tenants to ensure that RFID infrastructure is maintained and used to enforce the clean truck program standard at the gates. b. Monitor RFID data to ensure that non-compliant trucks are being turned away at the terminal gates	- Continue enforcing the program on an ongoing basis
4. Continue programs to discourage diesel filter tampering. a. Continue work with PSCAA and Ecology to encourage EPA to increase efforts to enforce anti tampering rules for emission systems. b. Continue to work with others to provide information and outreach about DPF maintenance.	*- Supports enforcement of 2007 engine year standard*
5. Phase out pre 2007 trucks at domestic terminals. a. Evaluate level of compliance with the 2007 engine year standard and methods for ensuring 100% compliance at TOTE and SSA-West Sitcum terminals. b. Determine and implement an appropriate method of enforcement of Clean Truck Program requirement at TOTE and West Sitcum gates c. Assess the age of the truck fleet serving T-115. d. Based on truck fleet size and level of compliance, create a plan for implementing the 2007 engine year standard at T-115. e. Implement compliance mechanism at the domestic terminals. f. Communicate new program requirements to trucking community.	- Assess compliance levels and determine the appropriate method of compliance at TOTE and West Sitcum by the end of 2023. - Begin assessing truck population at T-115 by the end of 2023. - Determine methods for phasing out pre 2007 trucks from T-115 by the end of 2024 - Implement compliance mechanism by end of 2025.

Action	Milestone
Collaboration towards getting to zero	
6. Lead the creation of a regional or state Clean Truck Collaborative a. Starting in 2021, work with other trucking and environmental stakeholders in the region and state to form a collaboration around getting the trucking sector to zero by 2050. b. Regional ZE truck infrastructure needs assessment*:* An important component of the regional collaboration will be to assess, plan, and deliver infrastructure to support a zero-emission trucking fleet. We will advocate for completing such an analysis by 2025.	- Clean Truck Collaborative formed - 2022 - Regional ZE truck infrastructure needs assessment complete by 2025
7. Engage with the City of Seattle and ICCT on the Seattle Zero-emission Drayage project a. Provide data and insight into the city's project. b. Incorporate findings into our own strategies. i. Cost and financing options for zero-emission trucks. ii. Driver demographics iii. Truck routes and potential infrastructure locations. c. Collaborate with the City on potential demonstration projects to deploy zero-emission trucks in Seattle and Tacoma.	- ICCT propose to complete their study by mid-2022 - NWSA will use the results of the ICCT study to inform implementation of a zero-emission truck demonstration in our gateway
8. Help develop and implement one or more zero-emission drayage truck demonstration projects a. Support and/or facilitate partnerships between trucking companies and manufacturers to demonstrate zero-emission class 8 trucks in the Puget Sound Region. b. Pursue grant funding to help facilitate a ZE truck demonstration project.	- At least 10 zero-emission trucks operate in the gateway by the end of 2025
9. Complete a port truck fleet and trip analysis a. To inform both the regional clean truck collaboration and our own efforts, perform a detailed analysis of the port truck fleet origins and destinations, along with truck age statistics by origin and destination. This will help inform where infrastructure is needed and what segments the oldest trucks operate in.	- Complete the parking and trip study by the end of 2022.

Action	Milestone
10. Support management and development of truck parking solutions a. Work with trucking stakeholders to understand and plan for truck parking needs including conducting a parking needs survey. b. Include parking needs and potential locations in assessment of port role in providing infrastructure to support ZE trucks on port property. c. Prioritize parking solutions that will reduce truck parking in neighborhoods.	
Increase efficiency and reduce idling	
11. Expand gate queue efficiency and anti-idling program a. Work with the Operations Service Center and terminal operators to develop a set of best management practices to minimize idling at the gates. i. Collect data in 2022 ii. Develop program in 2023 iii. Implement program in 2024	- Implement program by 2024 (collect data in 2022 and develop program in 2023).
Trucking community engagement and support	
12. Strengthen trucking community outreach and capacity-building support a. Use the NWSA website and "trucker blasts" to communicate key program information to the trucking community. b. Use the WTA Trucker Outreach Forum to communicate program information to the trucking community and report out on key milestones, opportunities, and policies. c. Work with the African Chamber of Commerce or other capable organizations to ensure that our communications are equitably available. d. Beginning in 2022, make a financial counselor available to truckers on a regular basis, with the goal of enabling truckers to improve their credit and increase access to capital for truck upgrades.	- Begin providing financial counseling support by the end of 2022.

5.6. Cargo-handling equipment

Cargo handling equipment (CHE) are nonroad equipment (i.e., not licensed for over the road use) that are used for moving cargo (containers, general cargo, and bulk cargo) around terminals and to and from marine vessels, railcars, and on-road trucks. The main types of CHE working at the NWSA's facilities are terminal tractors, top handlers, side handlers, reachstackers, rubber-tired gantry cranes (RTGs), straddle carriers, and forklifts. A summary of cargo handling equipment counts across the NWSA gateway is shown below in Table 15. Range of engine horsepower ratings by equipment type are included as an indicator of engine size and impact. In total, there were 722 pieces of cargo handling equipment operating across the gateway in 2019, and 68 of them were owned by the NWSA or Port of Tacoma (Port of Tacoma owned CHE work NWSA cargo facilities). Terminal tractors are the most abundant type of cargo handling equipment by a wide margin, followed by forklifts and top handlers. The majority of CHE is diesel powered, while some of the smaller forklifts are powered by propane or electricity. As of the 2019, 50% of the CHE within the NWSA's scope met Tier 4 emission standards or equivalent.

Table 15. 2019 Gateway Cargo Handling Equipment Counts by Type

Equipment Type	Total Number	Port Owned[a]	Engine Rated Horsepower[b]
Forklift	136	34	45-375
Reachstacker	11	2	200-375
RTG	22	0	300-972
Side Handler	24	0	152-250
Straddle Carrier	79	29	185-455
Terminal Tractor	347	3	110-275
Top Handler	103	0	200-365
Total	**722**	**68**	**-**

[a] Equipment owned by the NWSA and Port of Tacoma
[b] Equipment horsepower range taken from the 2016 Puget Sound Maritime Air Emissions Inventory.
** Excludes data from T-46, as container handling activities were ceased early in 2019.

5.6.1. Emissions from CHE

When considering the NWSA's emissions across the airshed compared with other sectors, cargo handling equipment contributes the fourth most GHGs and tied for third most DPM. However, when just emissions on port property are considered, CHE is the second largest source of both GHG and DPM emissions.

5.6.2. Level of Influence

The NWSA, in partnership with the Port of Tacoma, has direct operational control over the CHE that are owned by the NWSA and Port of Tacoma and serve NWSA's cargo operations, primarily at the East Blair One (EB1) Terminal and the North Intermodal (NIM) Yard. While the Port of Tacoma owns most of the existing equipment, the NWSA purchases and retains ownership of this equipment as the old PoT equipment is replaced. This equipment makes up about 9% of the overall CHE fleet serving the gateway.

The remainder of the CHE are privately owned by terminal operating tenants and the NWSA has influence over this equipment through lease agreement requirements. In addition, the NWSA can work collaboratively with its tenants to identify opportunities to replace older dirtier equipment, with newer cleaner versions and to facilitate external funding to help make these projects happen. While the NWSA can negotiate requirements for CHE into new and amended leases, the tenant must agree for these requirements to be included in the lease.

5.6.3. State of Technology

Clean diesel requirements for new nonroad engines were implemented by the EPA starting in the 1990s and culminated in the implementation of "Tier 4" requirements in the mid 2010s. Tier 4 requirements are the strictest nonroad engine standards, requiring emission control technology for particulate matter, NO_x, and organic compounds. While the phase-in period of Tier 4 requirements varies by engine size, Tier 4 requirements were broadly applied to all new engines built after 2015[34]. In recent years, hybrid technologies have started to hit the market, greatly improving the fuel efficiency of diesel equipment. Notably, RTG diesel-electric hybrid retrofit systems can decrease GHG emissions by more than 50% and particulate matter emissions by greater than 70%[35] and can be installed at relatively low cost. We will pursue implementation of near-zero-emission solutions in the near-term, especially in areas where zero-emission options are not yet demonstrated or prohibitively expensive.

Zero-emission CHE is still largely in the demonstration stage for port applications, especially for larger, heavy-duty models, though some smaller equipment types have zero-emission options commercially available. Battery electric terminal tractors have been deployed in a number of logistics applications in recent years[36] and there are deployments ongoing at Port Terminals in California[37]. The 2018 San Pedro Bay Ports' CHE Technology Assessment[38] classifies battery electric terminal tractors as in the demonstration stage for port applications as of 2018, but predicts that the technology will be approaching 'fully demonstrated' (i.e., proven to work) by 2021. Hydrogen fuel cell terminal tractors are also being demonstrated but are farther from being commercialized. While the technology is nearing fully demonstrated, the purchase price of a battery electric terminal tractor is still about three

[34] Nonroad Compression-Ignition Engines: Exhaust Emission Standards (EPA-420-B-16-022, March 2016)
[35] https://www.epa.gov/verified-diesel-tech/mj-ecopower-hybrid-systems-inc-ecocrane-hybrid-system
[36] https://orangeev.com/deployed-markets/
[37] https://www.presstelegram.com/2019/10/02/ports-of-long-beach-l-a-unveil-new-zero-emission-vehicles/
[38] https://www.gladstein.org/wp-content/uploads/2019/09/Final-CHE-Feasibility-Assessment_August-2019-Master.pdf

times the price of a comparable diesel machine and the total cost of ownership is about twice that of a diesel machine without incentives. Incentives of roughly 60% of the cost of the battery electric terminal tractor and charging infrastructure are currently required to achieve cost parity with diesel by total cost of ownership.

The availability of zero-emission forklifts depends on the engine size and lift capacity, with battery electric and fuel cell forklifts widely available for smaller forklift sizes. As engine and lift capacity increases, the options and cost of zero-emission equipment becomes more limited. The San Pedro Bay Ports' Technology Assessment classifies the state of technology for large-capacity forklifts as in development, projecting that demonstrations will be occurring by 2021. Battery-electric lifts are generally more expensive to purchase than diesel lifts, especially those with larger batteries.

Zero-emission top-handlers were solidly in the development stage as of the 2018 technology assessment, as the first real-world demonstration of a battery electric unit began in 2019[39]. The technology is not yet broadly commercially available and is substantially more expensive than diesel equivalents. This technology is years away from being fully commercialized, with significant uncertainty as to when this will occur. Similar equipment such as reach stackers and side handlers will follow a similar timeline.

Grid electric RTG cranes are fully commercially available and demonstrated, for example, Georgia Ports has converted 19 RTGs from diesel to electric, using a bus bar system to connect the RTGs to the grid[40]. Cable reel systems can also be used to power grid connected electric RTGs. While this technology is well demonstrated, significant terminal redevelopment is required to install busbar or cable reel track infrastructure to support the technology and reduced operational flexibility by confining the RTGs to fixed, straight movement paths. Therefore, it is only a fit where terminal layout and operational strategy aligns with the constraints. Battery electric and fuel cell powered RTGs are still in the development stage.

5.6.4. Action Plan

Given that the NWSA and the PoT have direct control over our own CHE fleet purchases, the top priority is to ensure that we are implementing the cleanest technology practicable as new equipment is purchased. In addition, it is important that we maximize our influence to help tenants modernize their fleets and implement zero-emission solutions where possible, identifying suitable grant funding to help our tenants bridge the cost gap between zero-emissions and diesel versions. Since zero-emission technology is not likely to be cost effective in the short term, it is important that the cleanest diesel equipment is purchased in the interim as fleets turn over when incentives are not available to enable purchase of zero-emission equipment.

[39] https://www.portoflosangeles.org/references/news_100219_top_handler

[40] https://www.epa.gov/ports-initiative/georgia-ports-authority-reduces-diesel-emissions-improves-efficiency-and-saves

With the passage of a low carbon fuel standard in Washington State, the availability of renewable diesel is expected to increase in the coming years. Dropping in renewable diesel can significantly reduce the carbon footprint of CHE and would significantly reduce air pollutant emissions from older equipment (i.e., Tier 3 and older) that does not have the latest emission control technology. We will work to closely track the availability of renewable fuels and periodically assess the efficacy of encouraging and/or incentivizing its use.

Demonstrating zero-emission cargo handling equipment is a critical step towards broad adoption throughout our gateway; demonstrating that the technology works for duty cycles in our climate. Across the Tacoma and Seattle harbors, battery electric terminal tractors will be an area of focus in the near-term since they are commercially available. We expect that grant funding will be needed to advance battery electric terminal tractor projects, given the substantial price difference between battery electric and diesel versions. Near-zero-emission diesel hybrid RTGs are another technology that can be implemented today given adequate external funding and will also be an area of focus. Beyond these two technologies, any zero-emission technology deployments would be early-stage demonstrations that carry more risk. Given their prevalence in the NWSA and Port of Tacoma's own fleets, small scale demonstration of zero-emission straddle carriers could be an opportunity for the NWSA to be a leader in the zero-emission space. However, this technology is not yet commercially available, so such opportunities will need to be evaluated in the latter part of this five-year implementation period.

The main programmatic priorities in the CHE sector over the next five years are:

1. Pursue opportunities in our own fleet to invest in zero and near zero-emission technology, seeking to offset incremental cost with external funding.
2. Pursue opportunities with our business partners to invest in zero and near zero-emission technology, seeking to offset incremental cost with external funding.
3. Maximize our influence to ensure that when diesel equipment is purchased in our gateway, it is the cleanest feasible.
4. Continue to build collaborative relationships with our terminal operators.

Based on these priorities, the actions to be taken in the next five years are summarized in Table 16 below.

Table 16. Actions to be taken by 2025 to reduce emissions from CHE.

Action	Milestones
Cleaning up the existing CHE fleet	
1. Continue implementing and enforcing clean CHE requirements for new equipment purchases and hold ourselves to the same standard. a. Require all new CHE and replacement purchases or lease to meet Tier 4 emission standards or better.	- Include Tier 4 requirement in all leases signed

b. Ensure this requirement is in all new and amended leases. c. Monitor annual fleet reports from tenants to ensure they are following the lease requirements. d. Apply the same policy to port owned equipment purchases. e. Recognizing the long length of lease agreements, also consider including language requiring zero-emission equipment if the purchase price is equivalent to diesel, if commercially feasible.	
Tenant engagement and support	
2. Institute meetings/forums [2 per year] inviting all terminal operators to build support and partnerships to work towards NWPCAS goals. **Topics include:** a. Update on NWPCAS implementation. Chance for port and tenants to share successes and challenges b. Upcoming funding opportunities and matchmaking with tenants c. Infrastructure needs to support future zero-emission equipment d. State of technology and opportunities for adoption of zero/near zero-emission equipment	- Develop and begin implementing the engagement program in 2022
3. Provide technical support and develop partnerships. a. Provide technical support to help construct the business case for zero-emission equipment, calculate potential emission reductions, and identify projects that would be competitive for grant funding. b. Jointly identify projects that fill a need for tenants and would be competitive for grant funding. c. Facilitate collaboration with agencies that can provide funding.	*- Supports milestones in the implementing zero and near zero-emission technology section.*
Implementing zero and near zero technology	
4. Prioritize zero and near zero-emission options as NWSA owned equipment is replaced. a. Develop purchasing policies to require an analysis of the feasibility and cost of zero and near zero-emission technologies for each equipment replacement.	*- Supports the milestone to get 25 pieces of zero and near zero-emission equipment operating in the gateway by end of 2025*
5. Facilitate implementation of the SIM yard truck project with RMS to implement 6 battery electric yard tractors at the SIM yard. a. The NWSA and PoT will manage design and construction of the charging infrastructure. b. The NWSA manages pass through of grant funds to RMS to partially fund remanufacture of 6 yard tractors, managed by RMS.	- Complete by Q2 2022

6. Identify and execute significant additional zero and near zero cargo handling equipment projects in each harbor. a. Write grant applications and facilitate other external funding. b. Assist with cost estimating and engineering for charging infrastructure. c. Provide cost share on charging infrastructure upgrades. d. Focus on zero-emission yard truck deployments across both harbors. e. Focus on hybrid RTGs across both harbors. f. Evaluate demonstration of zero-emission straddle carriers in NWSA's own fleet. g. Evaluate zero-emission top pick demonstration. h. Evaluate hybrid options that could reduce emissions.	- 25 pieces of zero and/or near zero-emission cargo handling equipment are operating in the gateway by end of 2025

5.7. Locomotives

The railroad system is a nationwide enterprise consisting of national and local railroad companies that together serve to move a diverse variety of cargo over long distances. The two major “Class 1” railroad companies that serve the Gateway are Burlington Northern Santa Fe and Union Pacific, who move all rail cargo into and out of the region. The rail activities included in the NWPCAS scope are those that take place within and between ports and the near-dock rail yards that handle port-related cargos, and between these places and the airshed boundary.

Port related cargo is transferred to and from rail cars at on-dock railyards (such as those at PCT, WUT, the NIM, T-18, and T-5) and near dock rail facilities like the South Intermodal (SIM) yard and the BNSF and UP facilities in both Seattle and Tacoma. Many railyards in the region also accommodate “transload” cargo, or cargo that is truck to a warehouse and repacked into 53-foot domestic containers before being loaded on to railcars.

Locomotives are generalized into two categories based on their operational scope: switching (switchers) and line-haul locomotives. Switchers operate primarily on port terminals and railyards, sorting rail cars and assembling and disassembling trains. Switchers are generally stationed locally, especially those owned by local operators (Tacoma Rail), but the switchers owned by the Class 1 railroads are periodically moved between facilities in different regions as needed. Switching locomotives have smaller engines than linehaul locomotives, typically between 1,000 and 3000 horsepower and sometimes originate as older linehaul locomotives that have been converted. Line-haul locomotives are used by the railroads to haul trains over long distances and are the ones that move cargo into and out of the region. Locomotives used for line-haul operations are typically large, powerful diesel engines of 4,000 hp or more.

Locomotives have very long lifetimes (30-50 years), are very expensive, and are often remanufactured rather than fully replaced (which does not require them to implement the strictest emission controls). As a result, very few conform to the latest emission standards (Tier 4) and many remain from the era when emissions were unregulated and earlier emission standards,[41]. This is true of both switchers and line-haul locomotives.

While we have limited insight into the switching and line-haul locomotive fleets owned by the Class 1 railroads, detailed information on the fleet of switchers that are owned by local operators has been gathered as part of the Puget Sound Maritime Air Emissions Inventory. A summary of switching locomotive numbers by Tier, excluding the Class 1 railroads, can be found in Table 17 below. These locomotives operate both on and off port property.

Table 17. Switching Locomotives Excluding Class 1s by Emission Tier

Emission Tier	Number

[41] https://ww2.arb.ca.gov/sites/default/files/2020-06/final_rail_tech_assessment_11282016%20-%20ADA%2020200117.pdf

Unregulated	5
Tier 0	6
Tier 1	0
Tier 2	2
Tier 3	4
Tier 4	0
Total	**17**

5.7.1. Emissions from Locomotives

Locomotives are a significant source of emissions, especially DPM, ranking second behind OGVs in DPM emissions across the airshed. Locomotives are the largest source of DPM emissions of those that occur on port property. However, locomotives are just the third largest source of GHGs, both across the airshed and on port property. This reflects that as other sectors, (such as trucks and CHE) have adopted emission control measures for air pollutants, locomotives have not made similar progress. Of NWSA's total emissions, 10% of the GHG emissions are from locomotives and 15% of DPM emissions are from locomotives.

5.7.2. Level of Influence

The NWSA can play an important role in efforts to reduce emissions from locomotives by working with partners on efforts to repower diesel engines and/or implement cleaner technologies. Specifically, we can help convene working groups to conceptualize and deliver projects as well as bring in outside funding to make the projects happen. Our ability to influence locomotives is limited to being an influencer and collaborator, because we do not have regulatory authority over their emissions and very limited leverage to make requirements related to locomotive emissions in lease agreements.

Switching locomotives owned by local operators represent the most significant opportunity to influence emission reductions, particularly those owned and operated by Tacoma Rail, which is an agency of the Tacoma city government. For example, the Port of Tacoma partnered with Tacoma Rail in 2014 to facilitate federal grant funding to support a repower project for one of their switching locomotives. Tacoma Rail has also worked with the Puget Sound Clean Air Agency on repower projects for their switcher locomotives. In addition, Tacoma Rail has been proactive about installing devices to improve efficiency like automatic stop/start technology to reduce idling. There will likely be opportunities to work with Tacoma Rail and the Puget Sound Clean Air Agency in the future to encourage and support further upgrades to cleaner diesel technology. Since they are owned by a local agency, upgrades to locomotives owned by Tacoma Rail are much more likely to be competitive for grant funding than those owned by the Class 1 Railroads, since they will not be moved out of the region – air quality benefits would stay within Tacoma.

The switcher fleets owned and operated by the Class 1 railroads are generally housed at railyards owned by the railroad companies, but also provide some service to on-dock rail facilities, particularly in the North Harbor (Tacoma Rail is the primary provider of switching services in the South Harbor). Regulatory control over these engines is held by the federal government, state, and Puget Sound Clean Air Agency. Because these locomotives can often be rotated region to region, it is much more challenging to secure grant funding to support replacements, and without grant funding there is little to no incentive for the railroads to voluntarily upgrade their engines. Our partners at the Puget Sound Clean Air Agency are working on advancing voluntary efforts to reduce rail emissions from the Class 1 railroads, using their influence and reputation as the regulatory entity.

Similar challenges exist for the line-haul locomotives but are exacerbated by the fact that individual line-haul locomotives spend a relatively small proportion of their time within our airshed and may or may not regularly visit our facilities. Therefore, a broader national or continental approach to reducing rail emissions is likely needed if significant progress is to be made. For this sector, engagement at the federal level is likely the most impactful way to influence change.

5.7.3. State of Technology

Since 2015, new locomotives built have been required by federal law to meet Tier 4 emission standards, which for particulate matter, allow 95% less emissions than pre-Tier 0 standards. Given that there are no known Tier 4 locomotives operating in our region and a majority of the switching locomotives for which we have data are Tier 0 or unregulated, significant progress can be made by replacing or repower locomotives to conform with the latest standards. In many cases, older locomotives can't be upgraded to Tier 4 (or in some cases Tier 3) due to space constraints on board the locomotive, but significant emission reductions can still be achieved by upgrading the older engines to Tier 2 or Tier 3. In addition, CARB believes that implementing aftertreatment devices on Tier 4 locomotives is a cost effective and impactful way to further reduce emissions. Further emission reductions can be achieved by installing onboard batteries to augment the power supply for diesel-electric locomotives, reducing emissions and allowing for temporary zero-emission capabilities to be applied nearest to population.

Electric locomotives have been in existence since the 1800s[42] and electric rail systems power by catenary wires or electrified "third rail" systems operate in many locations around the world. While it is physically possible to electrify the whole American freight rail system, the staggering cost is prohibitive[43]. Change on this scale will require action on the federal policy level, and significant federal funding. Since most locomotives use electric drivetrains powered by diesel generators, one method of creating a zero-emission locomotive is to replace the diesel generator with a zero-emission power source such as batteries or a fuel cell. Both technologies are in the relatively preliminary stages of research and development, though

[42] https://www.american-rails.com/electric.html

[43] https://ww2.arb.ca.gov/sites/default/files/classic//railyard/docs/uoi_rpt_06222016.pdf?_ga=2.229875544.519388810.1612913378-65149391.1570662747

early-stage pilots are beginning to get underway. For example, BNSF is beginning a pilot of a battery electric locomotive in California[44]. Given the early stage of technology development and commercialization, it will likely be some time before clarity is achieved as to which zero-emission technology is best for each rail application.

5.7.4. Action Plan

Our best methods for reducing emissions are to support, facilitate, and advocate for financial incentives for operators to repower their engines and implement fuel efficiency measures. Drop-in renewable fuels may also be an option for reducing emissions in the short term. The Puget Sound Clean Air Agency is a key partner in this effort, as they have been successful in building partnerships with rail operators and facilitating grant funded repower projects in the past and have broader reach to address these regional sources of pollution that extend beyond port boundaries than we do.

The main programmatic priorities in the locomotive sector over the next five years are:

1. Work with our agency partners and rail operators to encourage repowers of the oldest switching locomotives in the fleets serving the NWSA facilities.
2. Support agency partners and rail operators in efforts to improve locomotive energy efficiency.
3. Advocate for more funding to support locomotive repowers and for advancement of federal rules on air emissions from locomotives.

Based on these priorities, the actions to be taken in the next five years are summarized in Table 18 below.

Table 18. Actions to be taken by 2025 to reduce emissions from Locomotives.

Action	Milestones
Support partner efforts to implement cleaner engine technologies and increase efficiency	
1. Participate in the Puget Sound Clean Air Agency's Western Clean Rail Collaborative and collaborate on efforts to work with rail operators to reduce emissions.	- Support at least one repower project by the end of 2025
2. Support or lead efforts to secure external funding to support switching locomotive repowers or other emission reduction measures. a. Provide letters of support. b. Lead grant application and management if necessary.	

[44] https://chargedevs.com/newswire/bnsf-railway-and-wabtec-begin-battery-electric-locomotive-pilot-in-california/

	Advocate for funding to support locomotive repowers and advance federal emission requirements	
3.	**Support advocacy agenda of our partners to increase funding for locomotive repowers and advance federal standards, while not compromising other priorities.**	- Develop advocacy agenda as part of our broader engagement strategy by end of 2022 - Continue to refine and implement through 2025

5.8. Harbor Vessels

The harbor vessel sector for the NWSA's scope includes assist tugs that help ocean-going vessels maneuver into and out of their berths. In total, there are 14 tugs operated by two companies that serve vessels calling NWSA terminals. These tugs are all powered by large diesel propulsion engines up to 4,100 horsepower. They also have auxiliary engines to supply power for onboard processes that can be as large as 500 horsepower. Most of the propulsion engines of these assist tugs are from the 1990s or older, while auxiliary engines tend to be newer. In the PSEI, assist tug emissions are calculated for their activity throughout the airshed and apportioned to each port proportional to its number of OGV calls.

5.8.1. Emissions from Harbor Vessels

Harbor vessels are the 5th largest source of GHGs and roughly tied for the third largest source of DPM emissions across the airshed. Of the NWSA's total emissions, harbor vessels make up 4% of GHG emissions and 8% of DPM emissions.

5.8.2. Level of Influence

The NWSA's best opportunity to influence tug emissions is with tug operators that are its tenants. Currently, the NWSA has one tug operator on an expiring lease and is exploring other opportunities. In these situations, we can help secure funding to put in shore power to reduce emissions while they are at the docks and, in the future, when zero-emission tugs are available and affordable, the NWSA can help provide charging and/or fueling infrastructure for tug operating tenants with zero-emission vessels. The NWSA can also work with industry partners to facilitate grant funding to offset the costs of cleaner technology such as diesel engine repowers and zero-emission technology. Assist tugs are typically hired by the ocean-carrier when their vessels need to maneuver into berth and therefore, the NWSA does not have a direct business relationship with them when they are performing their work.

5.8.3. State of Technology

The most current emission standard for diesel tugs is Tier 4 and would be installed on any tugboat built today. However, due to the size of emission control equipment that is required for Tier 4 engines, older tugboats may not be able to be retrofitted to accommodate Tier 4 engine systems and Tier 3 engine repowers may be the best that can be done in many cases. Renewable diesel and biodiesel blends, while not currently widely available in the Puget Sound region, are drop-in fuels that could be used to reduce emissions. Additionally, diesel electric hybrids are currently available[45] and can substantially reduce emissions. Shore power for tugs is also another demonstrated technology for reducing emissions while at dock.

[45] http://sanmartugboat.com/hybridtugboats/#:~:text=The%20use%20of%20hybrid%20tugboats%20is%20increasing%20in,providing%20the%20latest%20hybrid%20technology%20to%20its%20customers.

Zero-emission tugboat technology is still in the research and development phase to early demonstration phase. However, the debut of zero-emission technology in the tug sector is likely to occur in the next few years, for example, there are reports that a battery-electric tug is slated to be delivered at Port of Auckland in 2021[46]. In addition, hydrogen fuel cell tugs are also being developed[47]. Crowley has completed the first U.S. design of a zero-emission tug[48]. Until real world testing has occurred, it will be impossible to determine which technology will be technologically and financially feasible for the broader scale transition to zero-emissions. However, there may be opportunities to demonstrate hybrid and/or zero-emission technology if there is significant funding and willing partners available.

5.8.4. Action Plan

The NWSA plans to work to support the adoption of cleaner tug technologies over the next five years and shore power for any permanent tug tenants on our property. We will focus our efforts on collaborating with willing partners to implement hybrid and/or zero-emission tug technologies and on shore power installations on our property. This can include exploring more business relationships with tug operators and including providing infrastructure for zero-emission tugs in the value proposition.

The main programmatic priorities in the harbor vessel sector over the next five years are:

1. Support efforts by the tug industry to implement cleaner tug technologies.
2. Support deployment of shore power for any new tenants at facilities that do not already have shore power.
3. Advocate for more funding opportunities to support deployment of cleaner tug technologies.

Based on these priorities, the actions to be taken in the next five years are summarized in Table 19 below.

Table 19. Actions to be taken by 2025 to reduce emissions from Tugs.

