Puget Sound Zero-Emission Truck Collaborative

Decarbonizing Drayage Roadmap

March 2025

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Executive Summary

The transition to zero-emission vehicles (ZEVs) serving ports in the Pacific Northwest is a key step to improve air quality, reduce greenhouse gas emissions, and reduce environmental health disparities in communities living near port terminals and along major freight corridors. The shift toward ZEVs is being driven by industry trends, technology innovation, new state and federal policies, and public and private investments. As this transition is happening, trucking companies and independent owner-operators—self-employed truck drivers who own their own trucks and operate as a small business—are considering the new opportunities and challenges of zero-emission drayage.

To ensure that this transition is just and equitable requires a carefully crafted, long-term strategy that creates economic opportunity rather than disruption for drayage drivers and companies. The Puget Sound Zero-Emission Truck Collaborative (Collaborative) has developed this Roadmap to help guide that strategy. Over the course of many meetings, sessions with drivers and communities, presentations from experts and businesses, and small group discussions, the Collaborative developed recommendations to support an equitable, reasonable, and successful transition that provides opportunity, cleaner air, healthy communities, and an improved environment.

Key Issues from Drivers and Communities

Throughout its work, the Collaborative heard from drivers and community groups about how they viewed the ZEV transition. These discussions underlined the potential benefits of ZEVs, including cleaner air, less noise, and healthier work environments. They also surfaced many issues and concerns that guided the Collaborative's work, including:

- **The higher upfront cost of ZEVs compared to current diesel vehicles,** including ZEVs' purchase price as well as costs related to charging and fueling, insurance, maintenance, and taxes.
- **Concerns about securing financing,** including the availability of appropriate and accessible loans, financing eligibility, and concerns about predatory loans.
- **Lack of information and training** about new vehicle technology and charging and fueling processes.
- **Risk for early adopters** due to uncertainties about technology, cost, vehicle durability and value over time, access to charging and fueling, and other issues.
- **The potential for drayage sector disruption in challenging economic times,** especially for independent owner-operators and small businesses that are particularly vulnerable to changes in the cost of doing business.
- **Impact on routes, timing, and logistics,** especially for battery electric vehicles given range limitations and charging times.
- **Availability, accessibility, and security of charging and fueling infrastructure,** which is currently lacking in the region. Charging and fueling facilities will require new land and utility infrastructure and will affect important issues like vehicle parking and traffic patterns**.**
- **Vehicle range and broader access to charging and fueling along freight corridors** for drayage drivers and companies that also carry freight for long trips.
- **Availability and cost of maintenance and emergency services as well as other auxiliary services like vehicle insurance,** recognizing the need to adapt services to new needs and requirements for ZEVs.

- **The additional weight of ZEVs and potential limits on loads due to weight regulations,** which may limit the types of drayage loads that ZEVs can carry.
- **Impacts of infrastructure and traffic in communities that are already overburdened** if charging and fueling facilities are not carefully sited and designed.
- **Disposal and recycling of batteries and tires,** including concerns about environmental impacts and the development of sustainable end-of-life solutions.

Recommendations

To respond to these issues, this Roadmap offers nearly 70 detailed recommendations related to vehicles, charging and fueling infrastructure, and equity and opportunity as outlined below.

Regarding vehicles:

- Bring ZEVs into cost-parity with diesel through financial incentives
- Pilot and demonstrate deployment of ZEVs and charging and fueling infrastructure in the region to test, educate and learn
- Catalyze a secondary ZEV market
- Provide alternatives to vehicle ownership
- Mitigate impacts of additional vehicle weight on drayage operations
- Ensure adequate vehicle maintenance and services
- Advance programs for residual battery and tire recycling and disposal
- Provide non-financial benefits for ZEV drivers at ports

Regarding infrastructure:

- Develop initial publicly available charging and fueling infrastructure, and ensure a mix of options over time
- Ensure adequate power supply and infrastructure from utilities
- Enable an appropriate role for hydrogen vehicles and fueling as zero-emission solutions

Regarding equity and opportunity:

- Ensure drivers and small companies have opportunities to adopt ZEVs but don't bear the risk of the transition
- Provide opportunities for drivers to test and understand ZEVs
- Provide driver and small business education, outreach, assistance, and ongoing engagement
- Engage communities regarding new facility siting and maximize community benefits
- Leverage the opportunity for the ZEV transition to create jobs

Priority Near-Term Actions

Within the broader set of recommendations, the Collaborative identified several priority near-term actions that will be critical to undertake in the next three years to set the ZEV transition in motion. These critical first steps are:

- **Effectively implement sustainable local, state, and federal vehicle and infrastructure incentive programs:** Through Washington state's medium and heavy-duty vehicle incentive program, the Northwest Seaport Alliance's incentive program, and others, ensure that stackable point-of-sale rebates

and other tax reforms and innovative financing are helping to make new ZEVs cost-competitive with new and used diesel vehicles and reducing the upfront cost of charging and fueling infrastructure. Aggressively pursue long-term sustainability and predictability of public funding for financial incentives.