Action	Milestones
Support efforts by the tug industry to implement cleaner tug technologies	
1. Explore opportunities to work with tug companies to develop facilities to support zero-emission and/or hybrid tugs. a. Explore joint development of charging infrastructure for battery powered tugs on our property.	- Support the deployment of at least one zero or near zero-emission

[46] https://maritime-executive.com/magazine/the-zero-emissions-tug
[47] https://www.electrive.com/2019/05/23/ballard-abb-developing-fc-tugboat/
[48] Crowley Completes First U.S. Design for Fully Electric Tug

b. Explore joint development of hydrogen fueling infrastructure for tugs.	tug in the gateway by 2025
2. Lead and/or support efforts to win grant funding to assist in the purchase of hybrid and/or zero-emission tugs.	
Support deployment of tug shore power	
3. Support installation of tug shore power for future NWSA tenants a. This action would apply if the NWSA were to gain a permanent tug operating tenant at a facility without shore power.	- TBD
Advocate for funding opportunities to help implement cleaner tug technologies	
4. Support advocacy efforts of our partners to increase funding opportunities for tug repowers, while not compromising other priorities.	- Include advocacy agenda as part of our broader engagement strategy by end of 2022 - Continue to refine and implement through 2025

5.9. Light Duty Fleets and Facilities

The light duty fleets and facilities sector includes emissions from port and tenant fleets and facilities. As the NWSA relies on the home ports for fleet and facility services, the administration sector for the NWSA in this implementation plan focuses on fleets and facilities operated by NWSA tenants. Tenant fleets include passenger cars, pickup trucks, passenger vans, and other vehicles necessary for administration and maintenance. Tenant operated facilities include office buildings, equipment maintenance bays, yard lighting, fueling, among others. Emission impacts from fleets and facilities include fuel combustion and energy use.

5.9.1. Emissions from Fleets and Facilities

Fleets and facilities are the smallest source of emissions in NWSA's scope. DPM emissions from fleets and facilities are negligible and GHG emissions are less than 1% of NWSA's total.

5.9.2. Level of Influence

The NWSA does not have direct operational control over buildings or facilities, as this control is given to tenants and operating partners in leases and operating agreements. In some of these agreements, however, the NWSA is responsible for maintenance of certain facilities. The NWSA can influence fleet purchase decisions in a similar manner as the CHE sector, by negotiating requirements into the lease agreements. The NWSA can also install EV charging at facilities during renovations to enable tenants to purchase electric vehicles. The NWSA can encourage and facilitate energy efficiency improvements by performing analytical work to help tenants identify opportunities to save money by investing in energy efficiency improvements.

5.9.3. State of Technology

Battery electric, zero-emission versions of light duty vehicles are broadly commercially available, and pickup trucks are nearing commercial availability[49]. While zero-emission vehicles are, or will soon be, widely commercially available, they are still more expensive than gasoline and diesel vehicles to purchase and also require charging infrastructure to support. Some projections have stated that 2025 is roughly the year that passenger cars will reach price parity[50], while price parity may be further away for pickup trucks and other heavier vehicles, though the Ford F-150 lightning is expected to hit the market in 2022 at $40,000 for a base model[51].

[49] https://www.caranddriver.com/ford/f-150-electric
[50] https://about.bnef.com/blog/electric-cars-reach-price-parity-2025/
[51] The 11 most exciting electric vehicles hitting streets in 2022, from Ford's electric F-150 to an ultra-sleek Cadillac SUV (yahoo.com)

There are many types of energy efficiency measures that can be taken on port buildings and facilities including but not limited to: upgrading yard and interior lighting to modern light emitting diodes (LED), upgrading building HVAC systems, upgrading windows and switching from natural gas heating to electric heating. As new buildings and facilities are built, energy codes generally prescribe best practices in energy efficiency. However, efficiency improvements can also be retrofitted to existing buildings and facilities. Utilities' conservation programs are often a good source of incentive funding to help make energy efficiency retrofits cost effective.

5.9.4. Action Plan

Facility energy use contributes the most emissions from the administration sector and presents the greatest opportunity for energy cost savings. Therefore, identifying and facilitating energy efficiency improvements is a primary focus of this sector. The NWSA does not currently own any light or medium duty vehicles (relying on the home ports for those services), but if the NWSA were to purchase vehicles in the future, we would develop policies and procedures to incorporate zero-emission technology as practicable.

The main programmatic priorities in the NWSA administration sector over the next five years are:

1. Work with tenants to identify cost effective energy efficiency projects and incentive funding.
2. Encourage and assist tenants to adopt zero-emission fleet vehicles.

Based on these priorities, the actions to be taken in the next five years are summarized in Table 20 below.

Table 20. Actions to be taken by 2025 to reduce emissions from fleets and facilities.

Action	Milestones
Facilities	
1. **Complete LED lighting upgrade projects at EB-1 terminal and NIM yard.**	- End of 2021
2. **Systematically identify opportunities for energy efficiency upgrades at NWSA operated facilities.** a. Establish an internal working group. b. Maintain small pool of funds for energy audits. c. Conduct walkthroughs by utilities' conservation teams. d. Work with the utility to secure incentive funding to support energy efficiency projects.	- By the end of 2022
3. **Help tenants identify and finance opportunities for cost-effective energy efficiency and clean energy improvements**	- Complete at least three additional

a. Engage tenants annually on potential for energy efficiency or clean energy upgrades. b. Maintain a small pool of funding for energy efficiency audits conducted by a consultant. c. Conduct walkthroughs by utilities' conservation teams. d. Work with the utility to secure incentive funding to support energy efficiency projects. e. Identify and complete one additional energy efficiency or clean energy project per year through 2025	energy efficiency projects by 2025
NWSA-Owned Light and Medium Duty Fleets	
4. **Purchase zero-emission vehicles for any future fleet purchases if practicable (currently the NWSA does not own any light or medium duty vehicles)**	- TBD
Tenant Light and Medium Duty Fleets	
5. **Accelerate adoption of zero-emission vehicles in tenant-owned fleets (light and medium duty)** a. Engage with tenants to understand infrastructure needs. b. Connect tenants with incentive funding to support infrastructure installation.	*- Include in industry engagement program (action 3 of the industry engagement section, above)*

6. Funding Strategy

Significant external funding will be critical if we are to meet the 2020 NWPCAS vision. We project that the transition to zero-emissions for just trucks, CHE, and vessels at berth (i.e., shore power) could cost upwards of $4 billion beyond business as usual for the port and industry partners combined using today's prices, including infrastructure and equipment costs. A summary of the total projected costs of this implementation plan and the identified funding gaps are provided in section 5.2.2. This section describes sources of external funding that could help fill identified funding gaps (section 6.1), and more detailed descriptions of the major projects and initiatives that need funding (section 6.2). The funds attributed to the NWSA in this section are being incorporated into the NWSA's five-year capital investment program.

The NWSA's operating and capital budgets are approved on an annual basis at a public meeting and voted on by the NWSA Managing Members. Although a project may be included in the annual budget and approved by the Managing Members, individual projects have to undergo an additional project authorization process by the relevant Port Department, Executive Director, or Managing Members at a subsequent public meeting, dependent on the level of funding required. All public meeting materials are posted beforehand on the NWSA's website, and meetings are open for public comment[52].

6.1. External Funding Sources

Historically, we have funded air quality and climate projects through competitive federal and state grants, such as the federal Diesel Emission Reduction Act (DERA) program[53], the Congestion Mitigation and Air Quality grant program[54], the Washington State Department of Ecology's Clean Diesel Program[55], the Washington State Clean Energy Fund[56], and the state and federal Volkswagen Mitigation Settlements[57]. Continuing to win grant funding through these programs will be important as we look forward to the next five-year NWPCAS implementation period.

While these programs have helped make significant progress in improving air quality in our region, the challenge of transitioning to zero-emissions will require even larger investments that will require larger funding sources than we have used in the past. A significant difference from our previous air quality efforts, which focused primarily on scrapping and replacing diesel equipment and replacing them with newer diesel equipment, transitioning to zero-emissions will require significant investments in physical infrastructure. Infrastructure

[52] The Northwest Seaport Alliance (veconnect.us)
[53] Diesel Emissions Reduction Act (DERA) Funding | US EPA
[54] Federal Programs Directory: Congestion Mitigation and Air Quality (CMAQ) Improvement Program | US Department of Transportation
[55] Clean diesel grants - Washington State Department of Ecology
[56] Clean Energy Fund - Washington State Department of Commerce
[57] Volkswagen enforcement action grants - Washington State Department of Ecology

funding is not typically available in traditional air quality grant programs. As a result, we plan to apply for a broad set of grants to support our air quality and climate work including Washington State Clean Energy Fund grants and federal infrastructure grants such as the Port Infrastructure Development Program (PIDP) and the Rebuilding American Infrastructure with Sustainability and Equity (RAISE) program. These larger federal programs will allow us to combine infrastructure projects that support the transition to zero-emissions with seaport infrastructure development projects. We believe this combination will yield competitive applications.

Finally, we are excited to participate in and see the results of rulemaking processes for the recently passed Washington State Low Carbon Fuel Standard and the Cap and Invest Program in 2021, as we hope that significant funding from the revenues of these programs will be directed towards decarbonization of port operations. In addition, there may be opportunities for the NWSA and our business partners to claim credits under the low carbon fuel standard rule, which can generate revenue that will help offset the costs of implementing zero-emission technologies. In addition to policies enacted on the state level, the Biden Administration is working on its infrastructure funding package on the federal level. Decarbonization is a key component of this legislative package, and we are hopeful that significant funding will be directed towards port decarbonization as a result.

We will seek to leverage all of these new funding opportunities to support this NWPCAS Implementation Plan, and advocate for additional new sources of funding.

6.2. Funding Needs

There are several projects that we would like to progress as part of the NWPCAS Implementation Plan that will need external funding to move forward. In some cases, both external funding (i.e., grants, incentives, or other contributions) and industry partner funding will be needed. Table 21 details our best estimate of the industry and other external funding (i.e., grants, public funding, other private funding, etc.) needed to move forward with each action. The funding gap indicates the total of these funding needs not yet secured. This section details the items for which we have an existing funding gap.

South Harbor Electrification Roadmap:
Total cost: $500k
NWSA funds: $250k [50%]
Port of Tacoma Funds: $50k [10%]
External funds: $200k [40%]

This study is a critical element of our transition to zero-emission port operations in the Tacoma harbor. It will provide a flexible plan to deliver energy infrastructure to support future needs that include ocean-going vessel shore power, zero-emission cargo handling equipment, and charging for electric drayage trucks, light duty fleets, and others. We will be partnering with the utility to ensure that the plan identifies and will address key grid constraints and to build a partnership by which we can work together to explore new business models and ways to expedite the investments needed. We believe that we have enough funding to do the baseline planning work. Additional external funding and support will allow us to do more in depth engineering on specific short-term projects identified as high priority in the plan and allow us to take a more comprehensive look at innovative energy solutions like storage, on-site generation, and connected microgrids.

Husky Terminal Shore Power
Total cost: $11.1M
Port funds: $8M [50%]
State funds: $1.1M [11%]
Private grant funds: $1.0M [10%]
Federal funds: $1.0M [10%]
Additional external funding sought: -

This project would bring shore power to the NWSA's recently modernized Husky Terminal in the Tacoma harbor. Husky Terminal is a premier facility equipped with new ship-to-shore cranes that can accommodate the largest ships operating in the Pacific trade. The design of the shore power system for Husky Terminal has been completed and construction is currently scheduled to get underway towards the end of 2021. Funding support has already been provided by the EPA's Diesel Emission Reduction Act (DERA) program, the Washington State Volkswagen Settlement, and the TransAlta Centralia Coal Transition Grant Program.

Terminal 18 Shore Power:
Total cost: $27.7M
NWSA funds: $5.9M [21%]
State funds: $2.0M [7%]
Other external funds sought: $16M [50%]

This project would bring shore power to the NWSA's highest volume container terminal. We are advancing design for the project so that it will be ready to build when funding is secured. Of all our container terminals, bringing shore power to T-18 would have the largest emissions reduction impact for both air pollutants and GHG given its substantial vessel volumes. It will also be one of the more expensive terminals to electrify, which presents an obstacle to prompt implementation. A $2 million grant has been secured for this project from the Washington State Department of Ecology. We will be seeking additional funding through the large federal infrastructure grant programs and new funding opportunities that may emerge from recent legislative actions.

Tacoma Shore Power Installations
Total cost: $24.5M - $55.4M
Port funds: $4.9M - $11M [20%]
Other external funds sought: $19.6M - $44.4M

Through the Northwest Ports Clean Air Strategy, the NWSA has a goal to install shore power at its major international container terminals by 2030. This will require two additional installations in the Tacoma Harbor, at Washington United Terminal and Pierce County Terminal. The range of costs estimated above includes both projects. While these projects are early in the planning stages, the NWSA will be working on securing external funding to support them in the coming years. These projects are not included in section 6.3, as they are not yet in the NWSA's five-year capital improvement program.

RFID for Clean Truck Rule Enforcement at Domestic Terminals:
Total cost: $750k
Port funds: $375k [50%]
External funds sought: $375k [50%]

This project would install RFID technology at the TOTE and West Sitcum Terminals, which allows detailed truck registration information to be read by terminal gate guards and for data to be synced with the eModal terminal management platform. This would allow us to enforce our clean truck requirement at our major domestic terminals, which requires trucks entering our international container terminals to meet engine year 2007 emission standards. In addition to supporting enforcement of our clean truck requirement, use of the eModal platform would allow for more efficient traffic flow through terminal gates, and the potential for the terminal operator to implement an appointment system. This project has been on hold due to lack of funding and could be initiated within 1-2 years if external funding were awarded.

Seattle Harbor Zero and Near Zero-emission Cargo Handling Equipment Demonstration:
Total cost: $14.8M
Port funds: $1.2M [50% of infrastructure costs]
Marine terminal operator funds: $3.1M [25% of equipment costs]
Other external funds sought: $10.5M [72%]

Demonstrating zero-emission cargo handling equipment is a critical step towards broad adoption throughout our gateway; demonstrating that the technology works for our duty cycles in our climate. In addition to demonstrating zero-emission technology, hybrid technologies for rubber-tired gantry cranes can reduce fuel consumption up to 85% while demonstrating the efficacy of hybrid systems. Given that zero-emission equipment is at least 2-3 times more expensive than diesel and necessitates expensive infrastructure upgrades, offsetting these incremental costs and buying down the risk of piloting new technology is critical to making these demonstrations happen.

While the actual details of the project may change based on the advancement of zero-emission technologies and tenant needs, we have scoped a hypothetical potential project based on the current state of technology and existing fleets. This project would purchase and implement 10 battery electric terminal tractors and associated charging infrastructure, retrofit two rubber-tired gantry cranes with hybrid equipment, and purchase four new hybrid rubber-tired gantry cranes. This equipment would be owned by a private marine terminal operator and put into service at a major international container terminal in Seattle. The port would help fund and manage the infrastructure installation and the terminal operator would purchase the equipment with external funding support.

Tacoma Harbor Zero-emission Cargo Handling Equipment Demonstration:
Total cost: $17.2M
Port funds: $3.3M [25% of equipment costs for straddle carriers and 50% of infrastructure costs]
Marine terminal operator funds: $1.9M [25% of equipment costs for top handlers and terminal tractors]
Other external funds sought: $12.0M [72%]

While the actual details of the project may change based on the advancement of zero-emission technologies and tenant needs, we have scoped a hypothetical project based on the current state of technology and existing fleets. The Tacoma Harbor presents a unique opportunity for a cargo-handling equipment demonstration, as the Port of Tacoma and Northwest Seaport Alliance own and operate a fleet of straddle carriers themselves. Zero-emission straddle carriers have not been broadly demonstrated, presenting an impactful leadership opportunity. The Tacoma Harbor Demonstration would include purchasing two electric straddle carriers to be owned by the NWSA and supporting marine terminal operators to purchase and demonstrate 10 electric terminal tractors and 2 electric top handlers. We would support infrastructure installation for the equipment purchased by the marine terminal operators. External funding will be critical to making these demonstrations happen, offsetting incremental cost and mitigating risk.

Zero-emission Drayage Truck Demonstration:
Total cost: $8.4M
Port funds: $420k [5%]
Trucking company funds: $1.7M [20%]
Other external funds sought: $6.3M [75%]

Demonstrating zero-emission truck technology in the Pacific Northwest is on the critical path to getting the entire fleet to zero-emissions by 2050. Because the port does not own or operate drayage trucks, this technology demonstration will need to be a collaboration between the port, a trucking company, and a truck manufacturer. The demonstration project scope here is for 10 units but can be scaled up or down based on trucking company and manufacturer interests. Since the private trucking company we would partner with will own the trucks, they would be responsible for providing the majority of match funding, with the port providing a relatively small motivating contribution and technical support.

Zero-emission Truck Collaborative:
Total cost: $500k
Port funds: $40k [8%]

Local/State/Regional partner funds: $210k [42%]
Other external funds sought: $250k [50%]

Because port trucking is a relatively small segment of a broader trucking industry, our success in transitioning port trucking to zero-emissions will be contingent on the broader industry also moving in that direction. Specifically, robust state-wide, and ideally west coast wide, charging and hydrogen fueling networks will need to be developed to support zero-emission trucking. This challenge is much bigger than the ports. Collaboration across local, regional, and state government agencies, industry groups, utilities, and more will be needed to make this a reality. Currently, planning and deployment efforts for heavy-duty zero-emission vehicles are fragmented and may not be fully considering all segments of the trucking community. We believe that creating a collaborative group to bring the critical Washington State stakeholders together to create a unified plan for developing this infrastructure, working jointly on technology demonstrations, and sharing information would accelerate and increase the efficiency of the transition to zero-emissions. Funding for this collaborative would help cover consulting costs to convene and support the collaborative for its first two years, matched jointly by the participants.

Diesel Truck Scrap and Replace Program:
Total cost: $930k
Port funds: $20k
City of Seattle Funds: $110 [12%]
Other external funds: $800k [88%]

Removing pre-2007 diesel trucks from the fleet serving our gateway is a critical action in this Implementation Plan for reducing diesel particulate matter emissions. Our Scrap and Replace program provides scrap bonuses to owners of these older trucks to scrap their pre-2007 trucks and purchase a 2012 or newer truck. The scrap bonuses are sourced from grant funds - we used a Washington State Department of Ecology grant to scrap 6 trucks in early 2021. We currently have $110k in grant funding from the City of Seattle to scrap approximately 12 more trucks. The NWSA's main contribution to this program is staffing to support this program, which we estimate is about 50% of a full-time employee. In addition, we have been awarded a DERA grant in 2021 for $720k to add to the bonus pool which would allow us to scrap 36 more trucks.

Lighting and Building Energy Efficiency Projects:
Total cost: $3.0M
Port funds: $750k [25%]
Tenant funds: $750k [25%]
Other external funds: $1500k [50%]

Improving the energy efficiency of our facilities is also a critical component of our strategy to reduce environmental impacts by reducing emissions associated with energy usage and by reducing existing demand on the grid. The $3 million estimate reflects the approximate costs of three terminal lighting upgrades. The NWSA and tenant actual contributions would need to be scaled based on the distribution of resulting cost savings.

Acronyms:

3PL	Third Party Logistics
CHE	Cargo-Handling Equipment
DERA	Diesel Emission Reduction Act
DOE	Department of Energy
DOT	Department of Transportation
DPF	Diesel Particulate Filter
DPM	Diesel Particulate Matter
EPA	Environmental Protection Agency
GHG	Greenhouse Gas
hp	Horsepower
HVAC	Heating, Ventilation and Air Conditioning
IAPH	International Association of Ports and Harbors
ICCT	International Council for Clean Transportation
IMO	International Maritime Organization
IPCC	Intergovernmental Panel on Climate Change
LCFS	Low Carbon Fuel Standard
LED	Light Emitting Diode
NGO	Non-Governmental Organization
NO_x	Nitrogen Oxide
NWPCAS	Northwest Ports Clean Air Strategy
NWSA	Northwest Seaport Alliance
OCR	Optical Character Recognition
OGV	Ocean-Going Vessel
$PM_{2.5}$	Particulate Matter 2.5 microns or less in diameter
PNNL	Pacific Northwest National Laboratory
PNW	Pacific Northwest
PoS	Port of Seattle
PoT	Port of Tacoma
PSEI	Puget Sound Maritime Emissions Inventory
RFID	Radio Frequency Identification
RTG	Rubber Tired Gantry
VFPA	Vancouver Fraser Port Authority
WSU	Washington State University
ZE	Zero-emissions

Glossary:

Air Pollutants:
Natural and man-made substances in the air we breathe that negatively impact human or environmental health. In the 2020 NWPCAS, air pollutants include particulate matter (PM), ozone-forming pollutants (nitrogen oxides (NOx) and volatile organic compounds (VOC)), sulfur oxides (SOx), and carbon monoxide (CO).

Greenhouse gases (GHGs):
Gases that trap heat in the atmosphere. GHGs included in port inventories are carbon dioxide (CO2), methane (CH4) and nitrous oxide (N2O). Emissions are reported using carbon dioxide equivalent units (CO2e).

Lifecycle emissions:
Emissions that result from the extraction, processing, and transport of the fuel or technology prior to its final use, in addition to those that are emitted at the tailpipe.

Particulate matter:
A mix of solid particles and liquid droplets found in the air, e.g., dust, soot or smoke. Fine particulate matter ($PM_{2.5}$) measures 2.5 micrometers and smaller. Coarse particulate matter (PM_{10}) measures 10 micrometers and smaller. Diesel particulate matter (DPM) is particulate matter that results from burning diesel fuel.

Sector:
Six groupings that are also used in port emission inventories to estimate emissions by source, including: ocean-going vessels, harbor vessels, cargo-handling equipment, trucks, rail, and port administration and tenant facilities.

Supply chain:
The network involved in producing and transporting a product to a consumer.

Tailpipe emissions:
Chemicals released as a result of burning a fuel to operate an engine (e.g., gasoline, diesel, biofuels). Electric and hydrogen fueled engines have zero tailpipe emissions.

Zero-emission:
For this strategy, use of technologies and fuels that result in no tailpipe emissions, recognizing that emissions may still occur when looking at the full lifecycle.

Appendix 1: WSU Air Modeling Study Technical Report

Air Quality Impacts of Port Activities in Puget Sound: the PORTS PROJECT

Mahshid Etesamifard, Joseph K Vaughan and Brian Lamb
Laboratory for Atmospheric Research
Washington State University

Executive Summary:

The overarching goal of the PORTS study was to better understand the relative $PM_{2.5}$ impacts of the major sources of port-related air pollution in the Puget Sound Airshed. The study leverages the Air Indicator Report for Public Access and Community Tracking v.5 (AIRPACT-5) regional air quality forecasting model to spatially allocate $PM_{2.5}$ emissions associated with port-related sources, estimate resulting concentrations, and estimate population exposure by correlating the modeled concentrations with population data. The AIRPACT-5 model is regularly used by state and local agencies to make air quality management decisions.

The PORTS study used a finely resolved version of the AIRPACT-5 air-quality modeling framework, which uses the Community Multi-Scale Model for Air Quality (CMAQ), version 5.2, to simulate the atmospheric chemistry and physics of air pollution. This special version of AIRPACT-5's study domain covered the Puget Sound and surrounding areas, as shown in Figure 1. The model incorporated updated port emissions provided by several agencies. To estimate concentration contributions from each port-related source, simulations were completed for a base case representing all emissions and for 'knock-out' cases where each port-related emissions category was zeroed out. Comparisons using the results from the base case and 'knock-out' cases allow for the attribution of air pollution to specific categories of seaport activities and supports creation of a human exposure metric for the various seaport emission sources. Four calendar months (January, April, July, and October) were modeled, for each of the base and 'knock-out'

cases, to capture seasonal differences in meteorology and emissions. Annual averages were constructed using the pro-rated seasonal averages.

The outcomes of the modeling study included a summary of estimated spatially allocated emissions across the airshed, modeled air pollutant concentration contributions that result from these emissions, including annual and seasonal averages, and computed population exposure to particulate matter from ocean going vessels (OGVs, including both cargo and cruise ships), trucks, cargo handling equipment (CHE), and locomotives. Map graphics showing annual average emissions, annual average concentration contributions, and population exposure to these concentrations are provided in section 3.

In addition to generating graphical representations of spatial distributions of the emissions, concentration contributions, and population exposures, an analysis was also performed to estimate the total values of population exposure to $PM_{2.5}$ from port-related sources across the airshed and also to normalize the estimated exposure to the modeled emissions for each source. This analysis is summarized below in **Error! Reference source not found.** and produced two metrics for assessing the impacts of each port-related sources; total population exposure across the airshed and exposure per emission source. It should be noted that these metrics were created for the purpose of comparing the sources modeled to one another, not to other sources (port or non-port) that weren't separately modeled. For ease of interpretation, these metrics have been normalized to the highest value of the four sources, allowing quick comparison of the relative magnitude of the metric for each source. The total exposure provides insight into the total contribution of each port-related source across the airshed (accounting for population distribution). The exposure per emission metric is an approximation of the exposure benefit that would be realized by reducing emissions by 1 ton in each sector. A high exposure per emission suggests that emission reductions in that sector would have a relatively high impact. This metric is limited for sectors like OGVs and locomotives where the emissions and exposure cover multiple operational modes (i.e. transiting and hoteling for OGVs), but helps formulate conclusions when combined with the total exposure and map graphics.

The largest contributor to population exposure is OGVs. Qualitative assessment of the concentration "heat maps" (provided in the appendix) indicate that the majority of these impacts occur near the port areas, which suggests that control measures for vessels at berth, like providing shore power, are the best strategies for reducing these impacts. Additionally, the low exposure per emission metric, along with qualitative assessment of the exposure graphic suggests that reducing OGV transiting emissions is less impactful than reducing emissions from other sources, given where the population exposure occurs.

Trucks are the next highest on the list for population impacts. In addition, trucks are virtually tied with CHE for the highest exposure per emission, suggesting that reducing emissions from trucks is high impact as well.

While CHE rank last in the total exposure metric, they rank second highest in exposure per emission, closely behind trucks, indicating that their proximity to populations makes them a high impact target for emission reduction efforts.

The locomotive results indicate that locomotives rank low in both the total exposure and exposure per emission metrics. These metrics and qualitative assessment of the locomotive exposure map graphic suggest that line-haul locomotive emissions are lower impact than the other sources, presumably because a significant portion of their operations within the airshed occur away from urban centers. Based on the fact that switching locomotive activity is roughly co-located with CHE and vessels at berth, it is likely that reducing those emissions would be impactful, but the limitations of this analysis prevent quantitative analysis of switching locomotives separately.

Table 1. Summary of Study Results

	Total Exposure Ranking Metric	**Exposure/Emission Ranking Metric**
OGV	1.00	0.21
Trucks	0.78	1.00
Locomotives	0.32	0.47
CHE	0.29	0.98

The results of this study suggest that controlling emissions from OGVs at berth, trucks, and CHE are the most impactful means of reducing the population impacts of $PM_{2.5}$ from port-related sources. This conclusion considers total population exposure, exposure normalized to emissions, and qualitative assessment of the concentration and exposure graphics. It is important to note that exposure to $PM_{2.5}$ is one of many factors that need to be considered when the ports consider emission reduction measures. Some of the other factors include: GHG emissions (for which location does not matter), technical feasibility, cost, the ports' level of influence, and the ports' commercial strategy and goals.

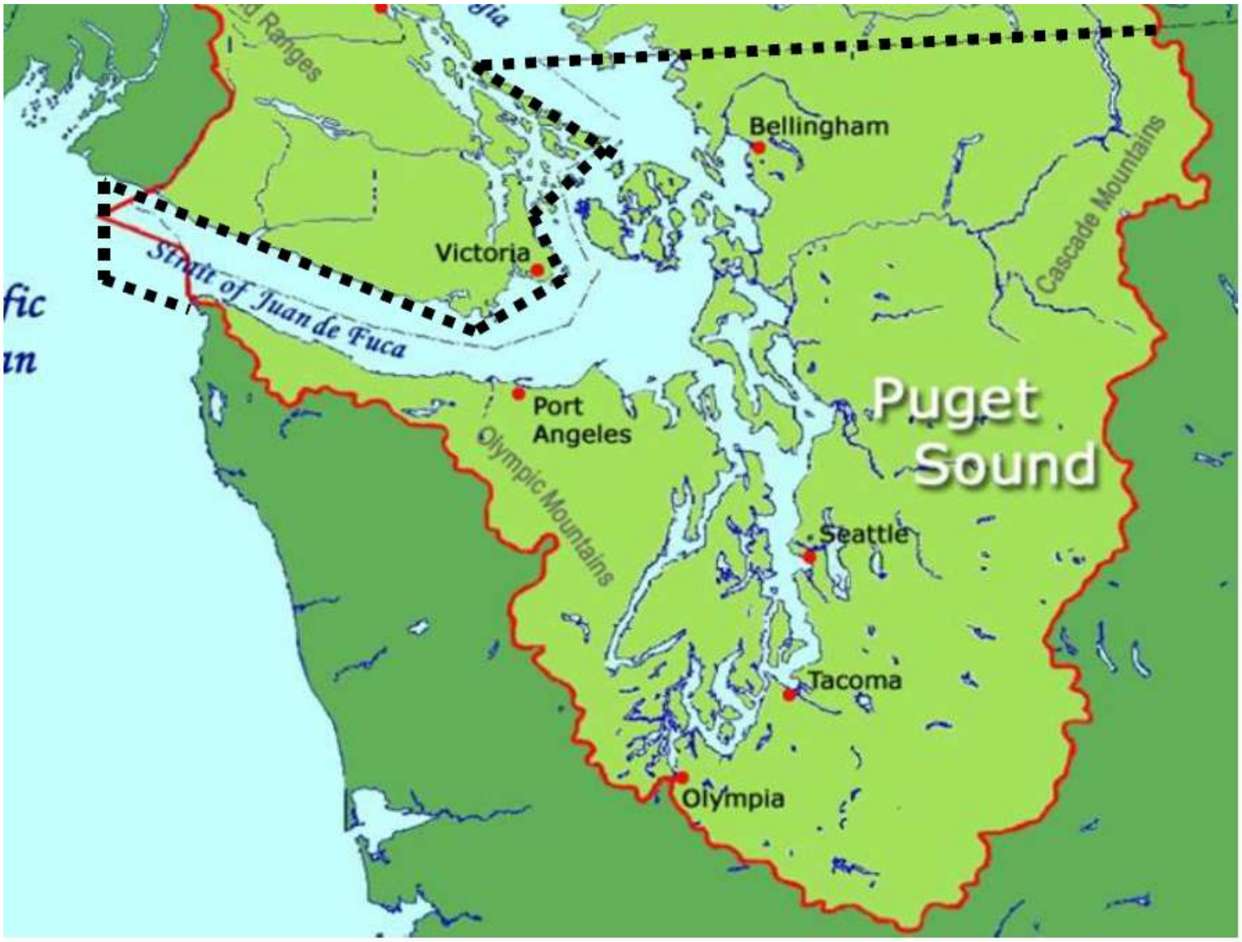

Figure 1. Puget Sound and surrounding areas covered by the high-resolution Ports domain.

1. Background and Motivation

1.1. Motivation

The Northwest Ports Clean Air Strategy (NWPCAS)[58] is being renewed, setting out a goal to phase out port-related emissions by 2050. The NWPCAS is a collaborative strategy between the Northwest Seaport Alliance (NWSA), Port of Tacoma, Port of Seattle, and the Port of Vancouver B.C. to address air and climate pollution in the shared Georgia Strait – Puget Sound airshed. The NWPCAS lays out a common framework for the ports' action on air quality and climate in order to advance action by the ports and create a level playing field between them. In addition to the update of the NWPCAS, the NWSA is developing a detailed implementation plan that will summarize near-term actions to reduce emissions. Emissions have been used in the past as the primary metric to consider human exposure to air pollution resulting from port activities. However, these emission estimates historically have not been finely spatially resolved, nor have the locations and intensities of port related emissions been quantitatively correlated with population densities. This study seeks to increase the understanding of the fate of port-related air pollution from each source to add additional context to how the NWSA considers prioritizing emission reduction actions in its NWPCAS Implementation Plan.

1.2. Scope

Port-related emissions, for purposes of this research, refer specifically to those emissions resulting from goods movement activities tied to port facilities. Specifically, these sources include Ocean Going Vessels (OGVs), Cargo Handling Equipment (CHE), and Locomotive and heavy-duty Truck operations connected to cargo handling within the geographic scope of the study (see Figure 1). Canadian port emissions are not included as part of this study.

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[58] Northwest Ports Clean Air Strategy | Northwest Seaport - Port of Tacoma (nwseaportalliance.com)

OGVs constitute one of the largest emission source types in the Ports domain. These large area emission sources carry cargo through the open ocean approaches via the Strait of Juan de Fuca, and the Strait of Georgia, and transit through the Puget Sound to ports where the ships maneuver and hotel. CHE is used to move containers and general and bulk cargo between ships and port terminals. CHE emissions have been incorporated into the model as point sources at the locations of the major terminals in Tacoma and Seattle. Switching locomotives and Line haul locomotives are non-road emission sources which sort rail cars on marine terminals and carry cargo on the rail network across the Puget Sound Airshed, respectively. Heavy duty on-road vehicles, including trucks used for carrying cargo are defined as mobile sources in the emission inventory. These sources are major port-related emission mobile sources covering major highways on the east side of Puget sound.

1.3. Study Objectives

- Determining each port-related source category's relative contribution to $PM_{2.5}$ concentrations in the Puget Sound Airshed.
- Better understand how $PM_{2.5}$ concentrations resulting from each port-related source affect population air pollution exposure.

1.4. Funding

The Northwest Seaport Alliance (NWSA) has funded this work through *Interlocal Agreement 071089, For Air Quality Modeling Study, By and Between The Northwest Seaport Alliance and Washington State University.*

2. Methods

This section summarizes the methods employed to conduct the study and meet the study objectives defined above. More detailed descriptions of the methods can be found below.

2.1. Process summary

- Adapted AIRPACT-5 emission inventory to create Ports inputs:
    - This was done using the Sparse Matrix Operator Kernel Emissions (SMOKE) emissions processing system.
    - Updated the existing OGV inventory based on data provided by Washington State Department of Ecology (WSDOE), from the 2016 Puget Sound Maritime Air Emissions Inventory (PSEI).
    - Updated CHE emission inventory. The existing CHE emission inventory was a point source defined in one location for each FIPS code. For more accuracy, NWSA provided total emission values for multiple locations in the ports of Tacoma and Seattle. To calculate the detailed emission values of each Source Classification Codes (SCC) within each port, two sets of constrained linear least-squares solutions corresponding to King and Pierce counties were found using MATLAB. More details are provided in Appendix A.

- Updated the AIRPACT-5 CMAQ model to take advantage of recent improvements in the model. Ports air quality simulations reported here were generated using CMAQv5.2.

- Operated the AIRPACT-5 4-km framework to generate a base case to provide initial and boundary conditions (ICON, BCON) for a Ports domain on a high-resolution 1.33-km mesh grid. This grid used horizontal spacing of 1.33 km in both North-South and East-West directions, with 37 atmospheric layers of varying thickness, increasing with altitude. The 1.33-km grid has 219 columns from West to East, and 141 rows, from South to North.

- Created a Ports framework of scripts for executing CMAQ simulations on the 1.33-km grid.

- Simulated the base case, using the Ports framework and Ports domain, wherein all port emission sources were included, along with other non-port emissions. The base case was simulated for four months of 2018 (January, April, July and October) to capture the four seasons of the year, and used ICON and BCON derived from the 4-km base case.

- Created scaling factors to apply to the SCCs corresponding to the emission categories which are not solely port-related sources in order to calculate their contribution in emissions (trucks and locomotives).

- Conducted four more simulation cases, using the Ports framework, using emissions created by zeroing out one port-related emission source category for each 'knock-out' case. The four categories are OGVs, CHE, locomotives, and trucks. For each 'knock-out' case air quality was simulated for four months of 2018 (January, April, July and October).

- Used the 'brute force' method to calculate estimates of the contribution of each port-related pollution source on Puget Sound Airshed over four months of 2018 (January, April, July and October), representing the four seasons of the year. This approach of computing CMAQ results with varying emissions allows attribution of pollution contribution to categories. This is done by subtracting the 'knock-out' cases' pollutant concentrations from the base case concentrations. This is called a 'brute force' method, in contrast to other approaches.

- Processed model results from base case and 'knock-out' results:
    - Determined $PM_{2.5}$ monthly average concentrations for each source type.
    - Generated contour maps illustrating the monthly average concentration distribution for each source type.
    - Estimated annual average concentrations for each source type.
    - Generated gridded concentration data in appropriate format for use in BenMAP model that assesses population exposure impacts.
    - Calculated the product of $PM_{2.5}$ concentration and the population, using 2010 Census data, in each grid cell to determine the exposure of the population to $PM_{2.5}$.
    - Generated contour maps to visualize the spatial distribution of $PM_{2.5}$ population exposure impacts related to each port-related source category.

2.2. Summary of the AIRPACT-5 Model and Ports framework

In this study a high-resolution modeling framework called Ports was derived from the Air Indicator Report for Public Access and Community Tracking v.5 (AIRPACT-5) framework[59]. AIRPACT-5 is a numerical air quality forecasting system for the Pacific Northwest which reports a two-day forecast of hourly, gridded air pollution to the public via the website. Industrial, transportation, residential, vegetation, agriculture and fire sources of emissions are incorporated into the AIRPACT-5 framework to deliver estimates of ozone, particulates, toxics and acid

[59] AIRPACT-5 | Dynamic Map (wsu.edu)

deposition using a domain with 37 vertical layers and a horizontal grid of 4 km by 4 km cells, covering Idaho, Oregon, Washington, and peripheral areas. The Ports framework was created for applying CMAQ version 5.2[60] on a higher resolution domain covering the Puget Sound (Figure 1). Ports was used to assess pollutant contributions from four major port-related emission sources. Concentrations were simulated for the Puget Sound Region on a domain using 1.33 by 1.33 km grid cells, centered on the Puget Sound airshed, arranged in 219 columns, from West to East, and 141 rows, from South to North. These simulations were conducted for a representative month from each season to efficiently represent a full year to estimate annual averages of air pollution contributions for each source type. Emissions from the sources in Table 2 were included in the study.

Table 2. Port-related emissions categories addressed in the Ports study.

Emission Source	Descriptions
Ocean going vessels (OGVs)	Large vessels that carry cargo across open ocean, including auto carriers, bulk carriers, containerships, general cargo vessels, passenger cruise vessels, refrigerated vessels (reefers), and roll-on/roll-off (Ro-Ro) vessels.
Cargo handling equipment (CHE)	Non-road equipment used to move cargo (containers, general cargo, and bulk cargo). Examples of cargo handling equipment include: forklifts, yard trucks, rubber-tired gantry cranes, and straddle carriers.
Locomotives	Switching locomotives, used to sort rail cars on marine terminals and related intermodal yards, and line-haul locomotives, used for transporting cargo trains to their destination on the rail network.
Heavy duty on-road vehicles	Trucks used to transport port-related cargo.

[60] Incremental Evaluation of CMAQv5.2 | US EPA

2.3. Emission inputs for port-related sources

The existing AIRPACT-5 emission inventory was based on the 2011 NEI[61]. For this project, Washington State University (WSU), WSDOE, and the NWSA cooperated to update the emissions inventory to include new vessel emissions from the 2016 Puget Sound Maritime Air Emissions Inventory (PSEI)[62]. The OGVs and CHE sources are all solely port-related sources. Therefore, in order to calculate these sources' contributions to the region using the 'brute force' method, all the pollutants corresponding to each of these source categories were simply zeroed out in the 'knock out case' model runs to create versions of the emission inventory representing conditions without those sources. On the other hand, locomotives and heavy-duty trucks are not easily broken out into port activities and non-port activities in the emission inventory, so ports emission contributions had to be calculated by applying scaling factors to the existing source classifications in the 'knock out cases'. The emissions data used to create the 'knock out cases' was sourced from the PSEI. Contributions from each of the sources was determined by subtracting the 'knock out case' model results from 'base case' model results, which includes all emissions. In the following sections we will review the details of updates applied to each source's emission inventory in addition to the methods we used for each emission source knock-out process.

2.4. Ocean going vessels

Some of the OGV SCCs in the existing emission inventory were related to residual fuel oil use, however the Sulfur Emissions Control Area (SECA) sulfur limits began in 2015 and have since led to a significant decrease in sulfur emissions from OGVs. Therefore, we updated the

[61] National Emissions Inventory (NEI) | US EPA
[62] 2016 Puget Sound Maritime Air Emissions Inventory – Puget Sound Maritime Air Forum

marine vessels emission inventory using the 2016 PSEI which accounts for this change. The updated marine vessel emission inventory attributes lower sulfur emissions to the OGVs and chooses diesel fuel SCCs for all the OGV SCCs. As shown in Table 3, the old OGV SCCs were replaced by the new SCCs, and the last two SCCs, which were associated with vessels using high sulfur residual fuel oil, were eliminated from the updated OGV emission inventory.

Table 3. Ocean going vessels updated SCCs

Old SCC	Desc.	New SCC	Desc.
2280002100	Mobile Sources - Marine Vessels, Commercial - Diesel - Port emissions	2280002104	Diesel, Port, C3 Auxiliary Engine. This SCC is used for all PSEI OGV Port emissions – maneuvering and hoteling
2280002200	Mobile Sources-Marine Vessels, Commercial - Diesel - Underway emissions	2280002203	Diesel, off-Port, C3 Main Engine. This SCC is used for all PSEI OGV off-Port emissions – maneuvering and underway
2280003100	Mobile Sources - Marine Vessels, Commercial - Residual - Port emissions	NONE	Removed because use of high sulfur residual oil as fuel is now prohibited in the SECA area.
2280003200	Mobile Sources - Marine Vessels, Commercial - Residual - Underway emissions	NONE	Removed because use of high sulfur residual oil as fuel is now prohibited in the SECA area.

In order to generate the OGV ‘knock-out’ case, we generated an emission inventory zeroing out emission values corresponding to the new OGV SCCs (2280002104 and 2280002203) and kept everything else the same.

2.5. Cargo handling equipment

As explained in the introduction, CHE emission sources in the Ports domain are point sources assigned to two locations, the Port of Seattle and the Port of Tacoma. Emissions were included for CHE operating at Northwest Seaport Alliance facilities. Table 4 lists the cargo handling equipment SCCs and their description for this source.

Table 4. Cargo handling equipment SCCs

2270003040	Off-highway Diesel /Industrial Equipt /Other General Industrial Equipt
2270002060	Off-highway Diesel /Construction & Mining Equipt /Rubber Tire Loaders
2270003050	Off-highway Diesel /Industrial Equipt /Other Material Handlling Equipt
2270003070	Off-highway Diesel /Industrial Equipt /Terminal Tractors
2265006005	Off-highway Gasoline, 4-Stroke /Commercial Equipt /Generator Sets
2267003020	Off-highway LPG /Industrial Equipt /Forklifts
2270002027	Off-highway Diesel /Construction & Mining Equipt /Signal Boards/Light Plants
2270002045	Off-highway Diesel /Construction & Mining Equipt /Cranes
2270002066	Off-highway Diesel /Construction & Mining Equipt /Tractors/Loaders/Backhoes
2270002075	Off-highway Diesel /Construction & Mining Equipt /Off-highway Tractors
2270003010	Off-highway Diesel /Industrial Equipt /Aerial Lifts
2270003020	Off-highway Diesel /Industrial Equipt /Forklifts
2270003030	Off-highway Diesel /Industrial Equipt /Sweepers/Scrubbers
2270006005	Off-highway Diesel /Commercial Equipt /Generator Sets
2265003010	Off-highway Gasoline, 4-Stroke /Industrial Equipt /Aerial Lifts
2265003070	Off-highway Gasoline, 4-Stroke /Industrial Equipt /Terminal Tractors
2265006015	Off-highway Gasoline, 4-Stroke /Commercial Equipt /Air Compressors
2267003010	Off-highway LPG /Industrial Equipt /Aerial Lifts
2267003030	Off-highway LPG /Industrial Equipt /Sweepers/Scrubbers
2270002051	Off-highway Diesel /Construction & Mining Equipt /Off-highway Trucks
2270006015	Off-highway Diesel /Commercial Equipt /Air Compressors

In order to better represent these sources, we divided these two points, at the Port of Seattle and the Port of Tacoma, into seven and six locations respectively. Data from the PSEI provided the total CHE emission value in each location. The analytical challenge was how the emissions needed to be allocated to each SCC at each location such that they accumulate to the given total emission value in each location. To solve this algebra problem MATLAB was used to calculate the matrix of scaling factors for each location. The details of the method used to calculate the CHE scaling factors are available in Appendix A. In order to generate the CHE 'knock-out' cases, we generated an emissions inventory that simply zeroed out the point sources described in the paragraph above.

2.6. **Locomotives**

Locomotive SCCs are listed in Table 5. Not all of this source's emissions are port-related. Scaling factors are necessary to calculate their contributions to air quality of the region. The scaling factor is the proportion of emissions from each SCC that is port-related.

Table 5. Locomotive SCCs

2285002006	Mobile Sources- Railroad Equipment- Diesel- Line Haul Locomotives: Class I Operations
2285002007	Mobile Sources- Railroad Equipment- Diesel- Line Haul Locomotives: Class II / III Operations
2285002010	Mobile Sources- Railroad Equipment- Diesel- Yard Locomotives

In order to calculate the locomotives contribution scaling factors, we calculated the ratio of the port-related locomotive emissions from the PSEI over total locomotive emissions and used it in Equation 1 to calculate the value of the locomotive emissions after knocking out port-related emission values. In other words, the 'knock-out' runs used emissions equal to the base case emissions multiplied by the scaling factor so that the port-related locomotive contributions were equal to the base case emissions minus the ‘knock-out’ case emissions.

Equation 1. zeroing out port-related locomotive emissions.

$$\text{Locomotive emissions for each SCC after zeroing out port-related locomotive emissions} = \text{Locomotive emissions for each SCC} * \left(1 - \frac{\text{port-related locomotive emissions}}{\text{total locomotive emissions}}\right)$$

2.7. Trucks

Heavy duty on-road vehicle SCCs are listed in Table 6. Just like locomotives, not all truck emissions are port-related. In fact, port-related truck emissions represent a small fraction of truck emissions regionally. To estimate the spatially allocated port-related truck emissions for the ‘knock-out' runs scaling factors were applied to the existing SCCs for combination short haul trucks summarized in the table below.

Table 6. Heavy duty on-road vehicles SCCs

2230074230	Mobile Sources - Highway Vehicles - Diesel - Heavy Duty Diesel Vehicles (HDDV) Class 8A & 8B - Urban Interstate: Total
2230074250	Mobile Sources - Highway Vehicles - Diesel - Heavy Duty Diesel Vehicles (HDDV) Class 8A & 8B - Urban Other Freeways and Expressways: Total
2230074270	Mobile Sources - Highway Vehicles - Diesel - Heavy Duty Diesel Vehicles (HDDV) Class 8A & 8B - Urban Other Principal Arterial: Total
2230074290	Mobile Sources - Highway Vehicles - Diesel - Heavy Duty Diesel Vehicles (HDDV) Class 8A & 8B - Urban Minor Arterial: Total
2230074310	Mobile Sources - Highway Vehicles - Diesel - Heavy Duty Diesel Vehicles (HDDV) Class 8A & 8B - Urban Collector: Total
2230074330	Mobile Sources - Highway Vehicles - Diesel - Heavy Duty Diesel Vehicles (HDDV) Class 8A & 8B - Urban Local: Total

To calculate the trucks' scaling factors, we used the Vehicle Miles Traveled (VMT) values for port-related and total truck activities within the modeling domain. Port-related truck VMT within the Puget Sound Airshed were estimated as part of the 2016 PSEI, based on modeling work done by the Puget Sound Regional Council using their Travel Demand Model[63]. These VMT were assigned to the different SCCs based on the port truck VMT distribution developed as part of the 2011 PSEI[64]. These data also underlie the 2016 PSEI results. For each SCC, the ratio of port-related trucks VMT over total trucks VMT values were used in Equation 1 to calculate the value of the trucks emissions after knocking out port-related emission values. In other words, the knock-out runs used emissions equal to the base case emissions multiplied by the scaling factor and the port-related trucks contributions were equal to the base case emissions minus the knock-out case emissions.

Equation 2. Zeroing out port-related truck emissions.

$$\text{Trucks emissions for each SCC after zeroing out port-related trucks emissions} = \text{Trucks emissions for each SCC} * \left(1- \frac{\text{port}-\textit{related trucks}\ \text{VMT}}{\textit{total trucks emissions VMT}}\right)$$

2.8. Concentration Modeling Process

Once all the inputs were created, we ran the AIRPACT-5 and Ports frameworks to estimate the regional concentrations of the pollutant of interest. In this study we focused on $PM_{2.5}$ results in the surface layer where source attribution is relevant to human exposure. Base case AIRPACT-5

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[63] Activity-Based Travel Model: SoundCast | Puget Sound Regional Council (psrc.org)
[64] Microsoft Word - PV FINAL POT 2011 PSEI Report (7 Oct 12) MASTER scg (wordpress.com)

results using a 4-km grid provided initial and boundary conditions for Ports runs. In order to develop source contribution results we implemented a ‘brute force’ method to characterize concentration response to emissions in the CMAQ photochemical model. For that purpose, we simply reran the model with alternate emissions, knocking out source categories representing different ports activities as shown in Table 2, by either zeroing out the whole source category or using scaling factors as explained in the previous sections.

In this method two base case Ports simulations were conducted with all port source emissions included, one each for the 4-km AIRPACT-5 domain and the 1.33-km Ports domain, for each month being modeled. Then additional individual source sensitivity simulations were completed by withholding (zeroing out) emissions of all species from each source category. The difference in simulated concentrations, between the baseline (base case) and each ‘knock-out’ sensitivity simulation, is attributed to each ‘knock-out’ source category as the pollution contribution of that particular source category.

2.9. Population Exposure Impacts Estimation Process:

The population exposure impacts from each source were estimated using Geographic Information System (GIS) software to correlate 2010 Census population data with the $PM_{2.5}$ concentration data from this study. Through this process, we developed a simple metric for comparing population exposure impacts across the four port-related sources modeled with units of $\mu g\ m^{-3}$ person. The process for developing the metric for each source was to assign census block population data to the Ports 1.33 x 1.33 modeling grid using linear interpolation methods and simply multiply the population in each grid cell by the modeled annual average concentration. The gridded exposure metric data was plotted in map graphics shown in the results section. A total exposure metric was calculated for each source across the airshed, as shown in the results section, to allow for comparison of the population impacts across source categories.

3. Results and Conclusions

The outcomes of the modeling study included an estimation of spatially allocated emissions across the airshed, modeled air pollutant concentration contributions that result from these emissions, including annual and seasonal averages, and estimates of population exposure to particulate matter from OGVs (including both cargo and cruise ships), trucks, CHE, and locomotives. Map graphics showing annual average emissions, annual average concentration contributions, and population exposure to these concentrations are provided below. Further results that summarize the maximum concertation contributions for each source and the contributions by season are shown in the appendix. Overall, the $PM_{2.5}$ concentration contributions within the context of all sources of $PM_{2.5}$ in the region are small on an annually averaged basis; less than a maximum of 6% in any one grid cell for CHE, 0.5% for trucks, less than 3% for locomotives and less than 11% for OGVs. However, this study did not isolate non-port-related sources of diesel PM, of which port-related sources are thought to be a relatively larger contributor. Therefore, the results of the study are best used to compare the relative importance of port-related sources to one another, and not to other sources. Qualitative inspection of the annual average concentration maps reveals that truck and OGV concentration contributions tend to be spread most broadly across the airshed, while CHE and locomotive concentration contributions tend to be concentrated near port terminals and rail lines, respectively.

In addition to graphical representation of the emissions, concentration contributions, and population exposures, an analysis was also performed to summarize the total population exposure to $PM_{2.5}$ from port-related sources across the airshed and also to normalize the total exposure to the modeled emissions for each source. This analysis is summarized below in Table 7 and produced two metrics for assessing the impacts of each port-related sources: total population exposure across the airshed and exposure per emission. It should be noted that these metrics were created for the purpose of comparing the sources modeled to one another, not to other sources (port or non-port) that weren't modeled. The total exposure provides insight into the total impact of each port-related source across the airshed (accounting for population distribution). The exposure per emission metric is an approximation of the exposure benefit that would be realized by reducing emissions by 1 ton in each sector. A high exposure per emission suggests that emission reductions in that sector would have a relatively high impact. This metric is limited for sectors like OGVs and locomotives where the emissions and exposure cover multiple operational modes (i.e., transiting and hoteling for OGVs), but helps formulate conclusions when combined with the total exposure and map graphics.

Relative metrics for each of the two exposure metrics described above were also developed, to more simply represent the relative exposure impacts and exposure/emission for each source. We called these the exposure ranking metrics. These metrics were created by taking the ratio of each total exposure and exposure per emission value to the highest value amongst the 4 sources. For example, for total exposure, a value of 1 would indicate that the source had the highest total exposure metric value of the 4 sources and a value of 0.5 would indicate that the source had a total exposure value that was half of that of the highest source. These simplified metrics are shown below in Table 8.

The results of the study suggest that controlling emissions from OGVs at berth, trucks, and CHE are the most impactful means of reducing the population impacts of $PM_{2.5}$ from port-related sources.

The largest contributor to population exposure is OGVs. Qualitative assessment of the concentration "heat maps" (provided in the appendix) indicate that the majority of these impacts occur near the port areas, which suggests that control measures for vessels at berth, like shore power, are the best strategies for reducing these impacts. Additionally, the low exposure per emission metric, along with qualitative assessment of the exposure graphic suggests that reducing OGV transiting emissions is less impactful than reducing emissions from other sources, given where the population exposure occurs.

Trucks are the next highest on the list for population impacts. In addition, trucks are virtually tied with CHE for the highest exposure per emission, suggesting that reducing emissions from trucks is high impact as well. It is important to note that the emissions inventory data may not include all the projected reductions from the NWSA's recently implemented Clean Truck Program standards[65] (which require that all trucks meet engine model year 2007 emission standards or better), but by normalizing the exposure to emissions we still conclude that truck emission reductions are important based on their proximity to populations.

While CHE rank last in the total exposure metric, they rank second highest in exposure per emission, closely behind trucks, indicating that their proximity to populations makes them a high impact target for emission reduction efforts.

The locomotive results indicate that locomotives rank low in both the total exposure and exposure per emission metrics. These metrics and qualitative assessment of the locomotive exposure map graphic suggest that line-haul locomotive emissions are lower impact than the other sources, presumably because a significant portion of their operations within the airshed occur away

[65] Clean Truck Program | Northwest Seaport - Port of Tacoma (nwseaportalliance.com)

from urban centers. Based on the fact that switching locomotive activity is roughly co-located with CHE and vessels at berth, it is likely that reducing those emissions would be impactful, but the limitations of this analysis prevent quantitative analysis of switching locomotives separately.

There are some important limitations of the analysis that should be noted, specifically:

- The metrics developed were airshed wide, so there may be smaller scale air quality issues that do not conform to the conclusions made here. For example, there may be a community located near a rail line for which efforts to reduce emissions from those locomotives may be more important than the other sources. Individual community concerns will need to be addressed on a case-by-case basis. Isolating smaller geographic areas in the data may allow for more insight.
- The model was only "resolved" to 1.33 km by 1.33 km grid cells. In other words, all of the emissions that occur in each 1.33 km x 1.33 km area are "smeared" across that entire grid cell. This means that emissions and concentration variability on smaller spatial scales will be dampened since they are averaged over larger areas.
- Different operational modes and vehicle/vessel types could not be isolated in WSU's model. For example, the OGV sector includes cruise and cargo ships transiting and at berth and the locomotive sector includes switching and line-haul locomotives. This means that only qualitative analysis was possible for assessment of the importance of the different operational modes.
- Isolation of diesel PM was not possible within the scope and budget of this project, preventing comparisons of port-related diesel PM sources to other regional diesel PM sources.

- Exposure impacts were analyzed on an annual timescale, so effects of different magnitudes that may occur on smaller timescales are not represented.

Table 7. Airshed-wide Population Exposure Results

Source	Emissions (tons/year)	Population Exposure ($\mu g\ m^{-3}$ person)	Exposure/ Emission ($\mu g\ m^{-3}$ person ton^{-1})
OGV	158	50 $x10^3$	3.2 $x10^2$
Trucks	26	39 $x10^3$	15 $x10^2$
Locomotives	23	16 $x10^3$	7.1 $x10^2$
CHE	10	14 $x10^3$	15 $x10^2$

Table 8. Relative Population Exposure Results

	Total Exposure Ranking Metric	Exposure/Emission Ranking Metric
OGV	1.00	0.21
Trucks	0.78	1.00
Locomotives	0.32	0.47
CHE	0.29	0.98

3.1. Map graphics for annual average results

This section contains map graphics that present the annual averaged modeling results. The reader should note that scales are different on many of these maps, so the color bar should be interpreted carefully within the context of the legend (i.e., red on one map may be a lower level of concentration or emission than green on another). Additionally, the map lines are approximate and may omit some geographic features. Graphics in this section are organized by source. Each source's sub-section contains the following graphics.

Emissions contribution: The annual average amount of emissions (in grams per hour) that can be attributed to each source. The maps should be interpreted as visual heat map representations of how emissions are distributed in space, with blue representing lower emissions and yellow/red representing higher emissions.

Concentration contribution: The annual average contribution to ambient $PM_{2.5}$ concentration from each source, presented both in the absolute concentration (µg m^{-3}) and relative to the total concentration (percent, including all sources). The maps should be interpreted as visual heat map representations of how concentration contributions are distributed in space, with blue representing lower concentrations and yellow/red representing higher concentrations.

Population exposure: The annual average simple exposure metric (µg m^{-3} person) for each source. These maps represent the combination of the absolute concentration contribution maps (µg m^{-3}) and population data. The maps should be interpreted as visual heat map representations of how the exposure metric values are distributed in space, with blue representing lower exposure and yellow/red representing higher exposure.

3.2. OGVs

Emission contribution: The annual average amount of emissions (in grams per hour) that can be attributed to OGVs. The map should be interpreted as a visual heat map representation of how emissions are distributed in space, with blue representing lower emissions and yellow/red representing higher emissions.

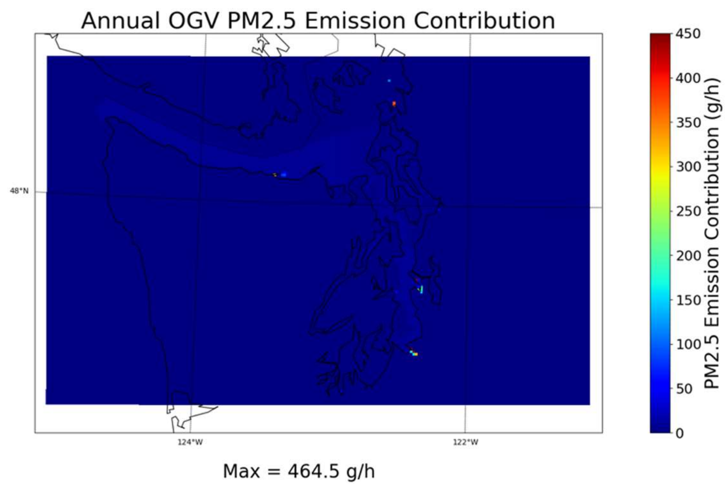


Figure 2. Annual OGV PM2.5 emission contribution

Absolute concentration contribution: The annual average absolute contribution to ambient PM2.5 concentration from OGVs in μg m^{-3}. The map should be interpreted as visual heat map representations of how concentration contributions are distributed in space, with blue representing lower concentrations and yellow/red representing higher concentrations.

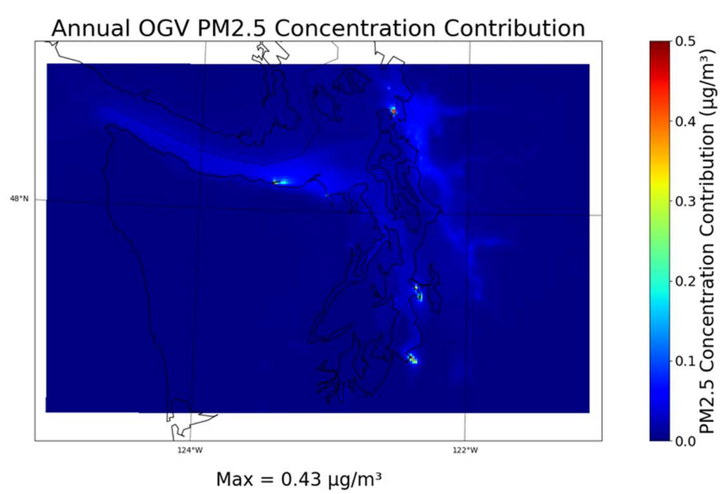


Figure 3. Annual OGV PM2.5 concentration contribution, absolute values

Percent concentration contribution: The annual average percentage contribution to ambient PM2.5 concentration from OGVs (concentration from OGVs divided by total concentration). The map should be interpreted as visual heat map representations of how concentration contributions are distributed in space, with blue representing lower concentration contributions and yellow/red representing higher contributions.

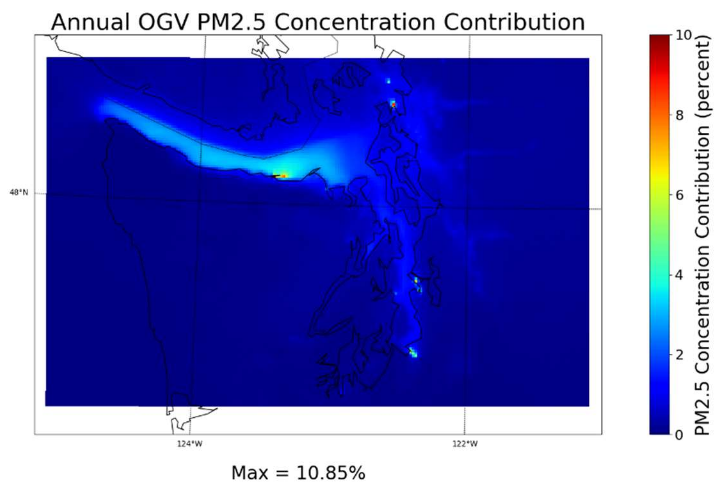


Figure 4. Annual OGV PM2.5 concentration contribution in percentage

Population exposure: The estimated simple exposure metric (µg m^{-3} person) for OGVs. This map represents the combination of the absolute concentration contribution maps (µg m^{-3}) and population data. The maps should be interpreted as visual heat map representations of how the exposure metric values are distributed in space, with blue representing lower exposure and yellow/red representing higher exposure.

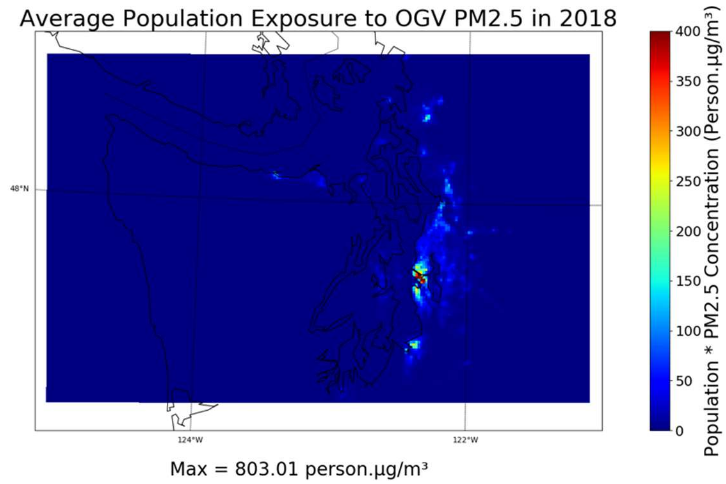


Figure 5. Average population exposure to OGV PM2.5 in 2018

3.3. Trucks:

Emission contribution: The annual average amount of emissions (in grams per hour) that can be attributed to trucks. The map should be interpreted as a visual heat map representation of how emissions are distributed in space, with blue representing lower emissions and yellow/red representing higher emissions.

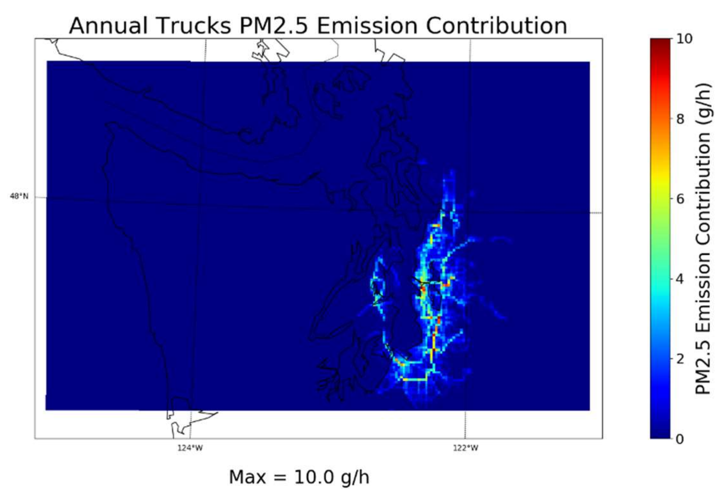


Figure 6. Annual trucks PM2.5 emission contribution

Absolute concentration contribution: The annual average absolute contribution to ambient PM2.5 concentration from trucks in µg m^{-3}. The map should be interpreted as visual heat map representations of how concentration contributions are distributed in space, with blue representing lower concentrations and yellow/red representing higher concentrations.

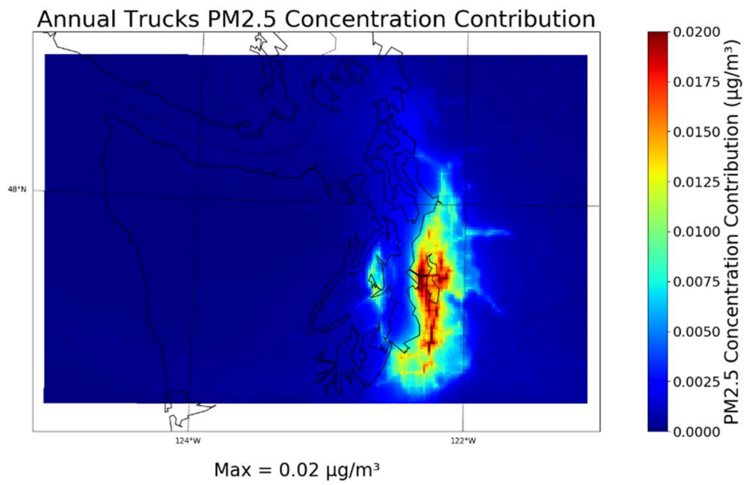


Figure 7. Annual trucks PM2.5 concentration contribution, absolute values

Percent concentration contribution: The annual average percentage contribution to ambient PM2.5 concentration from trucks (concentration from trucks divided by total concentration). The map should be interpreted as visual heat map representations of how concentration contributions are distributed in space, with blue representing lower contributions and yellow/red representing higher contributions.

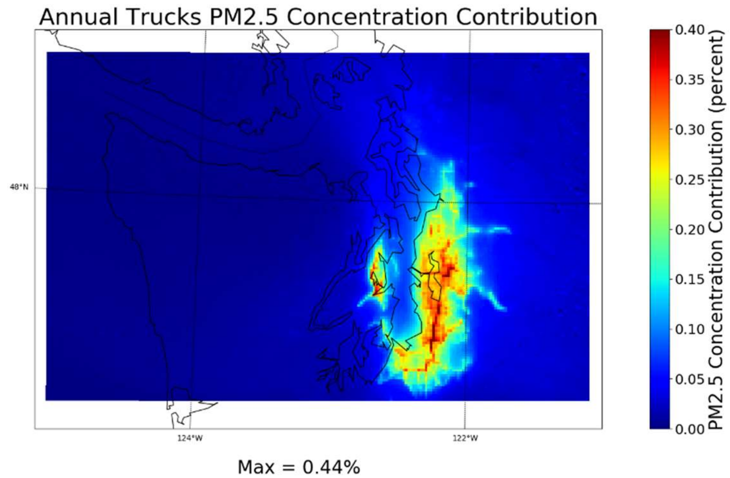


Figure 8. Annual trucks PM2.5 concentration contribution in percentage

Population exposure: The estimated simple exposure metric (µg m^{-3} person) for trucks. This map represents the combination of the absolute concentration contribution maps (µg m^{-3}) and population data. The maps should be interpreted as visual heat map representations of how the exposure metric values are distributed in space, with blue representing lower exposure and yellow/red representing higher exposure.

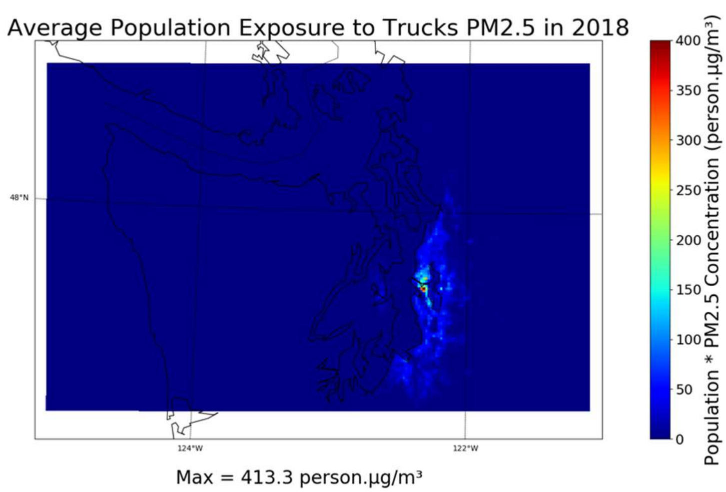


Figure 9. Average population exposure to trucks PM2.5 in 2018

3.4. CHE

Emission contribution: The annual average amount of emissions (in grams per hour) that can be attributed to CHE. The map should be interpreted as a visual heat map representation of how emissions are distributed in space, with blue representing lower emissions and yellow/red representing higher emissions.

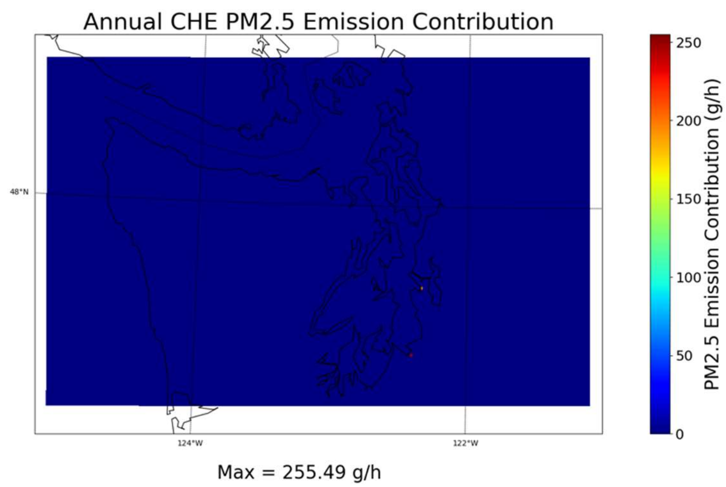


Figure 10. Annual CHE PM2.5 emission contribution

Absolute concentration contribution: The annual average absolute contribution to ambient PM2.5 concentration from CHE in µg m-3. The map should be interpreted as visual heat map representations of how concentration contributions are distributed in space, with blue representing lower concentrations and yellow/red representing higher concentrations.

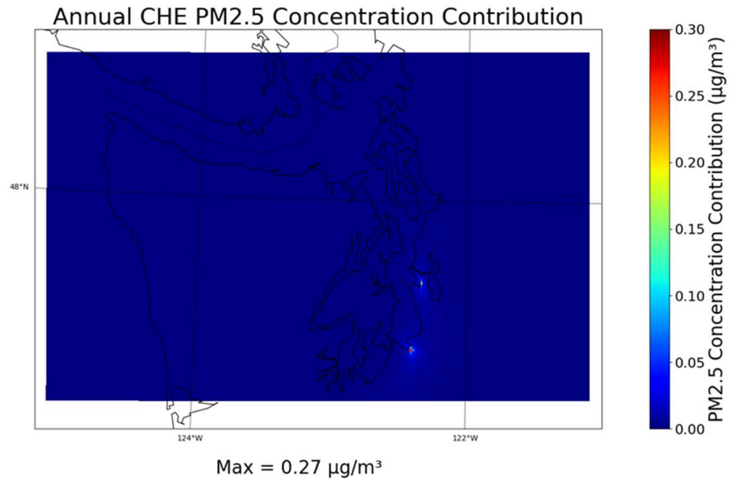


Figure 11. Annual CHE PM2.5 concentration contribution, absolute values

Percent concentration contribution: The annual average percentage contribution to ambient PM2.5 concentration from CHE (concentration from CHE divided by total concentration). The map should be interpreted as visual heat map representations of how concentration contributions are distributed in space, with blue representing lower contributions and yellow/red representing higher contributions.

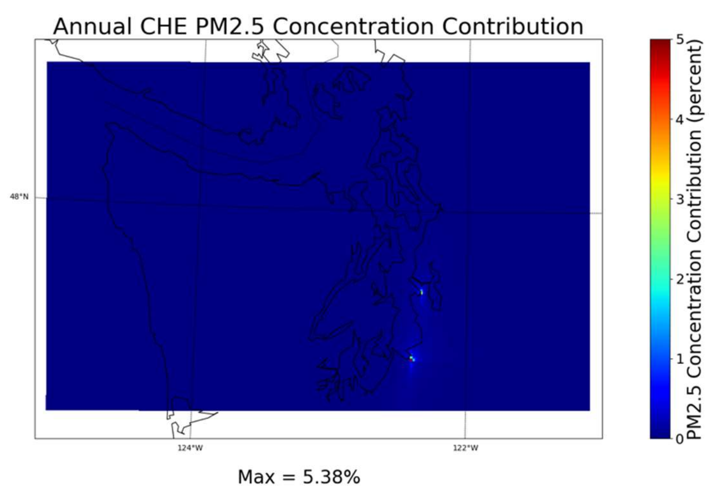


Figure 12. Annual CHE PM2.5 concentration contribution in percentage

Population exposure: The estimated simple exposure metric (µg m^{-3} person) for CHE. This map represents the combination of the absolute concentration contribution maps (µg m^{-3}) and population data. The maps should be interpreted as visual heat map representations of how the exposure metric values are distributed in space, with blue representing lower exposure and yellow/red representing higher exposure.

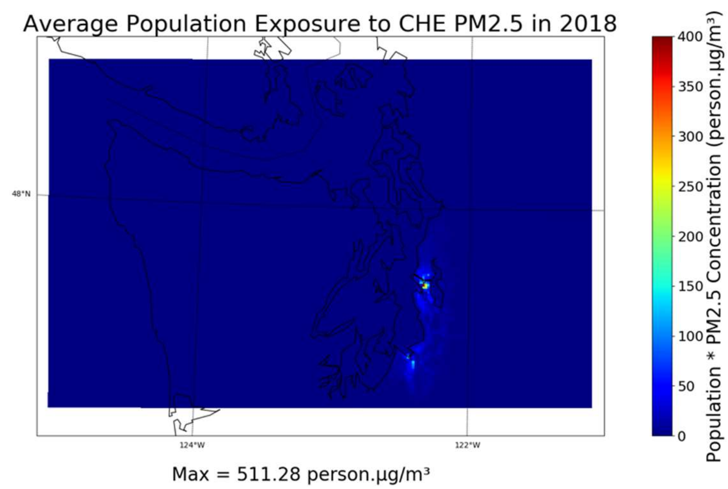


Figure 13. Average population exposure to CHE PM2.5 in 2018

3.5. Locomotives

Emission contribution: The amount of emissions (in grams per hour) that can be attributed to locomotives. The map should be interpreted as a visual heat map representation of how emissions are distributed in space, with blue representing lower emissions and yellow/red representing higher emissions.

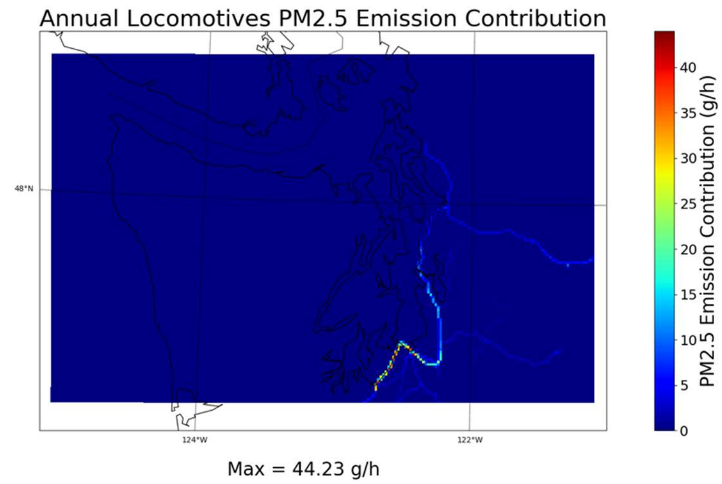


Figure 14. Annual locomotive PM2.5 emission contribution

Absolute concentration contribution: The annual average absolute contribution to ambient PM2.5 concentration from OGVs in µg m^{-3}. The map should be interpreted as visual heat map representations of how concentration contributions are distributed in space, with blue representing lower concentrations and yellow/red representing higher concentrations.

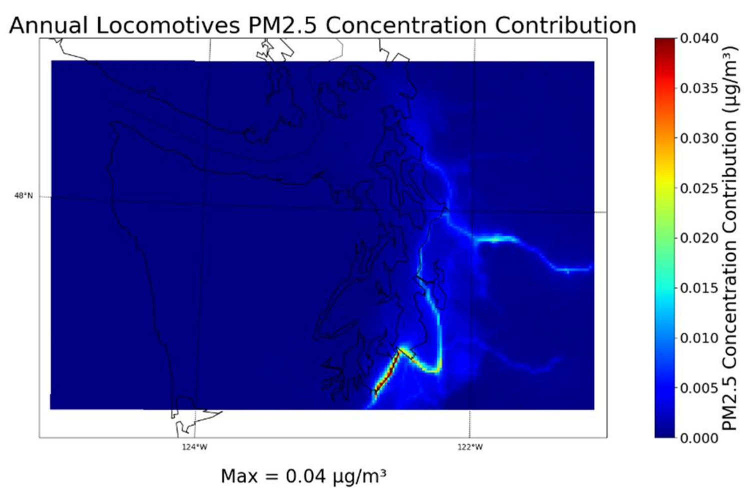


Figure 15. Annual locomotives PM2.5 concentration contribution, absolute values

Percent concentration contribution: The annual average percentage contribution to ambient $PM_{2.5}$ concentration from locomotives (concentration from locomotives divided by total concentration). The map should be interpreted as visual heat map representations of how concentration contributions are distributed in space, with blue representing lower contributions and yellow/red representing higher contributions.

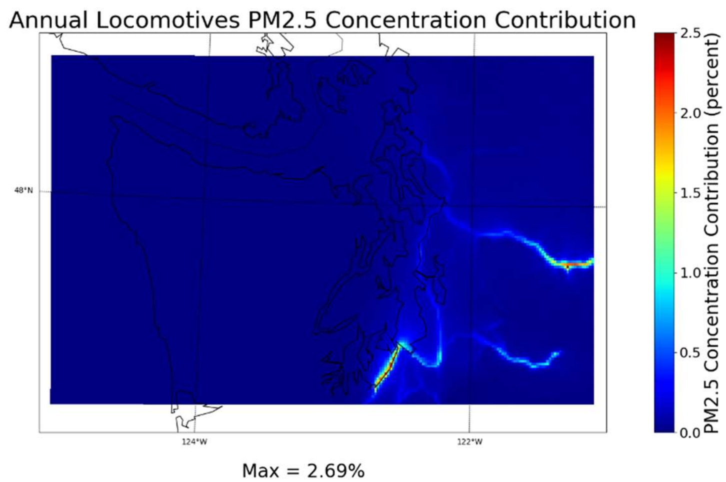


Figure 16. Annual locomotives PM2.5 concentration contribution in percentage

Population exposure: The estimated simple exposure metric (μg m^{-3} person) for locomotives. This map represents the combination of the absolute concentration contribution maps (μg m^{-3}) and population data. The maps should be interpreted as visual heat map representations of how the exposure metric values are distributed in space, with blue representing lower exposure and yellow/red representing higher exposure.

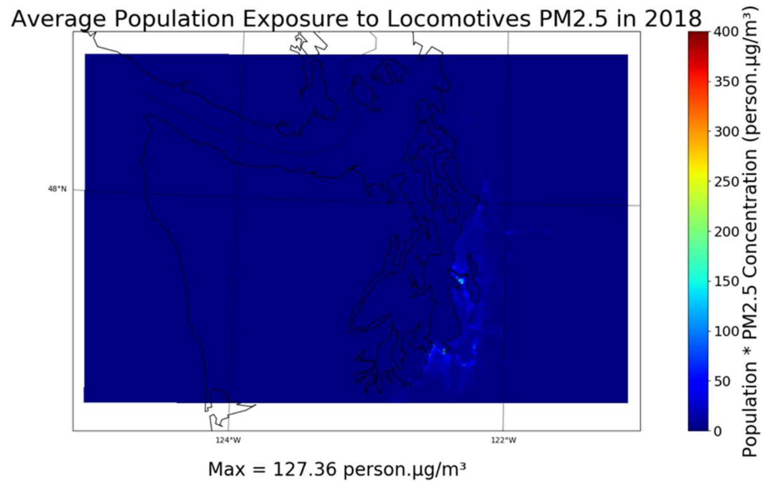


Figure 17. Average population exposure to locomotives PM2.5 in 2018

6.2.1. Appendix A: Calculating cargo handling equipment scaling factors by MATLAB

Let's suppose in location i, the values for P pollutants are emitted. Then the vector Loc_i, containing the emitted values for each pollutant in location i, is defined as follows.

$$Loc_i = \begin{bmatrix} Pollutant\_1_{Loc_i} \\ Pollutant\_2_{Loc_i} \\ \vdots \\ Pollutant\_P_{Loc_i} \end{bmatrix}$$

where $Pollutant\_1_{Loc_i}$ shows the value of pollutant 1 emitted at location i. Vector SCC_j shows the amount of each pollutant emitted for source type j.

$$SCC_j = \begin{bmatrix} Pollutant\_1_{SCC_j} \\ Pollutant\_2_{SCC_j} \\ \vdots \\ Pollutant\_P_{SCC_j} \end{bmatrix}$$

In this vector, $Pollutant\_1_{SCC_j}$ indicates the values of pollutant 1 from source j.

It is known that the amount of pollutants in each location is a linear combination of pollutants emitted from different sources. Therefore, for each location, we can have the following equations:

$$\begin{aligned} Loc_1 &= x_1.SCC_1 + x_2.SCC_2 + \cdots + x_N.SCC_N \\ Loc_2 &= y_1.SCC_1 + y_2.SCC_2 + \cdots + y_N.SCC_N \\ &\vdots \\ Loc_M &= z_1.SCC_1 + z_2.SCC_2 + \cdots + z_N.SCC_N \end{aligned}$$

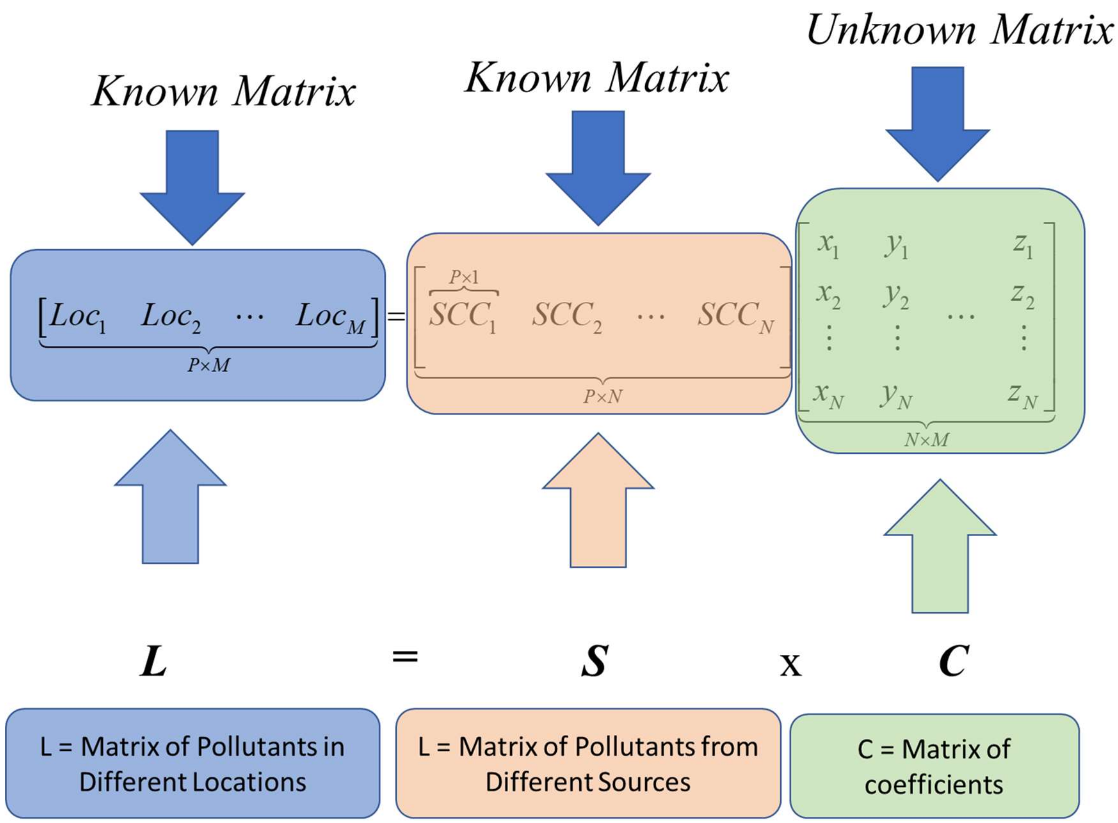
For each location, the above equation can be written in the following matrix form:

$$\underset{P\times 1}{\underset{\Uparrow}{Loc_1}} = \underbrace{\begin{bmatrix} \overbrace{SCC_1}^{P\times 1} & SCC_2 & \cdots & SCC_N \end{bmatrix}}_{P\times N} \underbrace{\begin{bmatrix} x_1 \\ x_2 \\ \vdots \\ x_N \end{bmatrix}}_{N\times 1}$$

If all the equations for all location are summarized in one matrix, the following equation would be obtained:

$$\underbrace{\begin{bmatrix} Loc_1 & Loc_2 & \cdots & Loc_M \end{bmatrix}}_{P\times M} = \underbrace{\begin{bmatrix} \overbrace{SCC_1}^{P\times 1} & SCC_2 & \cdots & SCC_N \end{bmatrix}}_{P\times N} \underbrace{\begin{bmatrix} x_1 & y_1 & & z_1 \\ x_2 & y_2 & \cdots & z_2 \\ \vdots & \vdots & & \vdots \\ x_N & y_N & & z_N \end{bmatrix}}_{N\times M}$$

The following figure shows how a linear equation is relating emitted pollutants from different sources to different locations. In this equation, the coefficient matrix C is unknown and should be calculated.



Due to the structure of this equation, the matrix of unknows should be obtained in the least-square sense. Furthermore, there are two constraints in our problem:

1- All coefficients in matrix C must be non-negative:

$$C_{i,j} \geq 0$$

2- The summation of coefficient for a certain SCC should be equal to 1. In other words, emissions for a source type should be exhaustively allocated to different locations.

$$x_i + y_i + \cdots z_i = 1$$

Therefore, the final form of our problem would be as follows:

$$\min_{x} \|L - S.C\|_2^2$$
$$s.t.: \begin{cases} x_i + y_i + \cdots z_i = 1 \\ C_{i,j} \geq 0 \end{cases}$$

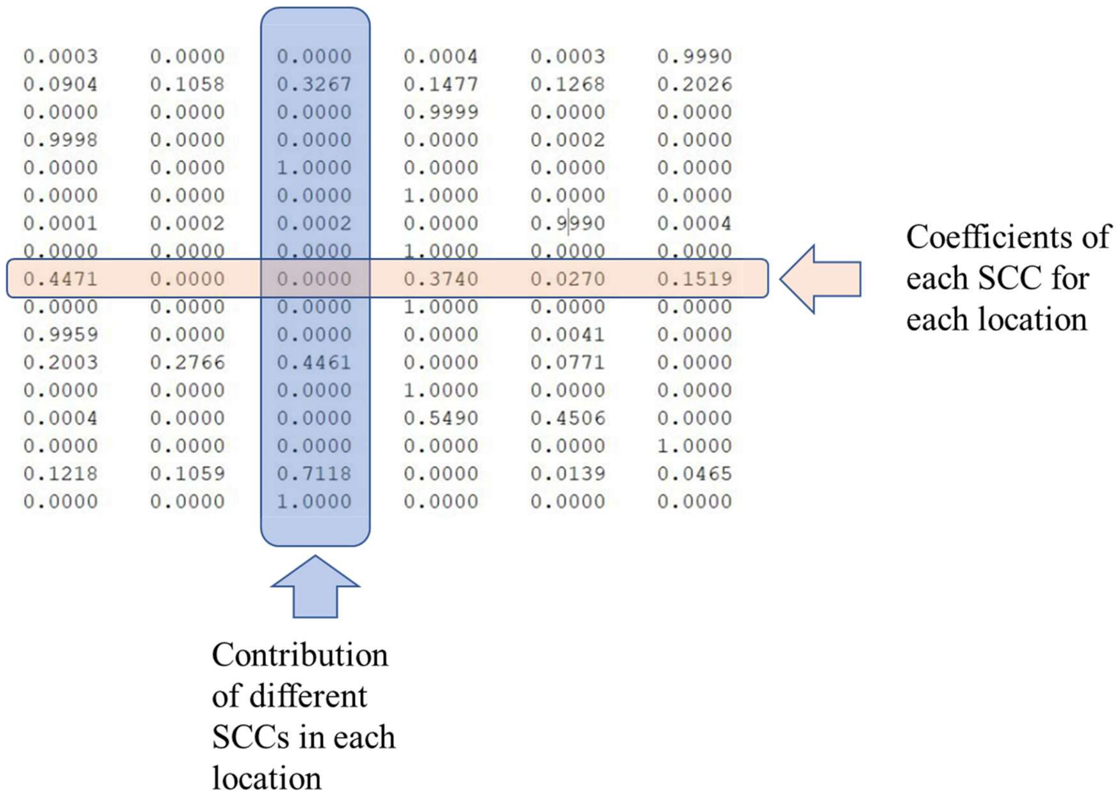
To solve this linear system, in the least square sense along with linear equality and inequality constraints, the Matlab lsqlin() function is used. Since this function needs vectors for unknowns, the problem is reformulated into the following equation.

$$\underbrace{\underbrace{\begin{bmatrix} Loc_1 \\ \vdots \\ Loc_M \end{bmatrix}}_{(P\times M)\times 1} = \underbrace{\begin{bmatrix} SCC_1 & & 0 \\ & \ddots & \\ 0 & & SCC_N \end{bmatrix}}_{(P\times M)\times(N\times M)} \underbrace{\begin{bmatrix} x_1 \\ x_2 \\ \vdots \\ x_N \\ \vdots \\ z_1 \\ z_2 \\ \vdots \\ z_N \end{bmatrix}}_{(N\times M)\times 1}}_{L'=S'\times C'}$$

Then the following final form of problem can be solved by the Matlab lsqlin() function.

$$\min_{x} \|L' - S'.C'\|_2^2$$
$$s.t.: \begin{cases} x_i + y_i + \cdots z_i = 1 \\ C_i' \geq 0 \end{cases}$$

Finally, we reshape the vector of unknowns to the original shape (C matrix). The following Matrix is one example of results:

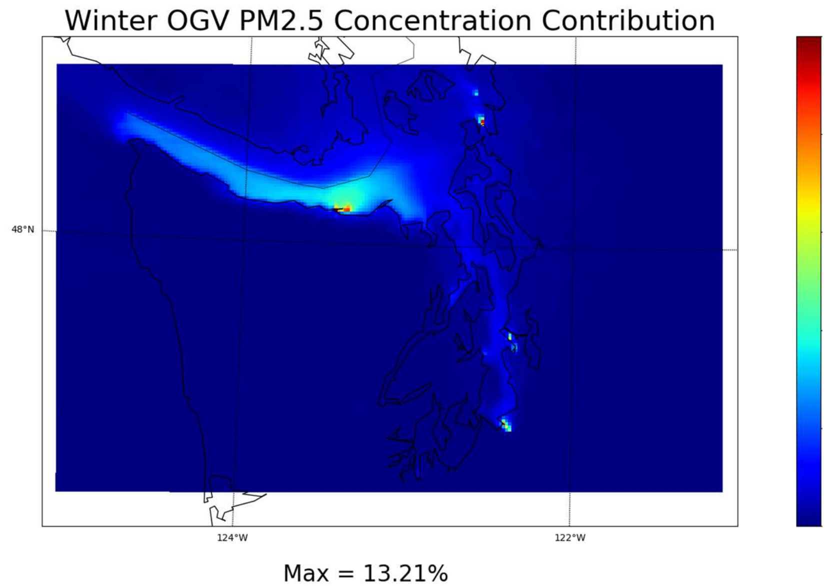


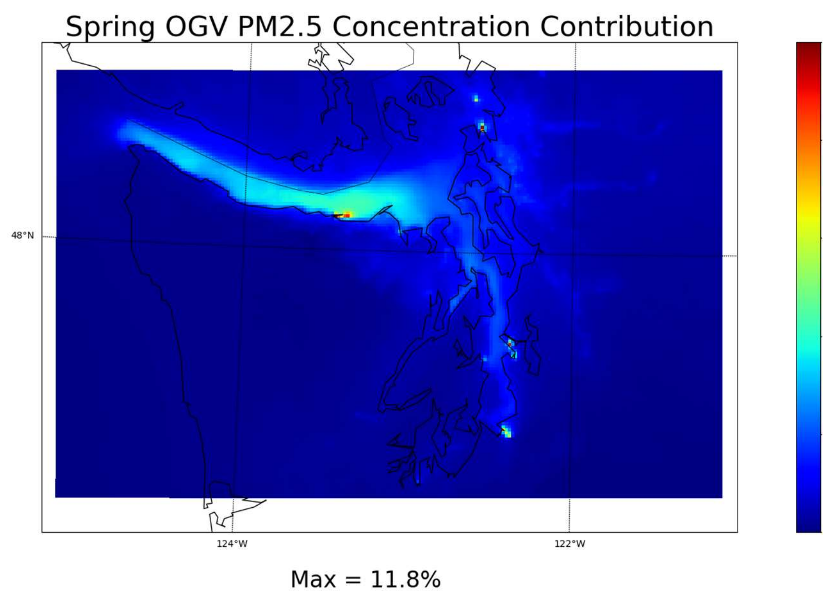
0.0003	0.0000	0.0000	0.0004	0.0003	0.9990
0.0904	0.1058	0.3267	0.1477	0.1268	0.2026
0.0000	0.0000	0.0000	0.9999	0.0000	0.0000
0.9998	0.0000	0.0000	0.0000	0.0002	0.0000
0.0000	0.0000	1.0000	0.0000	0.0000	0.0000
0.0000	0.0000	0.0000	1.0000	0.0000	0.0000
0.0001	0.0002	0.0002	0.0000	0.9990	0.0004
0.0000	0.0000	0.0000	1.0000	0.0000	0.0000
0.4471	0.0000	0.0000	0.3740	0.0270	0.1519
0.0000	0.0000	0.0000	1.0000	0.0000	0.0000
0.9959	0.0000	0.0000	0.0000	0.0041	0.0000
0.2003	0.2766	0.4461	0.0000	0.0771	0.0000
0.0000	0.0000	0.0000	1.0000	0.0000	0.0000
0.0004	0.0000	0.0000	0.5490	0.4506	0.0000
0.0000	0.0000	0.0000	0.0000	0.0000	1.0000
0.1218	0.1059	0.7118	0.0000	0.0139	0.0465
0.0000	0.0000	1.0000	0.0000	0.0000	0.0000

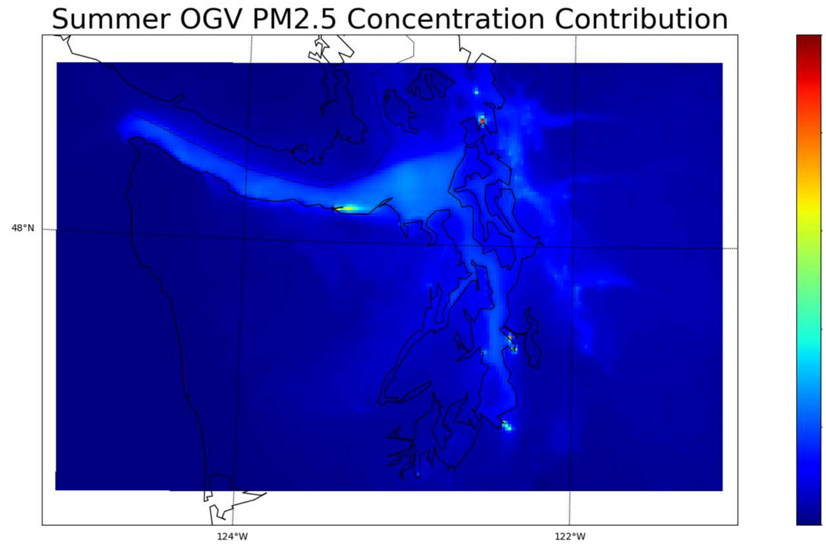
Appendix B. **Ports-related sources seasonal $PM_{2.5}$ contributions in percentage.**

To supplement the results discussed in the body of this document, this appendix contains the seasonal average concentration contributions for each of the port-related sources. These figures should be interpreted similarly to the annual average figures presented in the body of the document. Importantly, the reader should note that scales are different on many of these maps, so the color bar should be interpreted carefully with the context of the legend (i.e., red on one map may be a lower level of concentration or emission than green on another). Additionally, the map lines are approximate and may omit some geographic features.

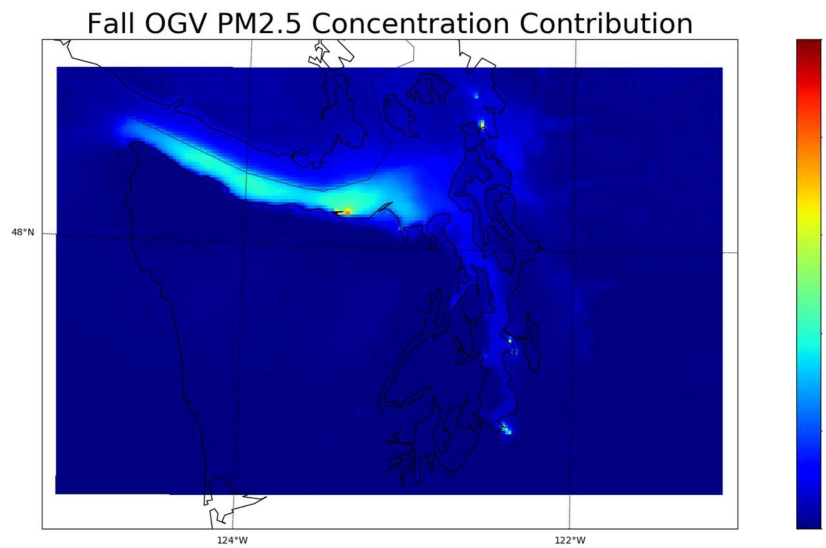
OGV seasonal $PM_{2.5}$ contributions in percentage







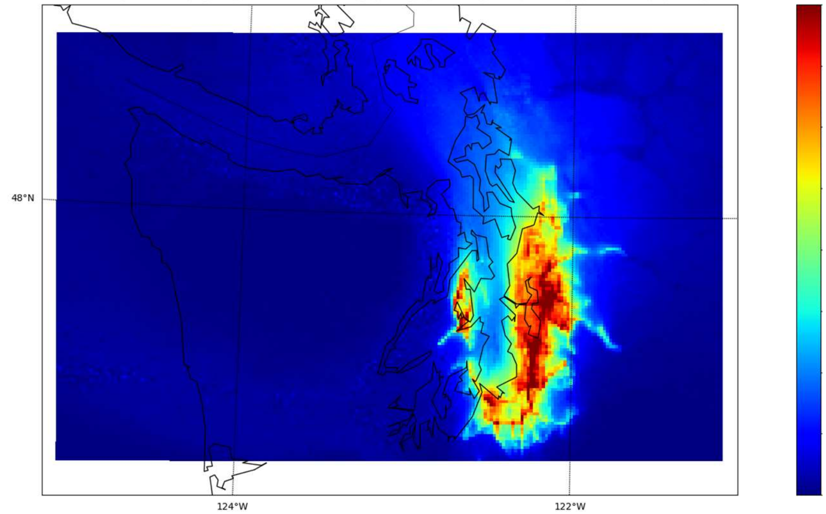
Max = 8.98%



Max = 11.22%

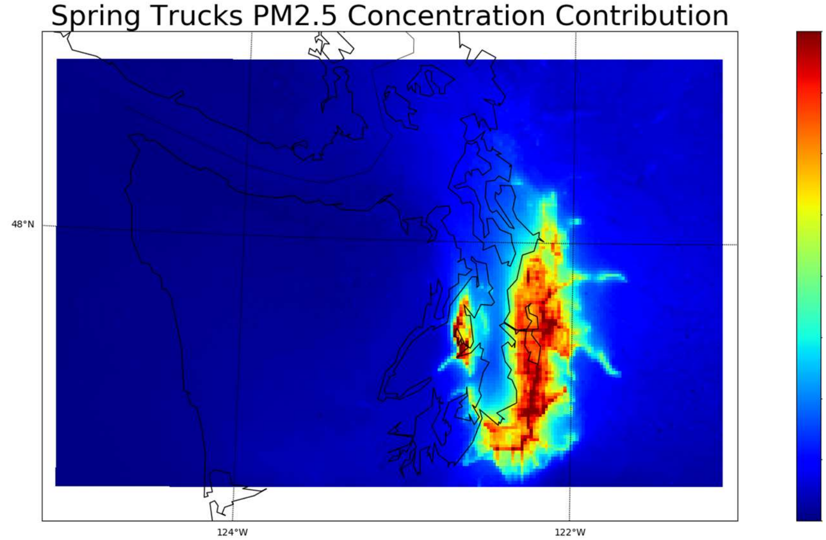
Trucks seasonal $PM_{2.5}$ contributions in percentage

Winter Trucks PM2.5 Concentration Contribution

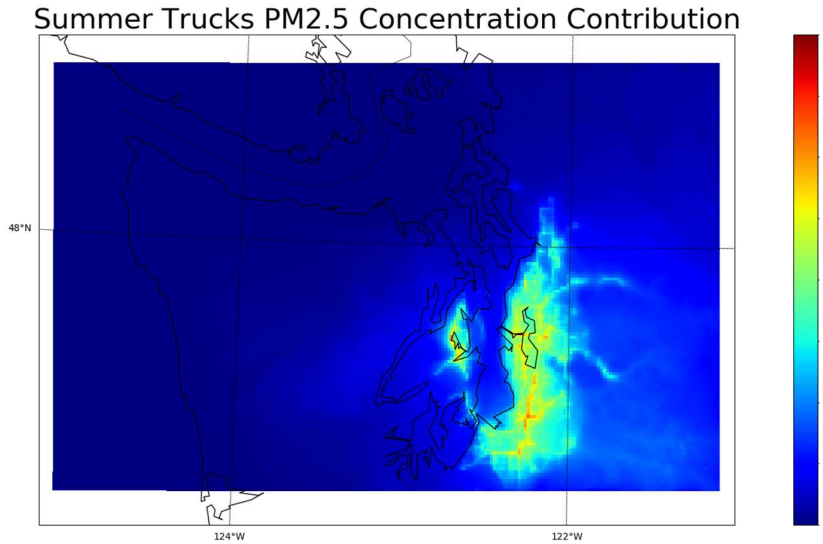


Max = 0.55%

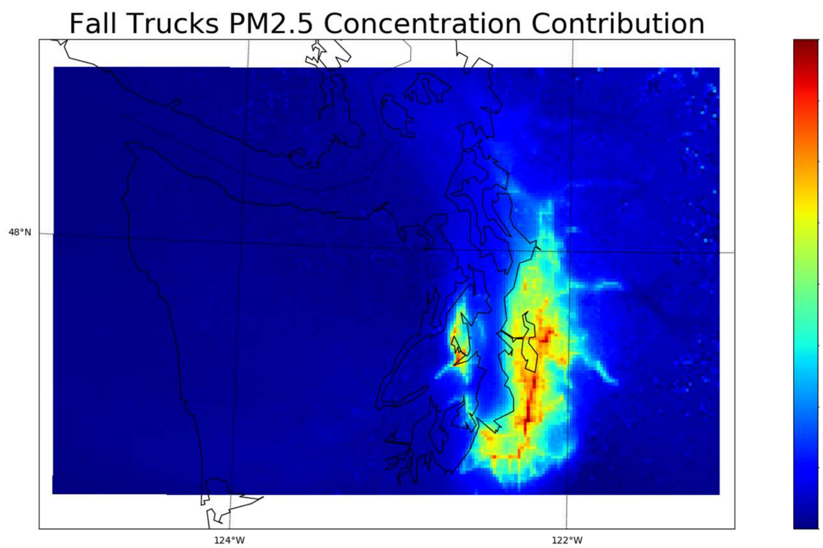
Spring Trucks PM2.5 Concentration Contribution



Max = 0.53%



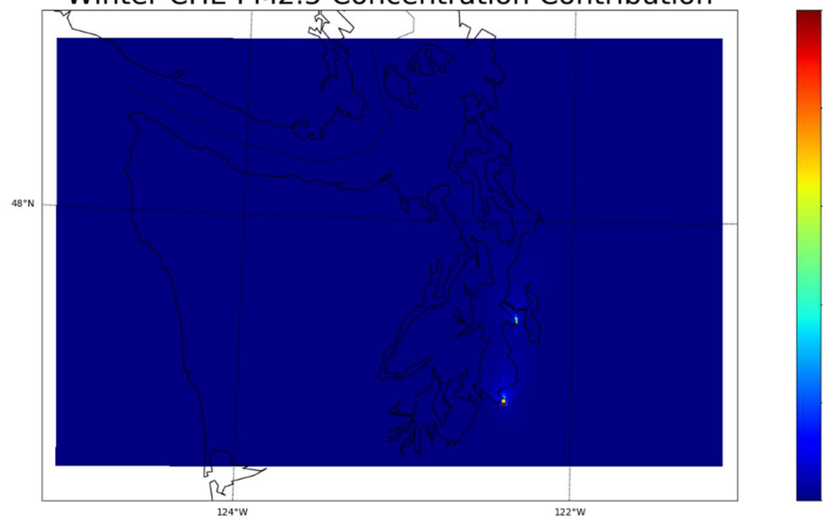
Max = 0.31%



Max = 0.4%

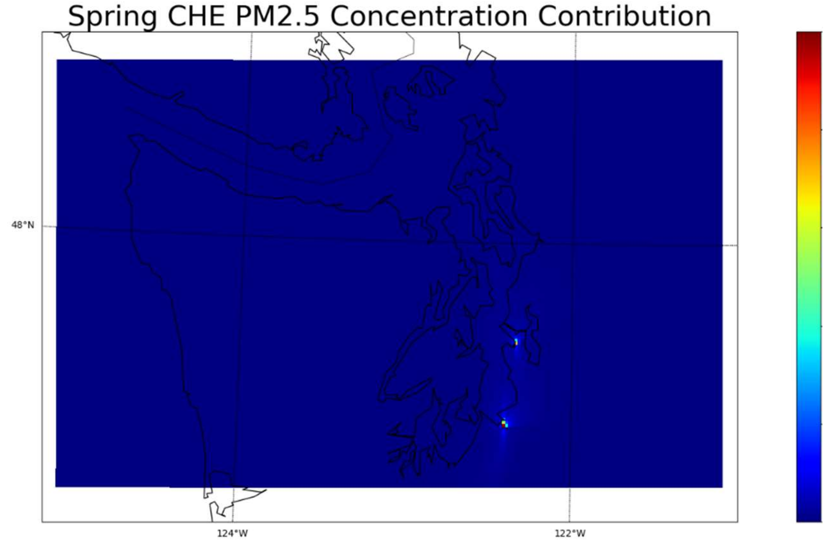
CHE seasonal $PM_{2.5}$ contributions in percentage

Winter CHE PM2.5 Concentration Contribution

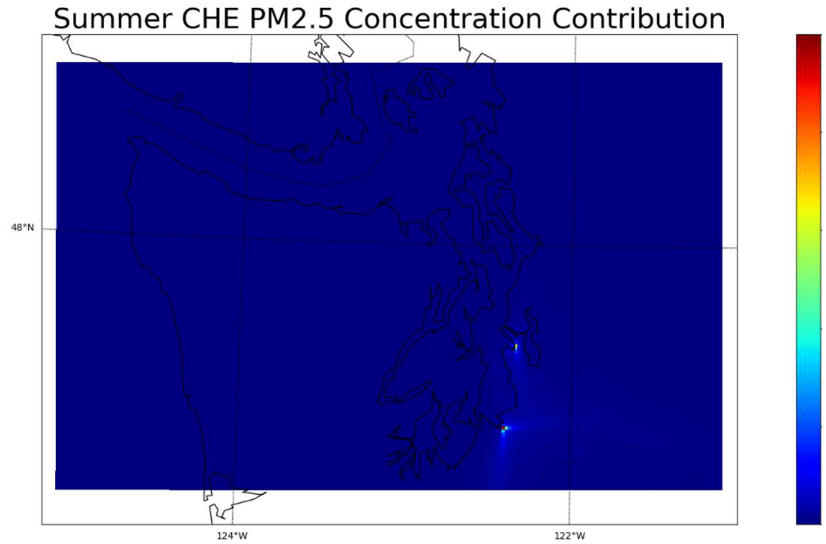


Max = 5.0%

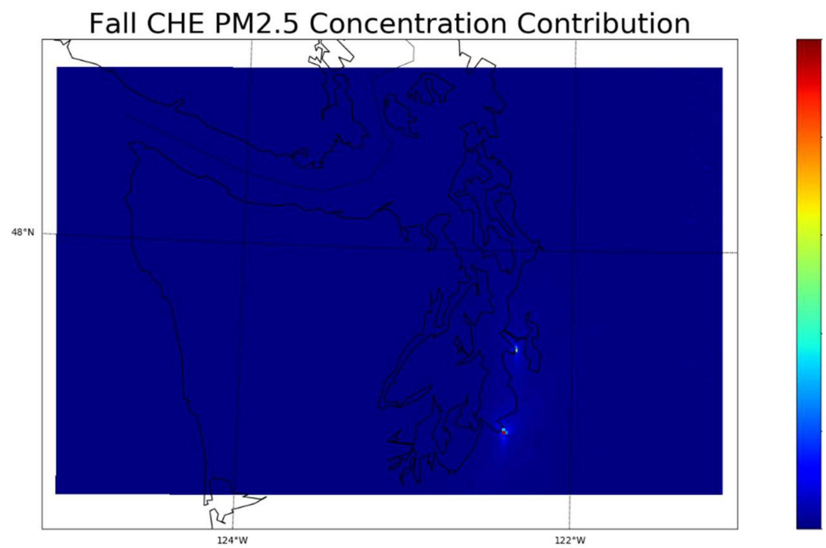
Spring CHE PM2.5 Concentration Contribution



Max = 6.27%



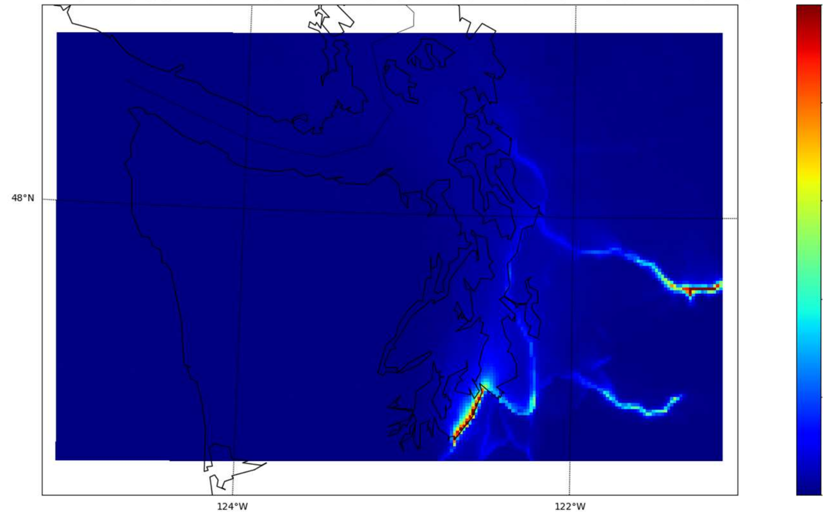
Max = 5.41%



Max = 4.85%

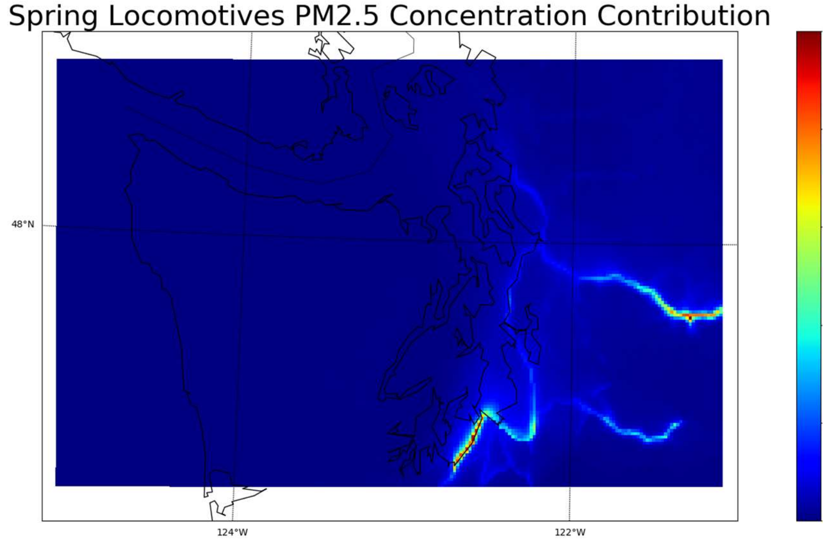
Locomotives seasonal $PM_{2.5}$ contributions in percentage

Winter Locomotives PM2.5 Concentration Contribution

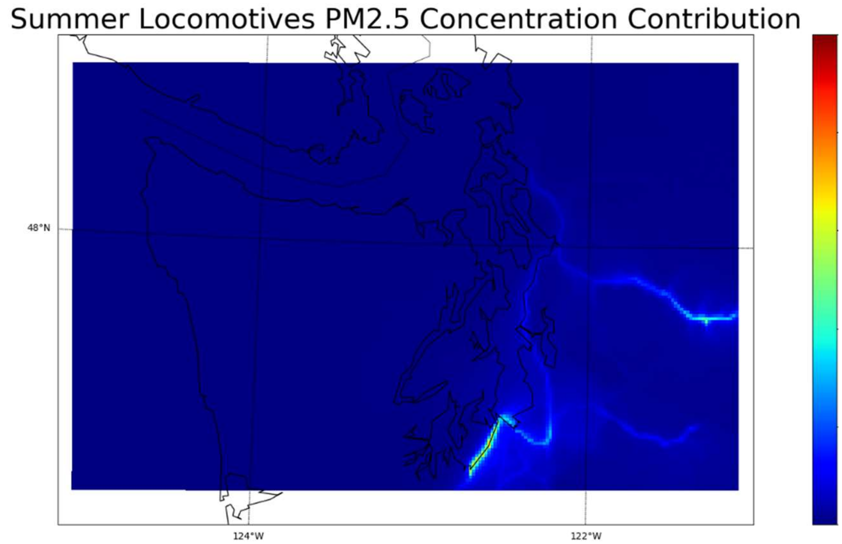


Max = 3.9%

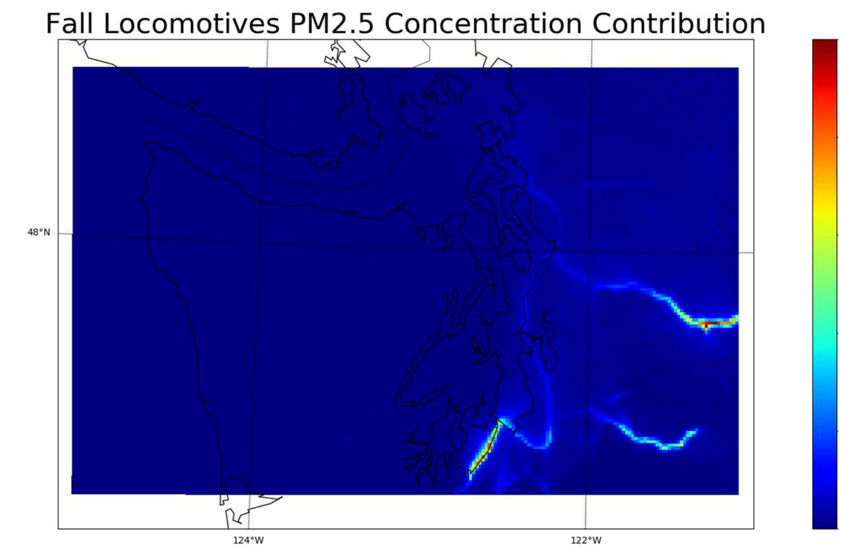
Spring Locomotives PM2.5 Concentration Contribution



Max = 2.69%



Max = 1.62%

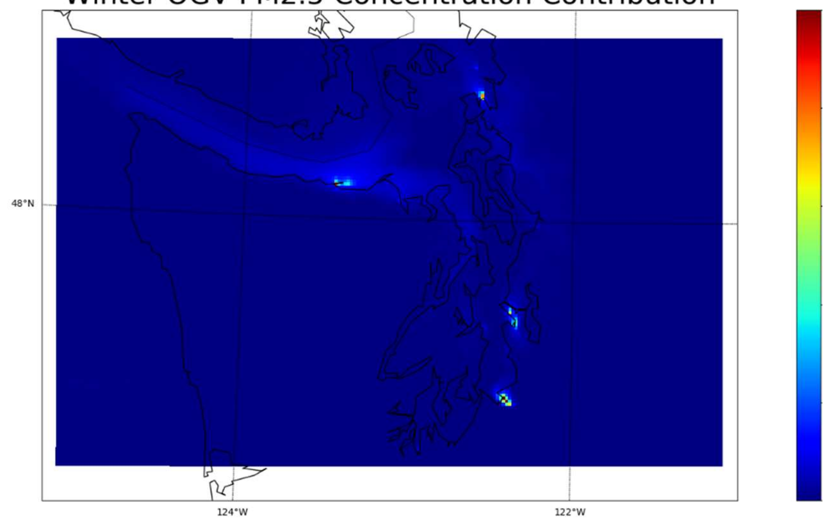


Max = 3.05%

Appendix C. Ports-related sources seasonal $PM_{2.5}$ contributions, absolute values.

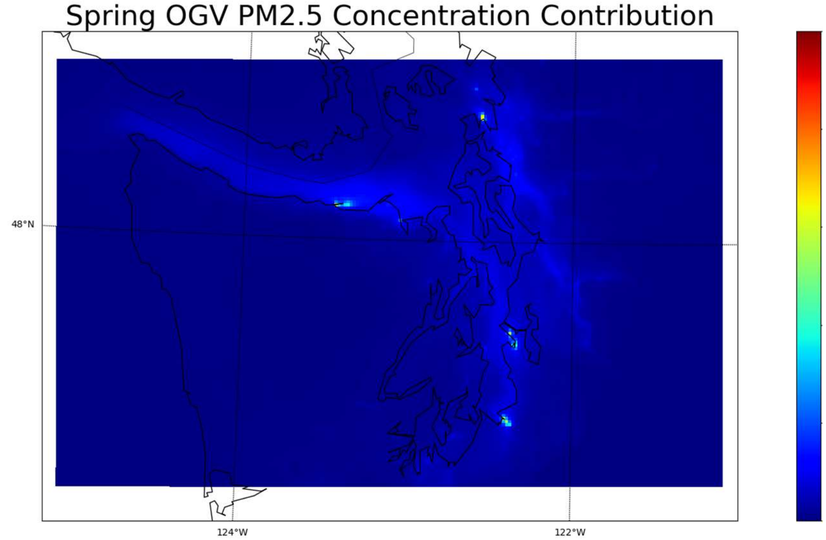
OGV seasonal $PM_{2.5}$ contributions, absolute values.

Winter OGV PM2.5 Concentration Contribution



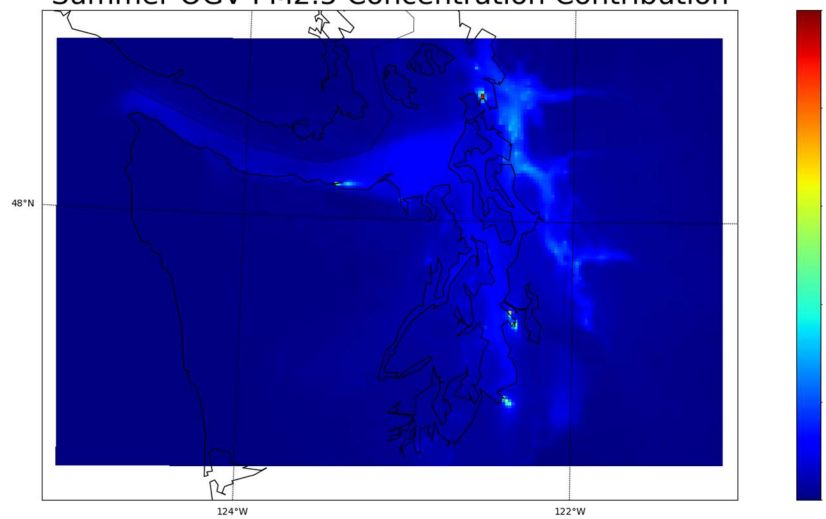
Max = 0.6 µg/m³

Spring OGV PM2.5 Concentration Contribution



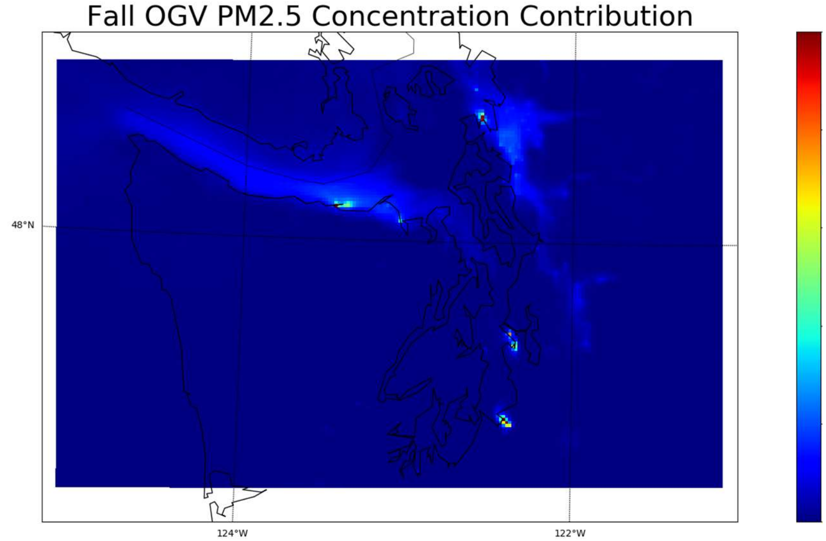
Max = 0.31 µg/m³

Summer OGV PM2.5 Concentration Contribution



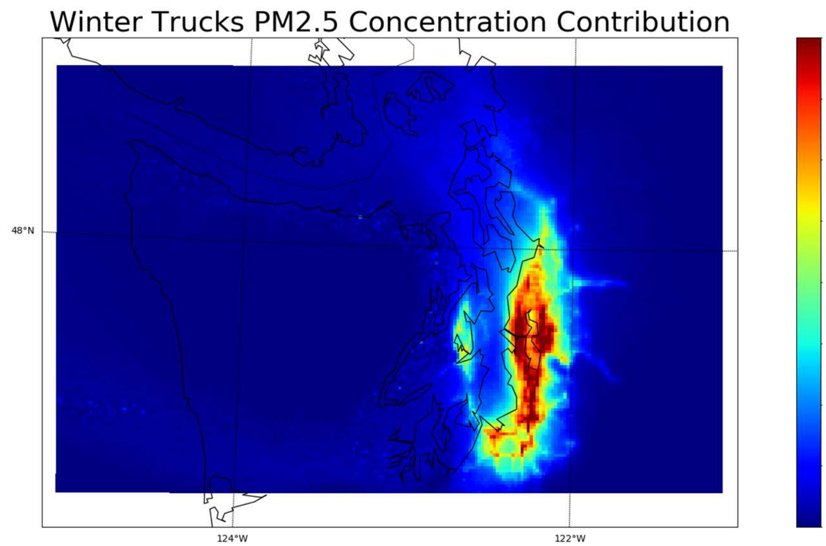
Max = 0.48 µg/m³

Fall OGV PM2.5 Concentration Contribution

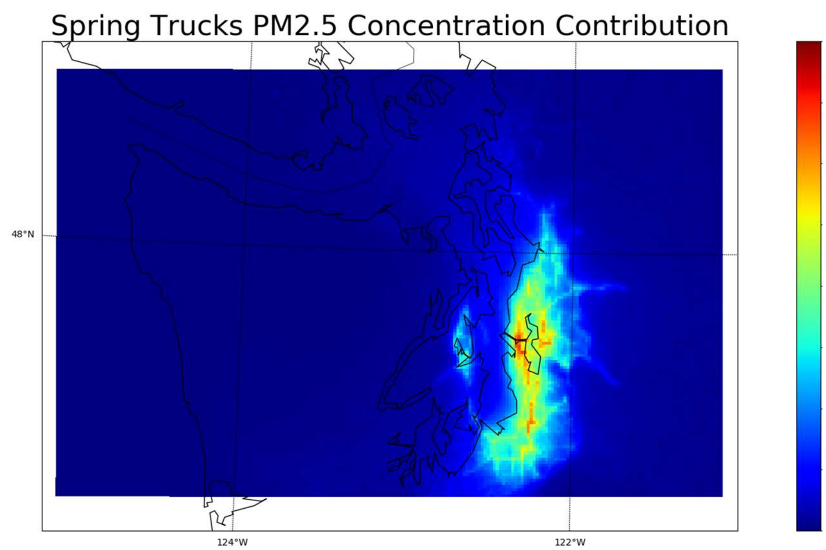


Max = 0.58 µg/m³

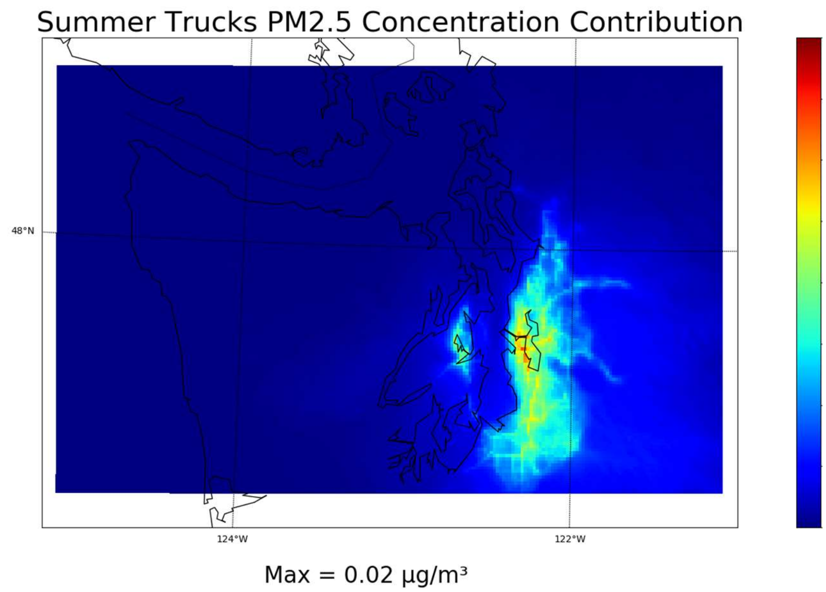
Trucks seasonal $PM_{2.5}$ contributions, absolute values.

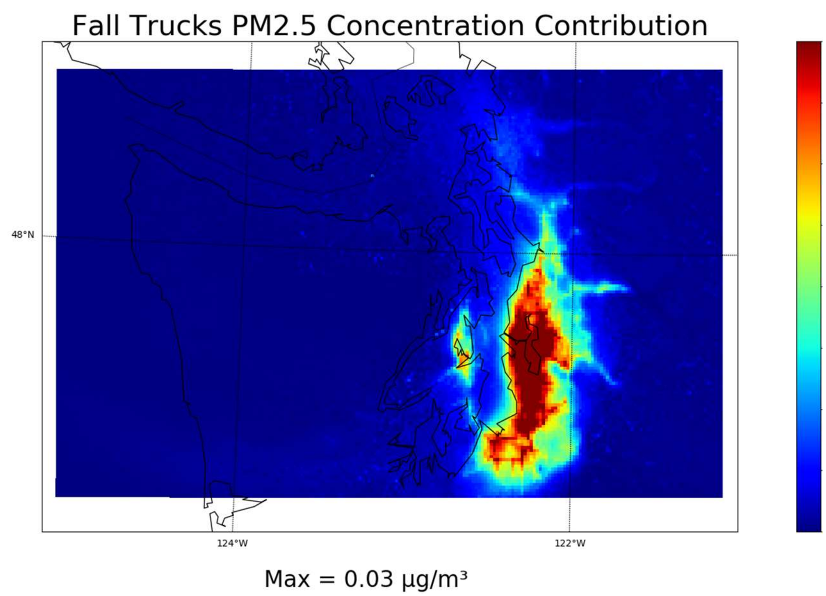


Max = 0.03 µg/m³



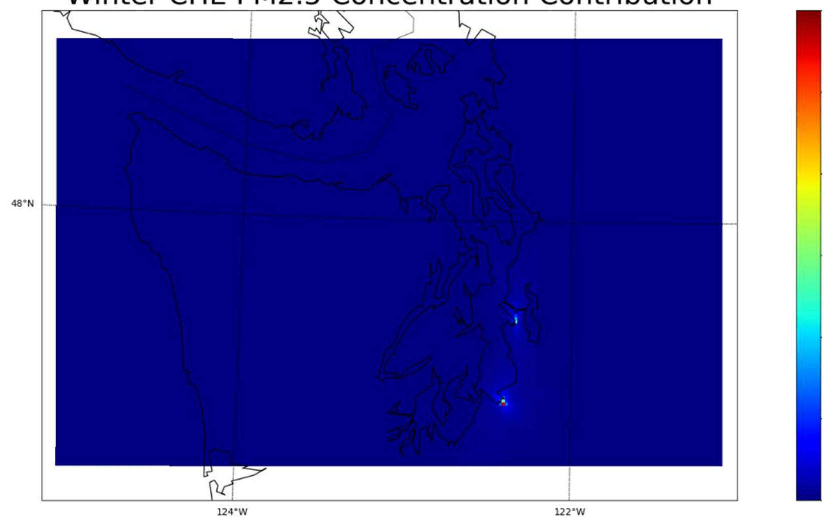
Max = 0.02 µg/m³





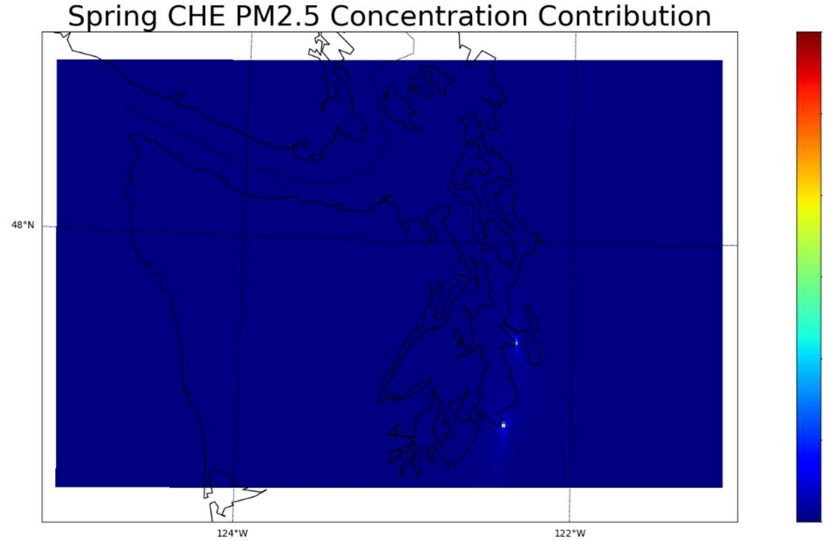
CHE seasonal $PM_{2.5}$ contributions, absolute values.

Winter CHE PM2.5 Concentration Contribution

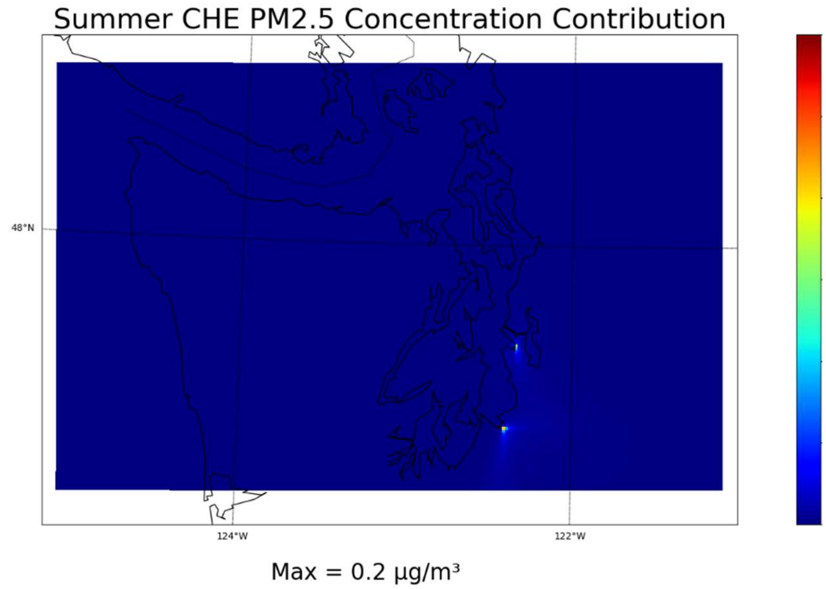


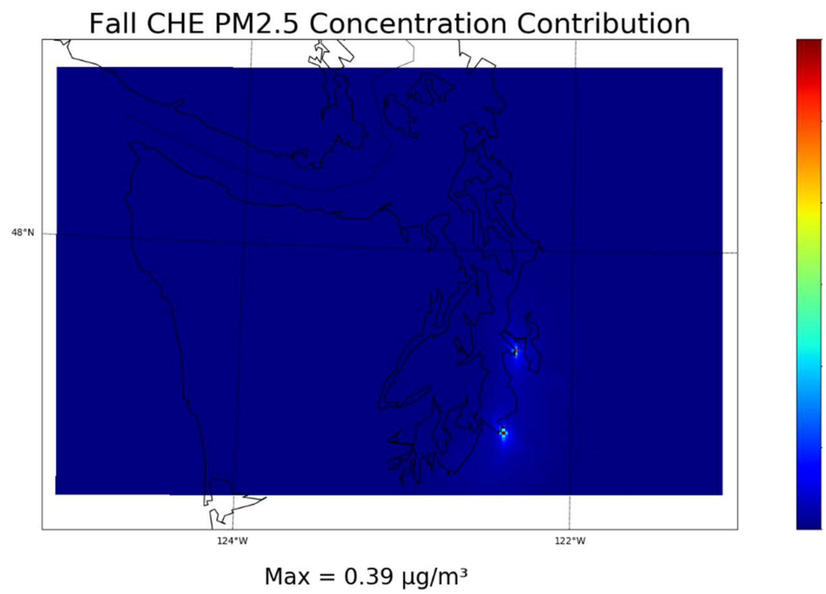
Max = 0.28 μg/m³

Spring CHE PM2.5 Concentration Contribution



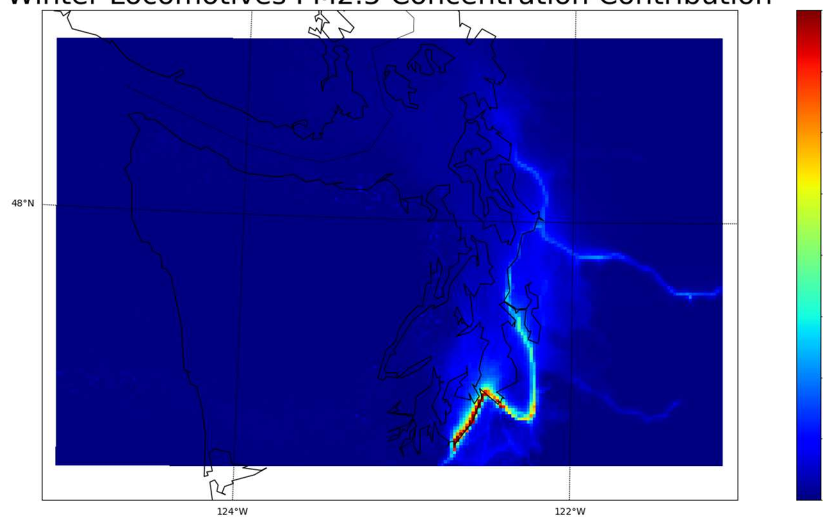
Max = 0.18 μg/m³





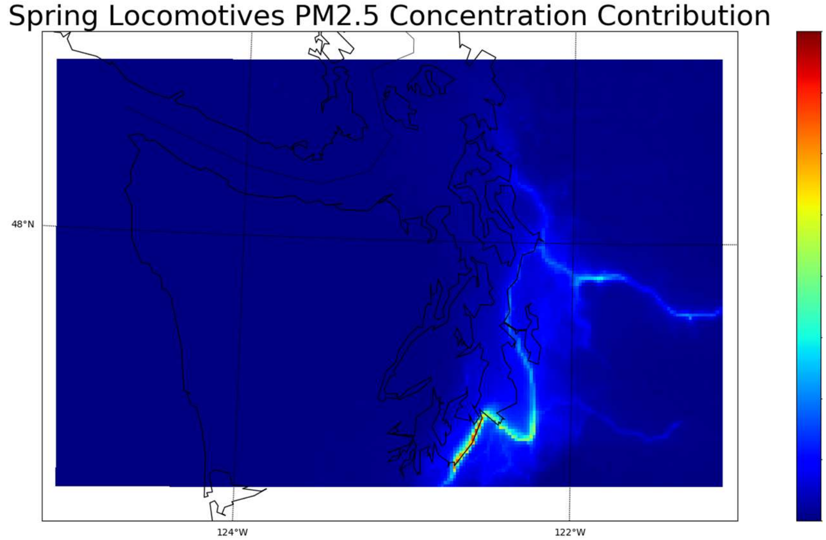
Locomotives seasonal PM2.5 contributions, absolute values.

Winter Locomotives PM2.5 Concentration Contribution



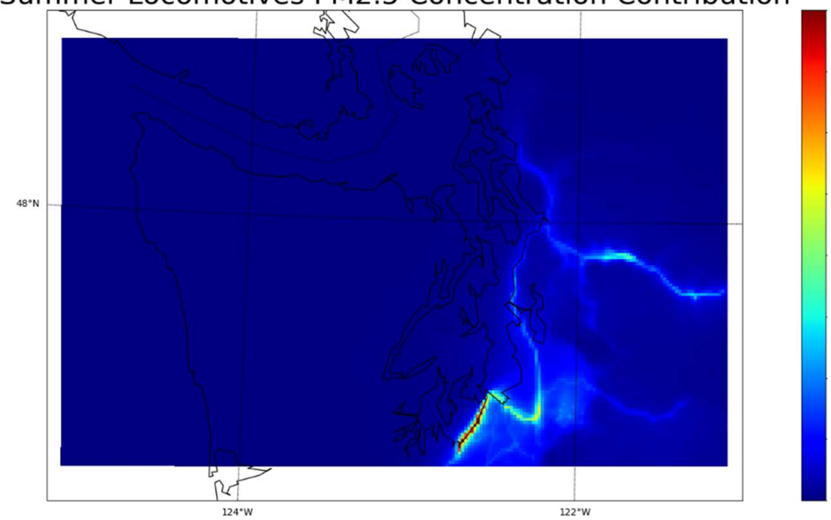
Max = 0.05 µg/m³

Spring Locomotives PM2.5 Concentration Contribution



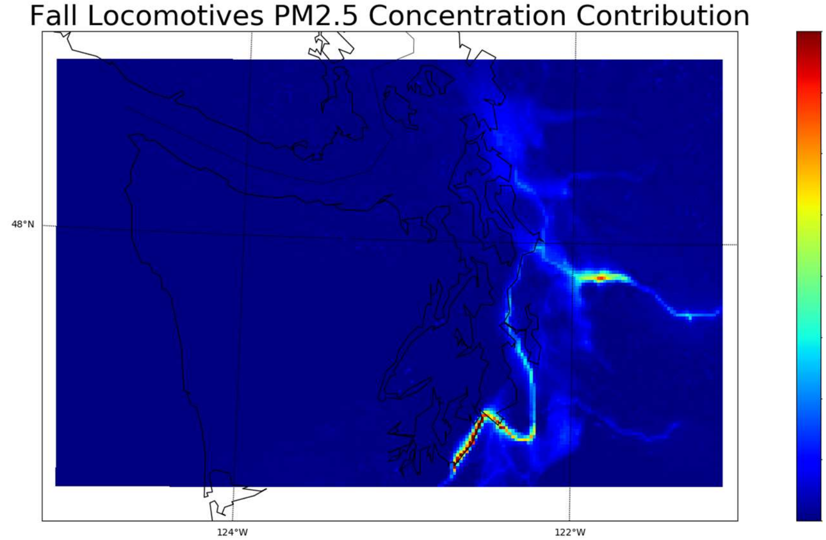
Max = 0.03 µg/m³

Summer Locomotives PM2.5 Concentration Contribution



Max = 0.04 µg/m³

Fall Locomotives PM2.5 Concentration Contribution

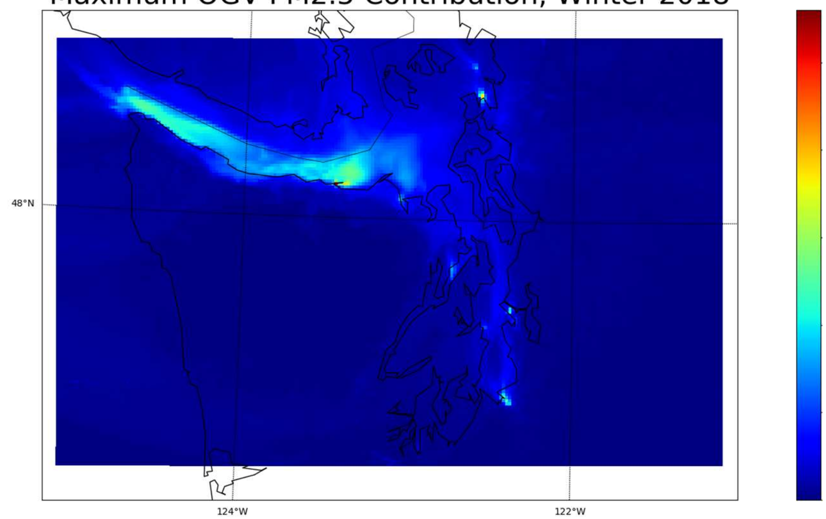


Max = 0.05 µg/m³

Appendix D. Ports-related sources seasonal maximum $PM_{2.5}$ contributions in percentage.

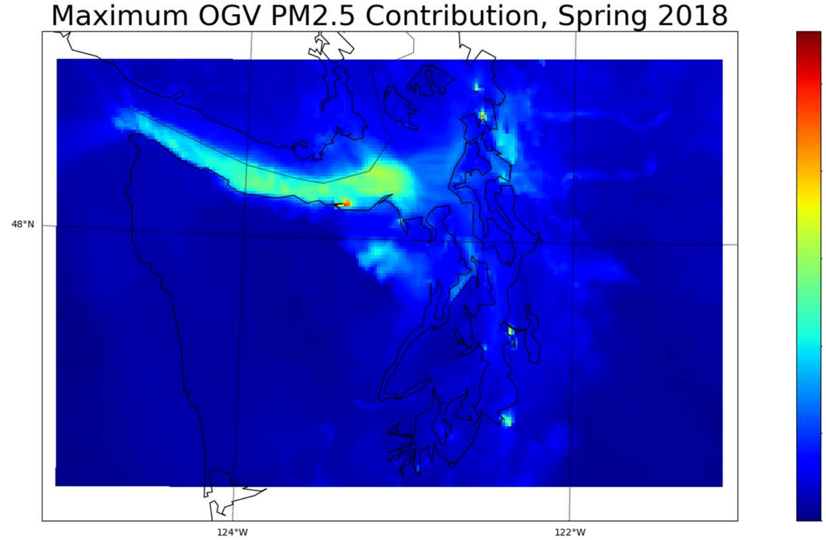
OGV seasonal maximum $PM_{2.5}$ contributions in percentage.

Maximum OGV PM2.5 Contribution, Winter 2018

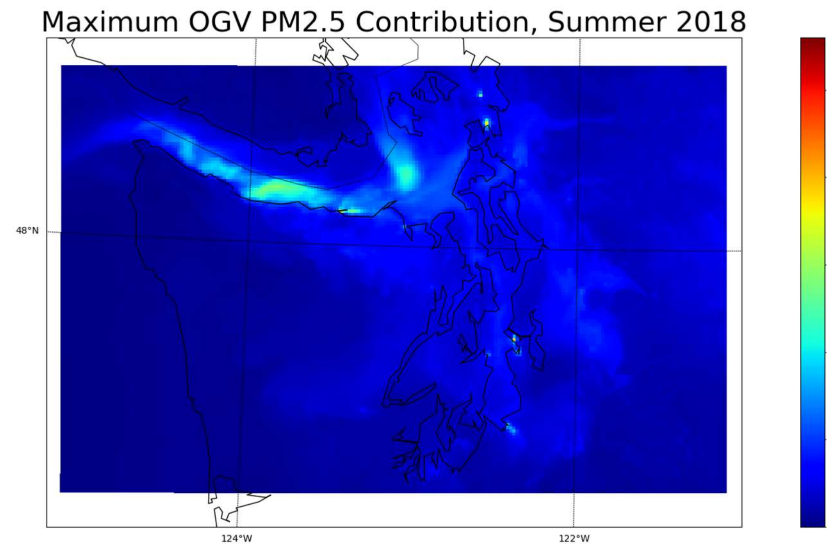


Max = 25.8%

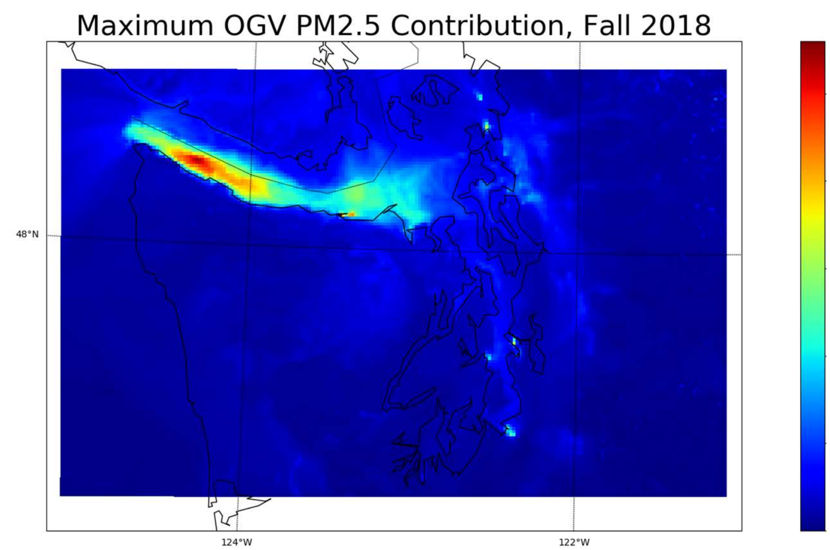
Maximum OGV PM2.5 Contribution, Spring 2018



Max = 26.78%



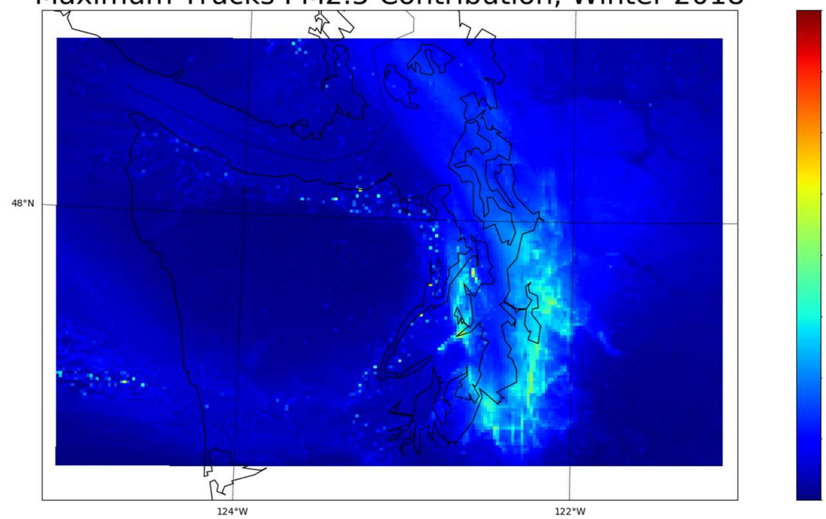
Max = 19.26%



Max = 28.23%

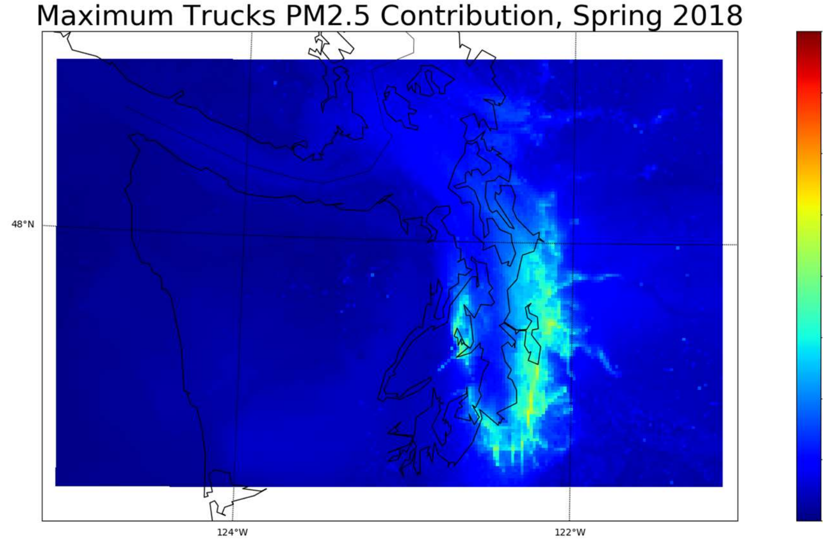
Trucks seasonal maximum $PM_{2.5}$ contributions in percentage.

Maximum Trucks PM2.5 Contribution, Winter 2018



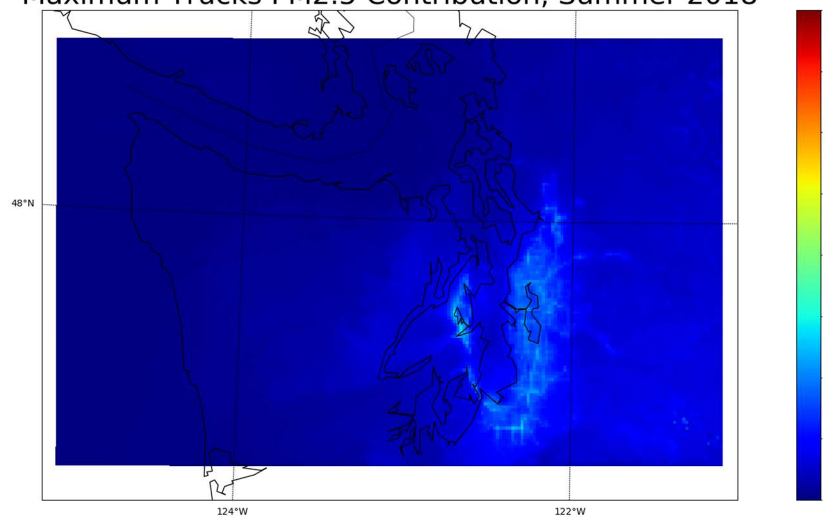
Max = 1.29%

Maximum Trucks PM2.5 Contribution, Spring 2018



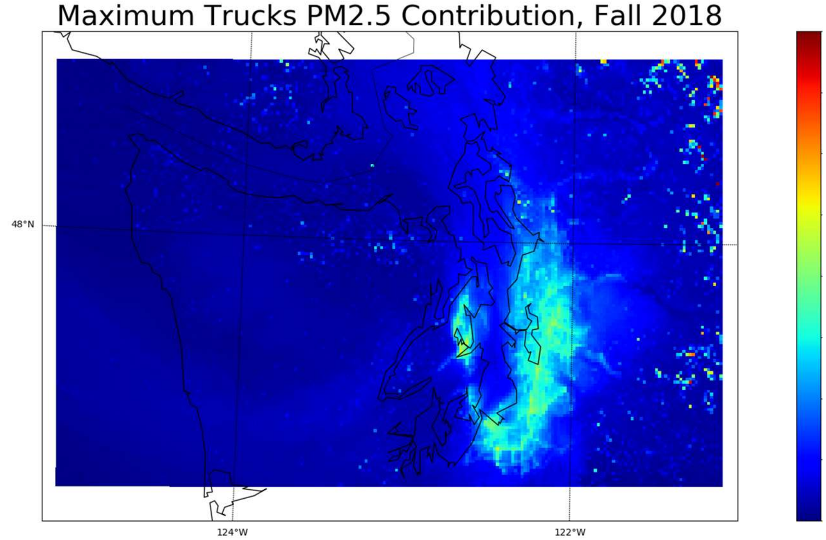
Max = 1.23%

Maximum Trucks PM2.5 Contribution, Summer 2018



Max = 0.71%

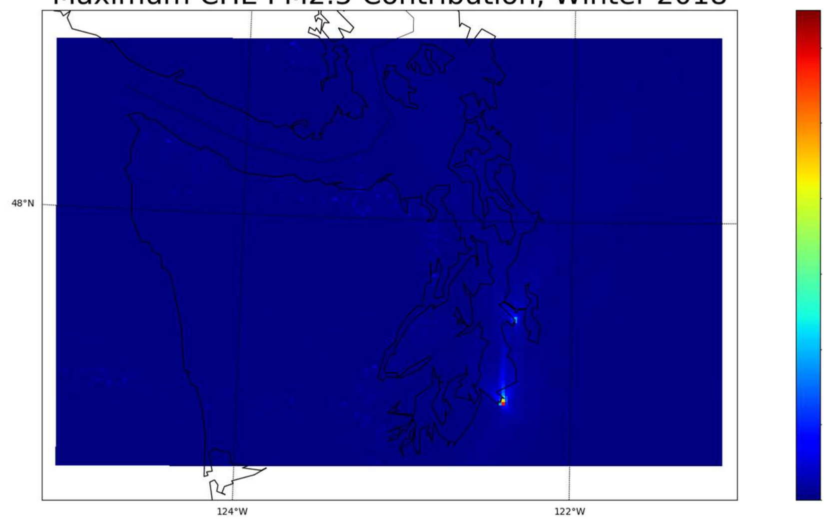
Maximum Trucks PM2.5 Contribution, Fall 2018



Max = 2.11%

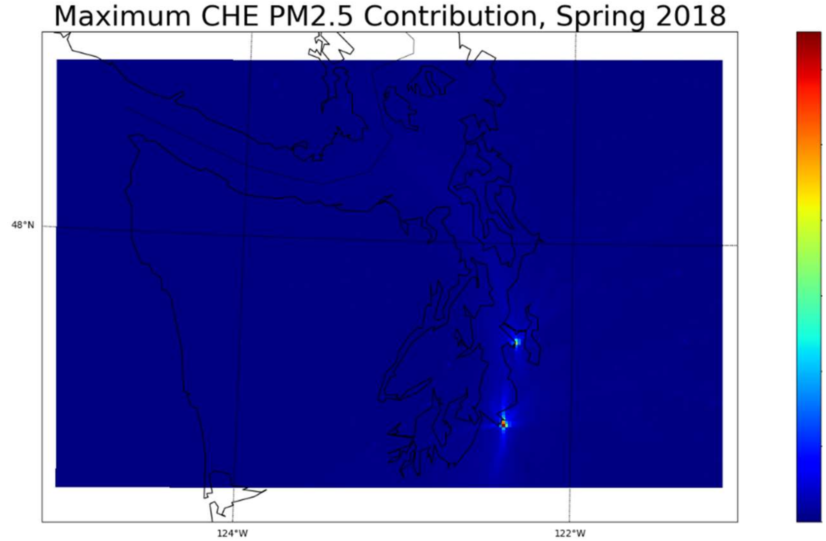
CHE seasonal maximum $PM_{2.5}$ contributions in percentage.

Maximum CHE PM2.5 Contribution, Winter 2018

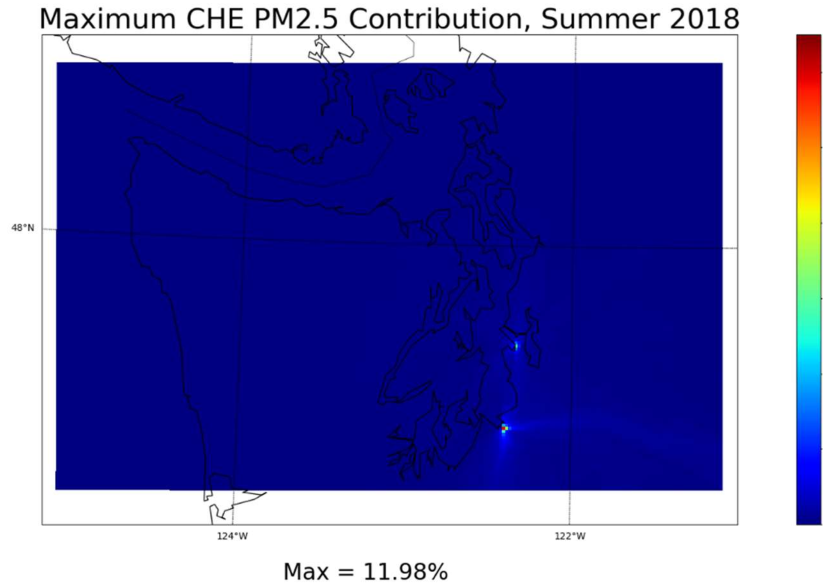


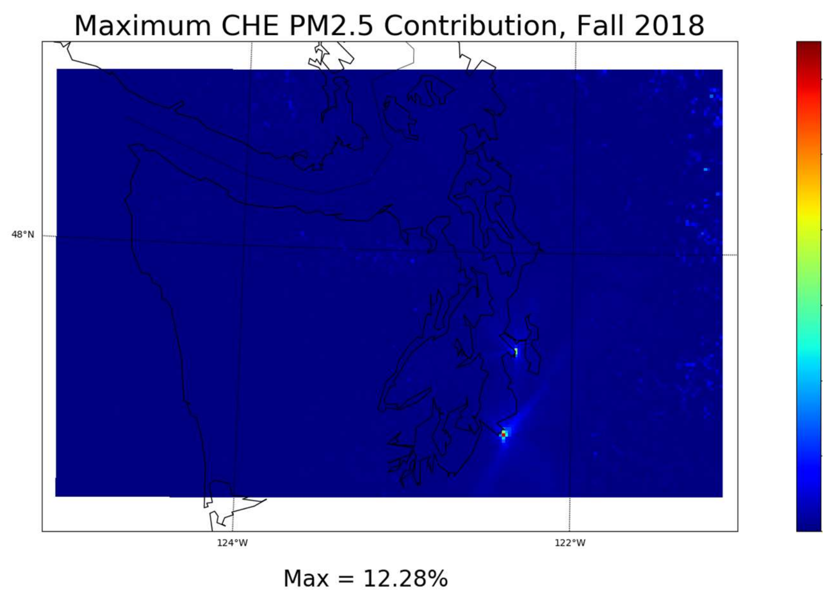
Max = 11.55%

Maximum CHE PM2.5 Contribution, Spring 2018



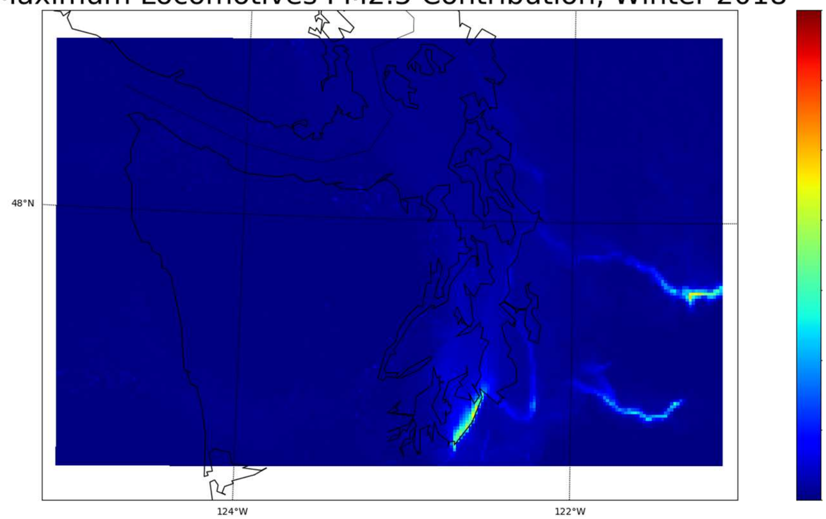
Max = 13.51%





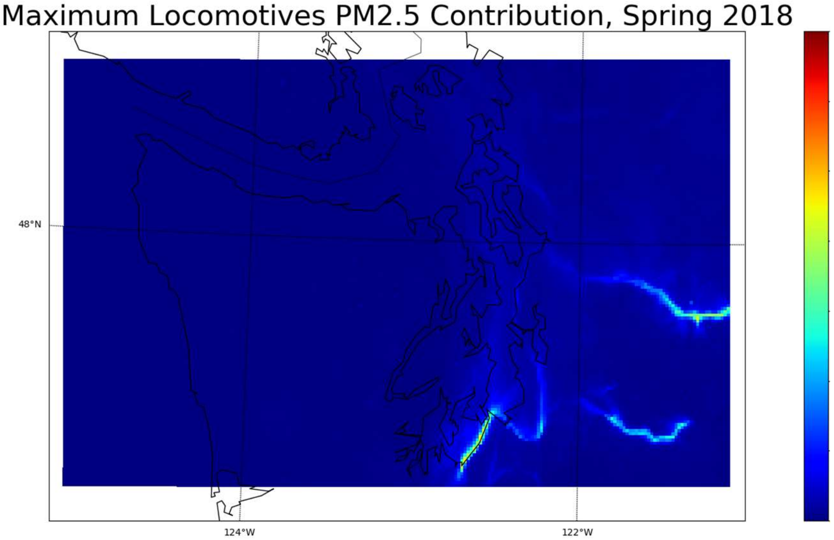
Locomotives seasonal maximum $PM_{2.5}$ contributions in percentage.

Maximum Locomotives PM2.5 Contribution, Winter 2018

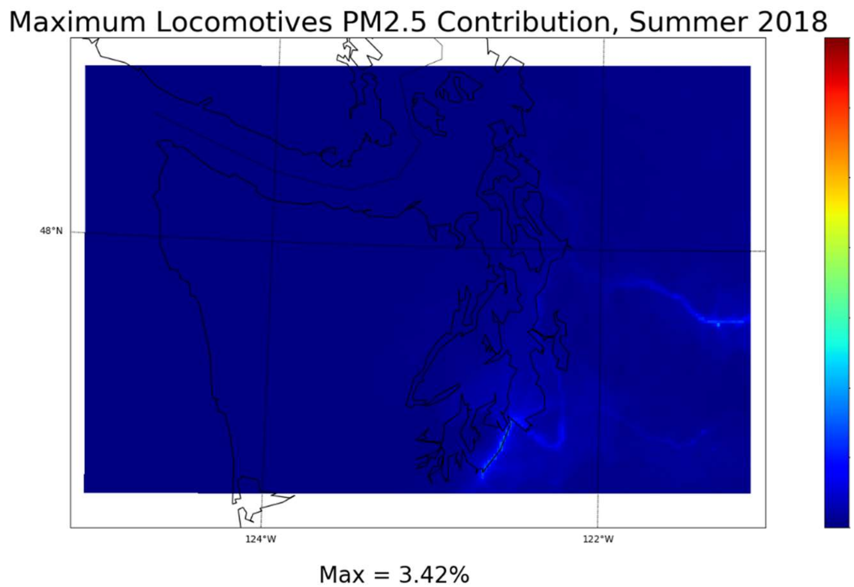


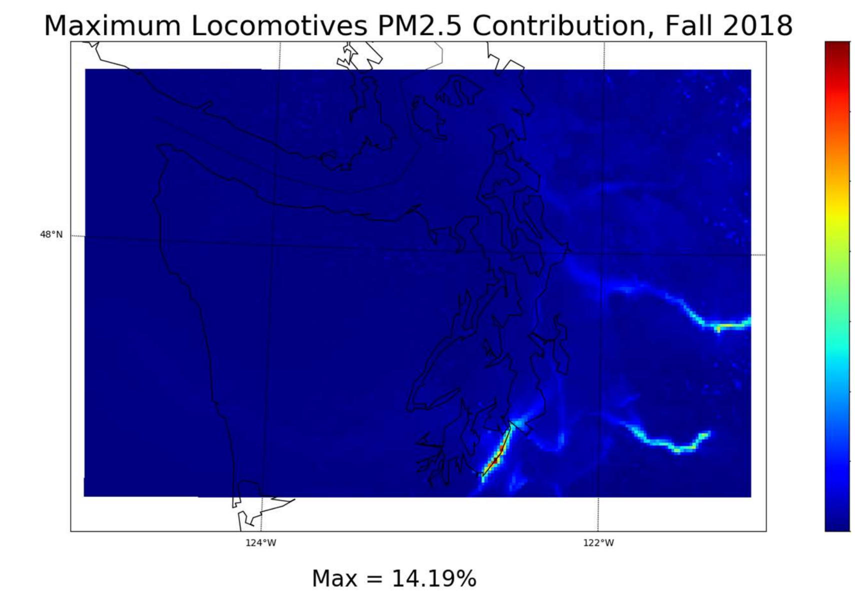
Max = 9.71%

Maximum Locomotives PM2.5 Contribution, Spring 2018



Max = 9.06%

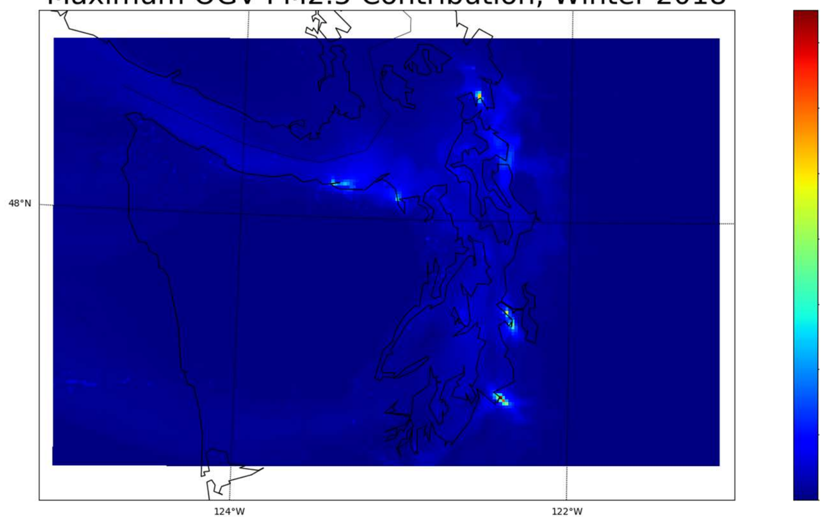




Appendix E. Ports-related sources seasonal maximum $PM_{2.5}$ contributions, absolute values.

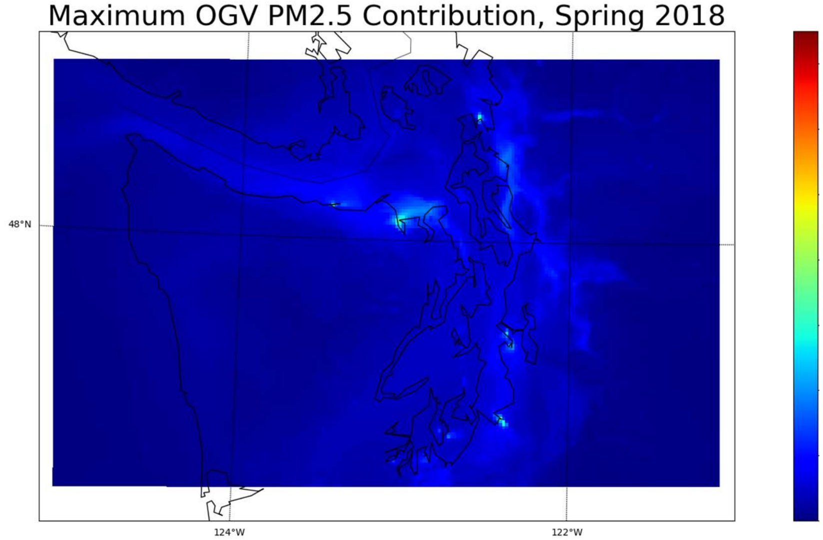
OGV seasonal maximum $PM_{2.5}$ contributions, absolute values.

Maximum OGV PM2.5 Contribution, Winter 2018

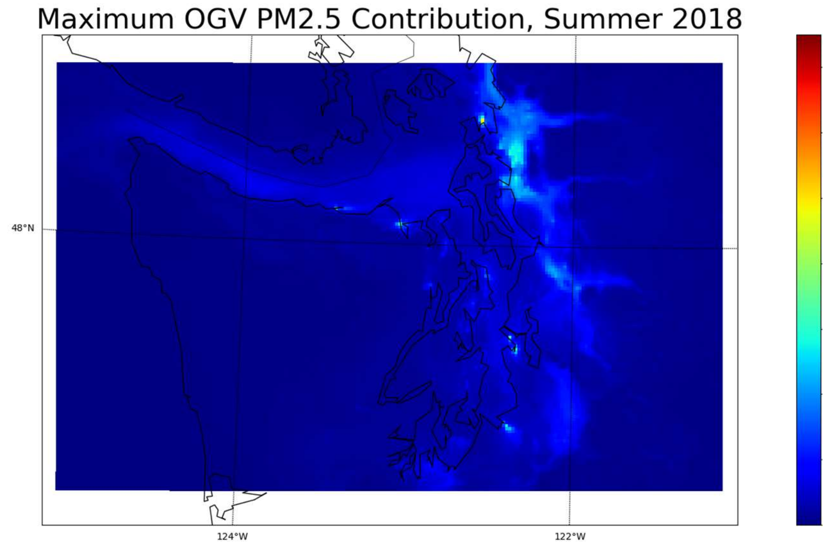


Max = 1.38 μg/m³

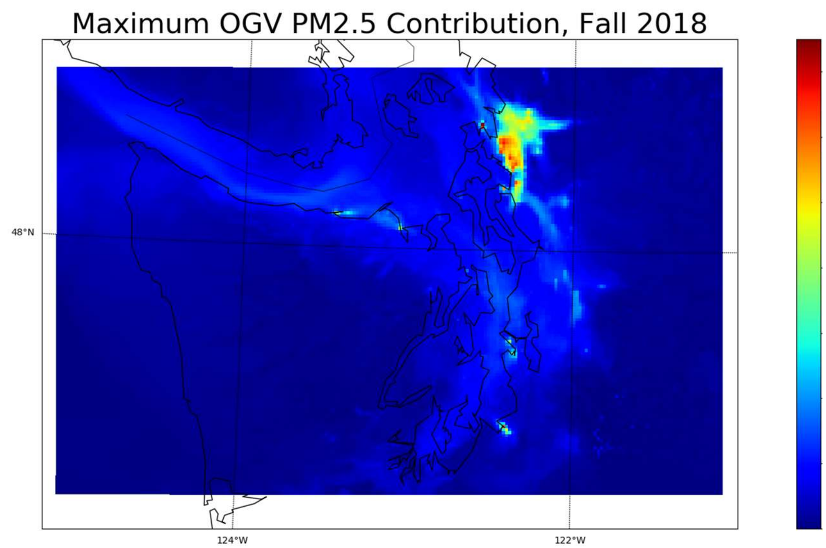
Maximum OGV PM2.5 Contribution, Spring 2018



Max = 0.72 μg/m³



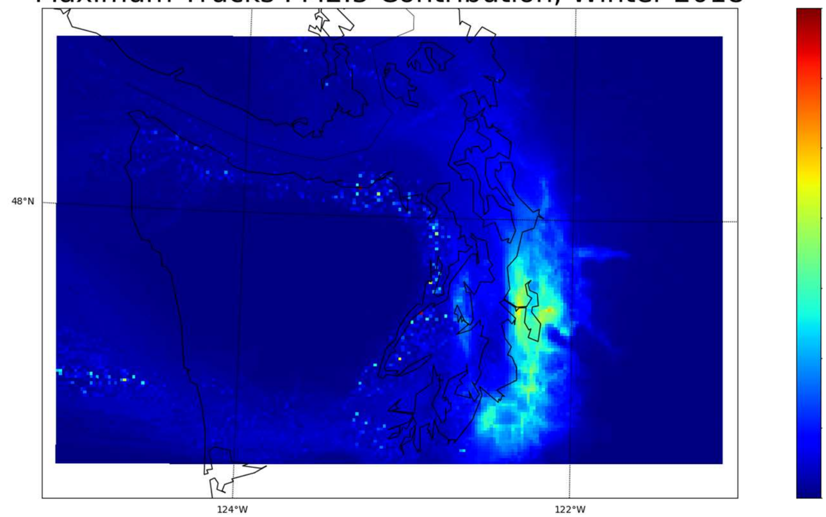
Max = 0.98 µg/m³



Max = 1.51 µg/m³

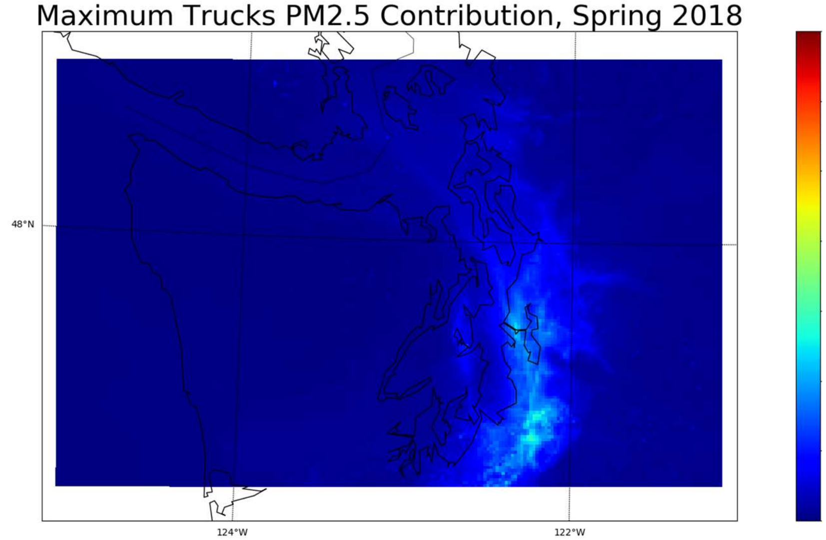
Trucks seasonal maximum $PM_{2.5}$ contributions, absolute values.

Maximum Trucks PM2.5 Contribution, Winter 2018

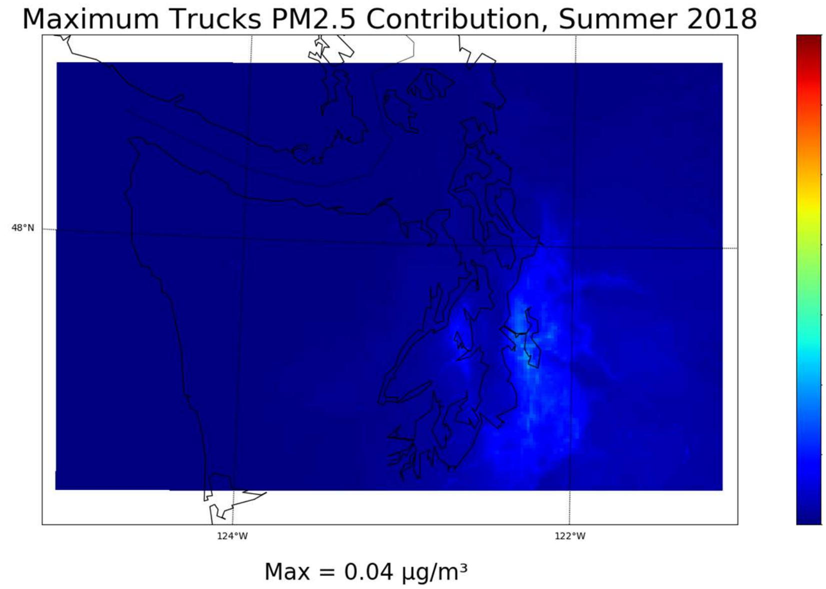


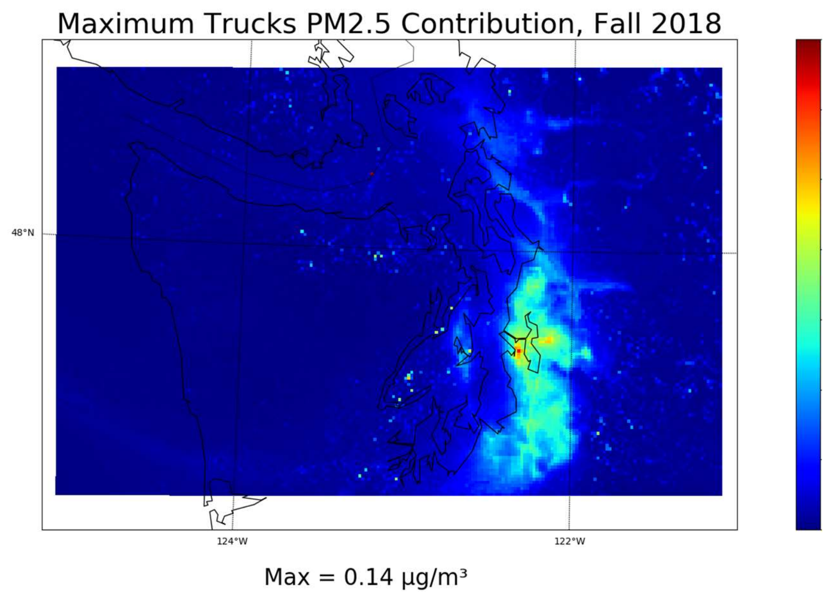
Max = 0.14 µg/m³

Maximum Trucks PM2.5 Contribution, Spring 2018



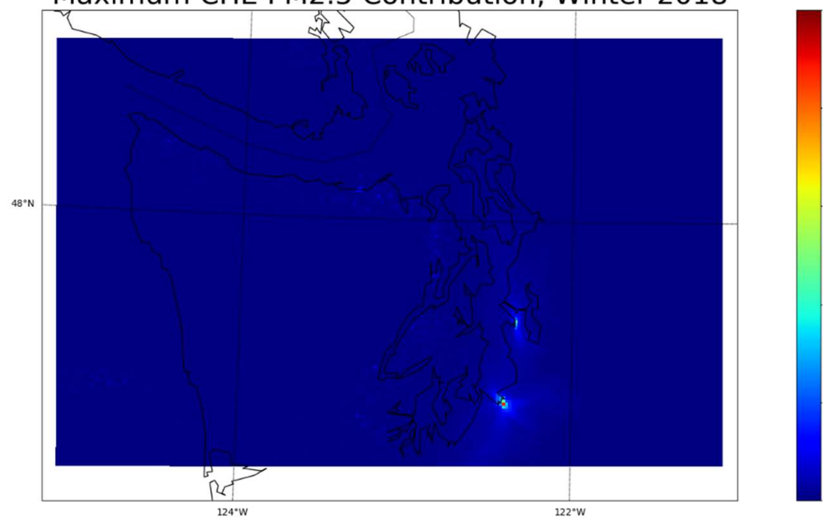
Max = 0.06 µg/m³





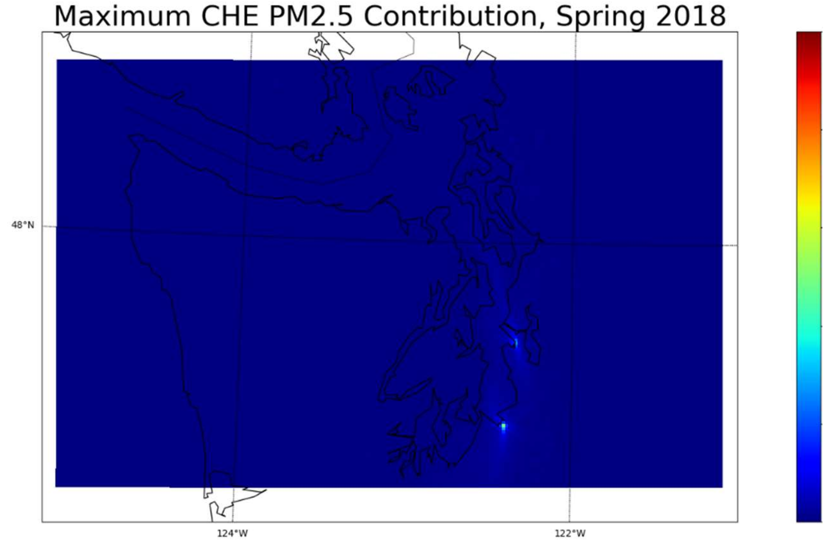
CHE seasonal maximum $PM_{2.5}$ contributions, absolute values.

Maximum CHE PM2.5 Contribution, Winter 2018

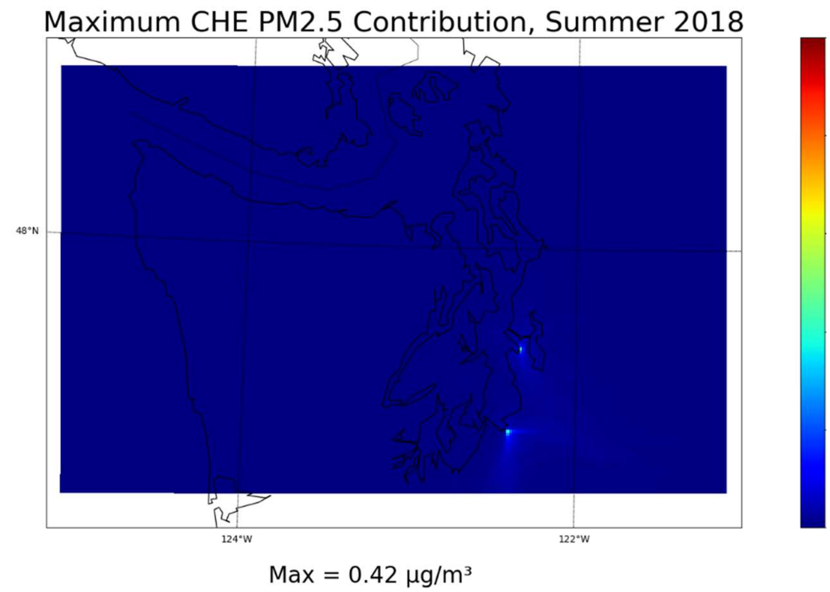


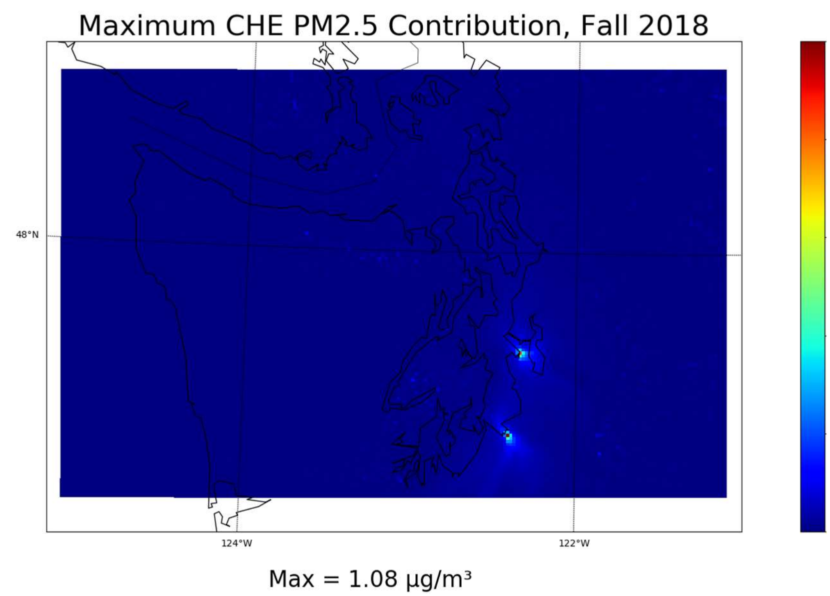
Max = 0.88 μg/m³

Maximum CHE PM2.5 Contribution, Spring 2018



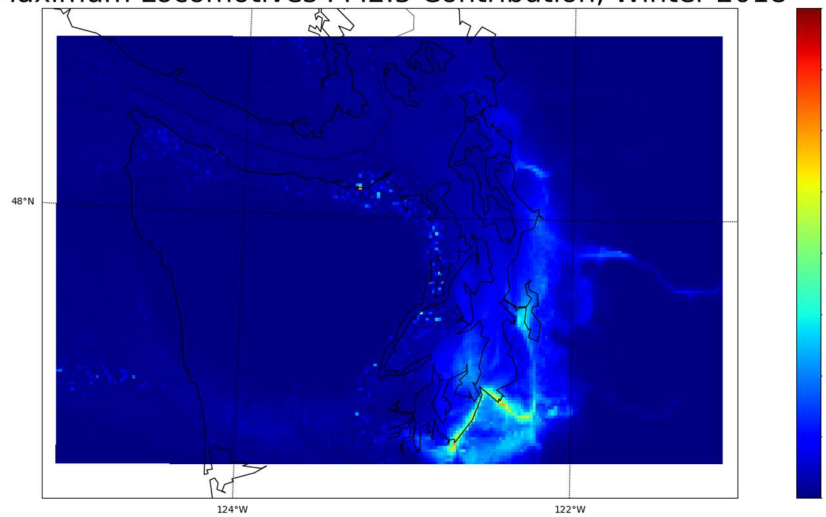
Max = 0.5 μg/m³





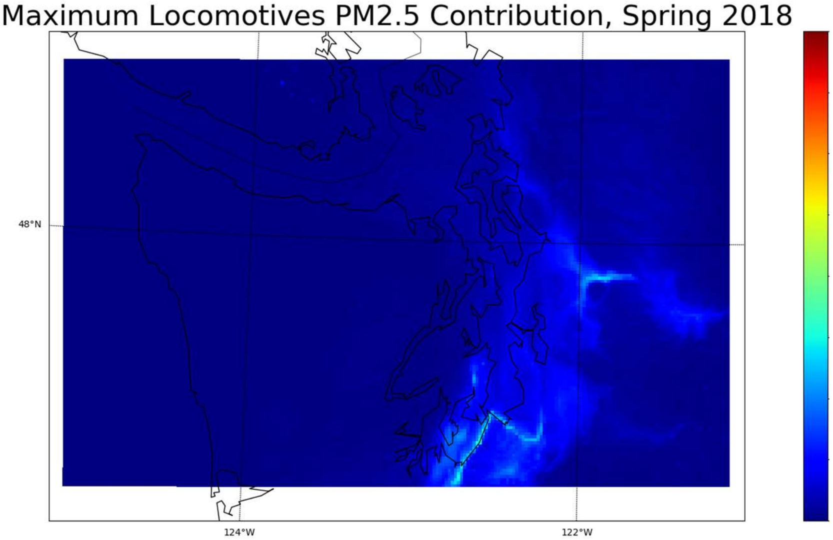
Locomotives seasonal maximum $PM_{2.5}$ contributions, absolute values.

Maximum Locomotives PM2.5 Contribution, Winter 2018

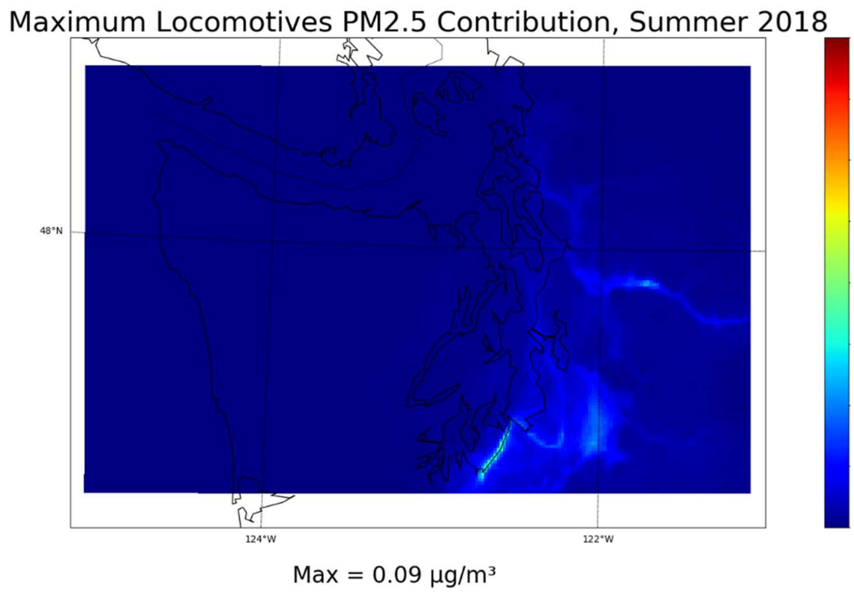


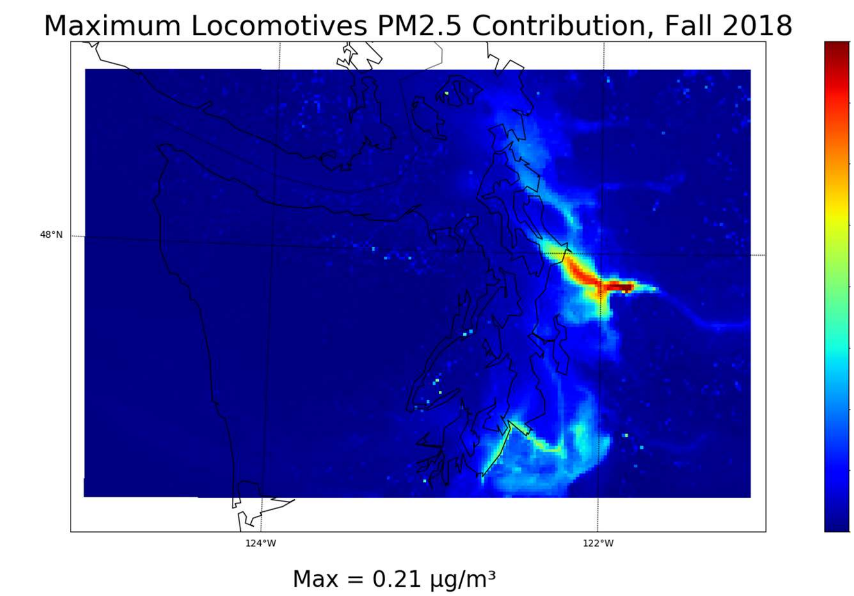
Max = 0.14 µg/m³

Maximum Locomotives PM2.5 Contribution, Spring 2018



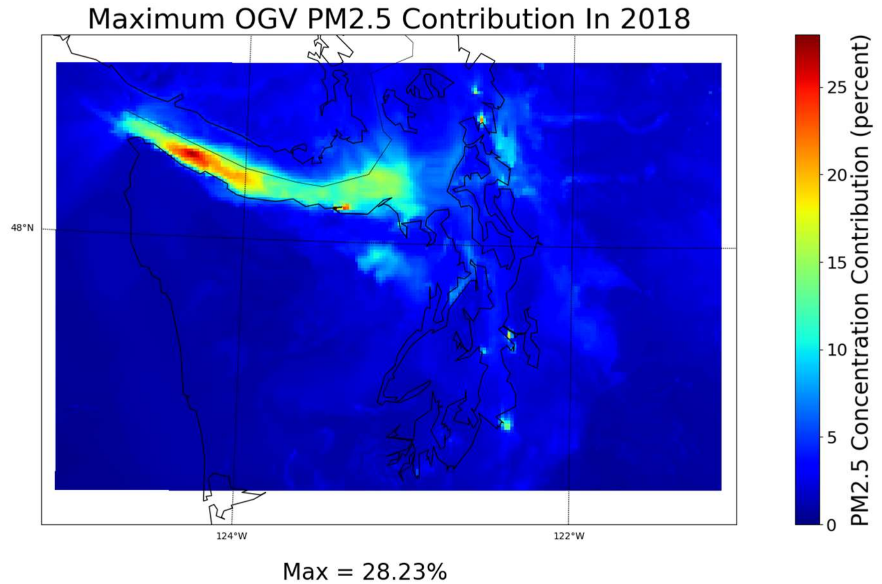
Max = 0.08 µg/m³



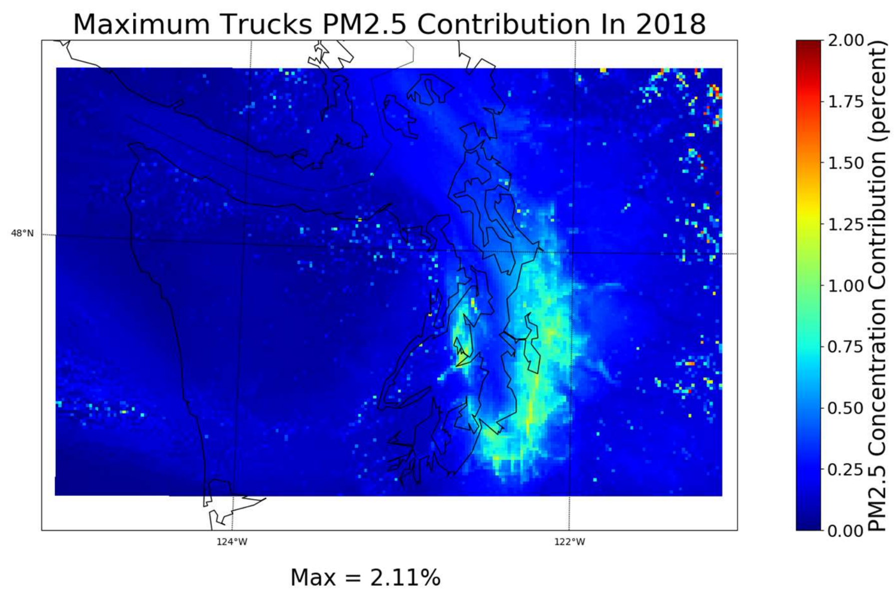


Appendix F. Ports-related sources annual maximum $PM_{2.5}$ contributions in percentage.

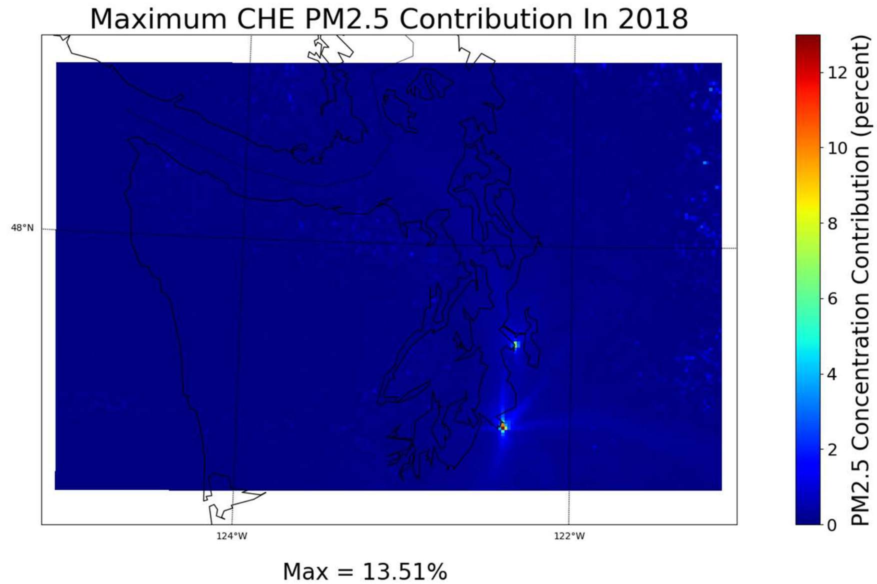
OGV annual maximum $PM_{2.5}$ contributions in percentage.



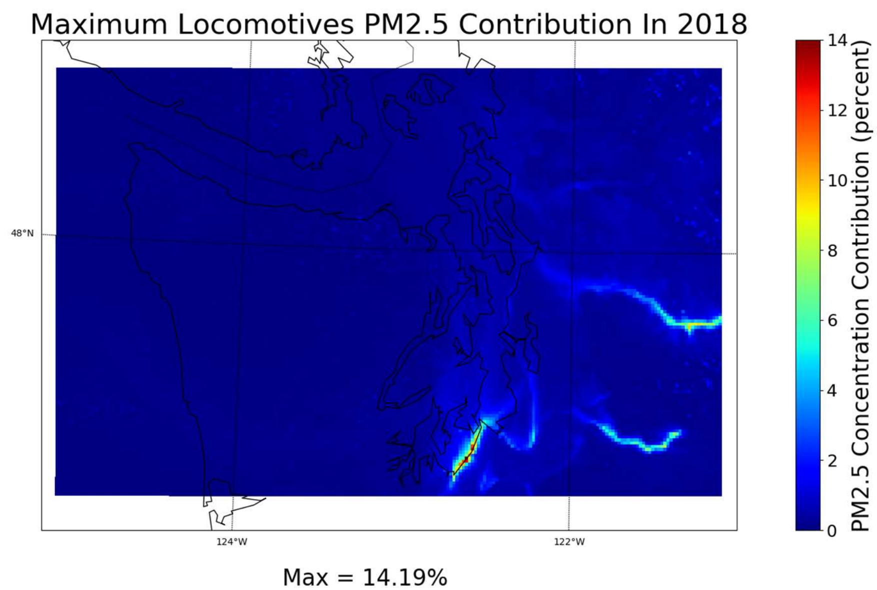
Trucks annual maximum $PM_{2.5}$ contributions in percentage.



CHE annual maximum $PM_{2.5}$ contributions in percentage.

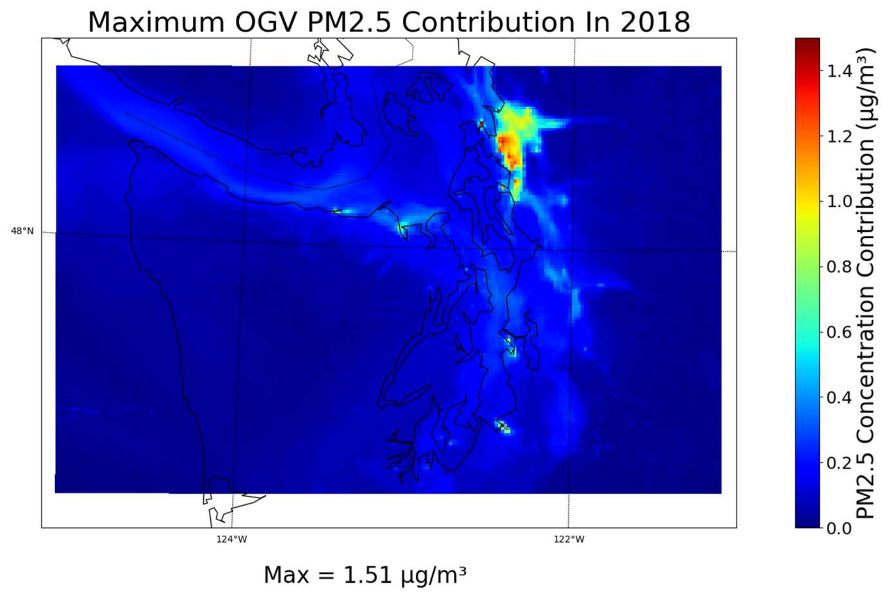


Locomotives annual maximum $PM_{2.5}$ contributions in percentage.

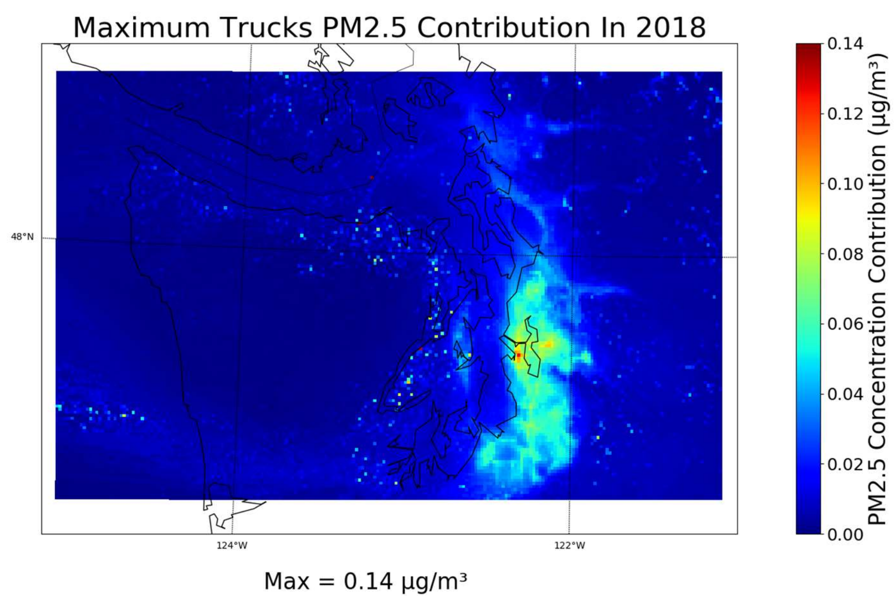


Appendix G. Ports-related sources annual maximum $PM_{2.5}$ contributions, absolute values.

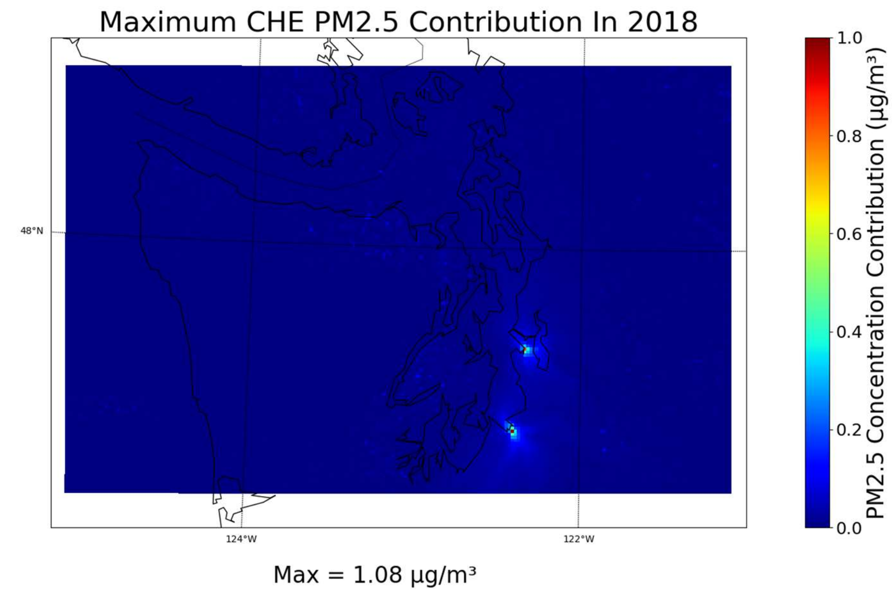
OGV annual maximum $PM_{2.5}$ contributions, absolute values.



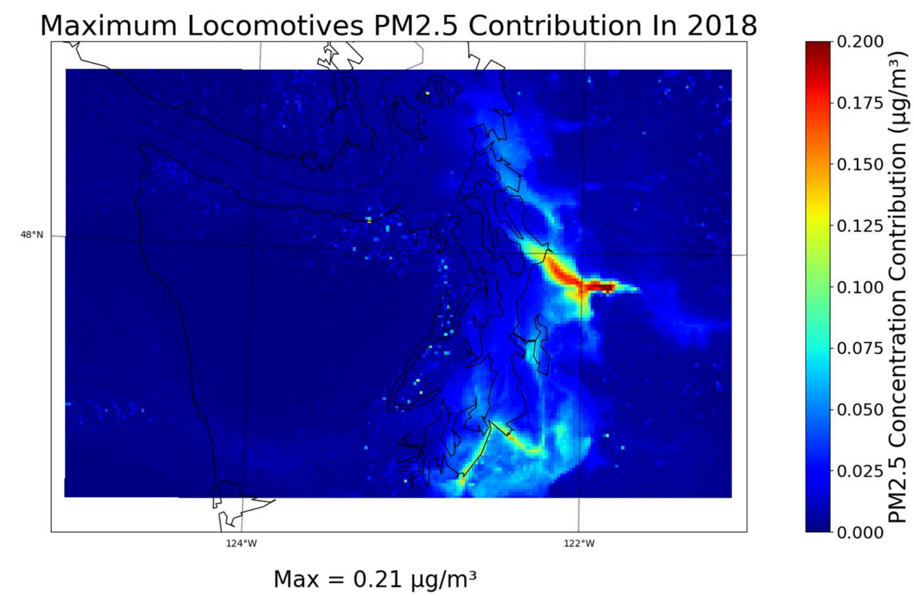
Trucks annual maximum $PM_{2.5}$ contributions, absolute values.



CHE annual maximum $PM_{2.5}$ contributions, absolute values.



Locomotives annual maximum $PM_{2.5}$ contributions, absolute values.



Northwest Ports Clean Air Strategy

2021-2025 Implementation Plan

THE NORTHWEST
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