- **Get initial ZEVs and infrastructure deployed in the region via demonstration projects:** Implement ZEV demonstration projects to gain experience with ZEVs in the region and catalyze early investments in vehicles and infrastructure. As part of this work, identify and engage "first movers" among supply chain partners and private sector entities who are most interested in helping to advance the transition to zero-emission drayage trucking.
- **Develop initial public charging infrastructure:** Provide opportunities for early adopters, including individual owner-operators and small companies that do not have the capital to establish their own charging infrastructure.
- **Engage in proactive utility planning:** Analyze and plan for future charging infrastructure needs. Advocate for policies that allow utilities to proactively develop infrastructure and programs that provide grid benefits from transportation electrification. Support initiatives that create a more robust grid to support large-scale electrification.
- **Actively engage drivers and communities:** Work with drivers to design and learn from incentive programs and demonstration projects. Engage communities about how to maximize local benefits and minimize impacts.
- **Provide technical assistance to fleets for vehicle adoption and infrastructure:** Support fleet managers and others to understand where shifting to ZEVs makes the most sense, how to transition fleets and build or access infrastructure most effectively, and how to connect with funding and programs that support the transition. Ensure that drivers and small companies have technical support to access financial incentives.

Additional actions valuable for accelerating and shaping the transition in the next three years are:

- **Lay the groundwork for secondary vehicle markets:** Implement used vehicle incentives and coordinated approaches for attracting used vehicles from California. Highlight opportunities through pilot deployment of used ZEVs in the region.
- **Provide opportunities for drivers to test out ZEVs:** Launch education, demonstration, ride-and-drive, and loaner programs for drayage drivers and smaller fleets to increase familiarity and reduce uncertainty about ZEVs.
- **Build local capacity for technical ZEV support:** Catalyze training and certification for ZEV maintenance, repair, and emergency services.
- **Advocate for operational and supply chain incentives for ZEV drivers:** Bolster financial incentives with operational incentives that improve access to terminals and warehouse. Help create buy-in and support from shipping and logistics companies that use the Puget Sound gateway.

The Path Forward

The work of the Collaborative affirmed that this is not an easy journey, but it is one very much worth taking. Like all maps, this Roadmap will be refined as we learn more about the landscape. The Collaborative is proud of its work together and looks forward to cooperating on the Roadmap's effective implementation.

1. Introduction

The transition to zero-emission vehicles (ZEV) serving ports in the Pacific Northwest is a key step to improving air quality, reducing greenhouse gas (GHG) emissions, and reducing environmental health disparities in communities living near port terminals and along major freight corridors. As a region, we have a window of opportunity to harness momentum toward zero-emission trucking, which is growing rapidly. Responding to industry trends, green supply chain initiatives, and new state and federal policies, truck manufacturers are ramping up their manufacturing and marketing of zero-emission trucks. Federal, state, and local governments are funding financial incentives for ZEVs and infrastructure. The private sector is investing in charging and fueling infrastructure. Utilities are planning for distribution system upgrades and increased loads as well as running programs to encourage charging infrastructure development and advise on conversions of fleets to ZEVs. Trucking companies and independent owner-operators (IOOs) are considering the new opportunities and challenges of a transition to zero-emission drayage. Shippers, ports, and others are calculating carbon emissions from their supply chains and developing plans for the role of zero-emission trucking as a carbon reduction strategy.

However, there is a large gap between the vision of zero-emission trucking and the status quo. While trends toward a future of zero-emission trucking are clear, *how* this transition happens in the drayage sector is critical. Significant challenges include social equity considerations, high capital equipment and infrastructure costs, and more. To be just and equitable, the transition will require substantial incentive funding until upfront acquisition costs are at parity with comparable diesel vehicles. It will also require significant investments in refueling, charging, and electrical distribution infrastructure to power vehicles. Navigating these needs and challenges requires a carefully crafted, long-term strategy rooted in the best available data, multi-stakeholder collaboration, and lessons from demonstration projects and related efforts throughout the country.

The Puget Sound Zero-Emission Truck Collaborative (Collaborative) was convened to develop such a Roadmap to help bridge the current state of port drayage in the Puget Sound region with a future zero-emission vision. The Collaborative aimed to develop clear actions to support a successful transition that meets the needs of industry, communities, and all involved by:

- Improving zero-emission truck availability and affordability in the Puget Sound region;
- Developing a robust network of accessible charging and hydrogen fueling stations;
- Ensuring an equitable transition for drivers, small businesses, and near-port communities; and
- Attracting sufficient funding and financing to the region for this work.

Success will provide cleaner air for disproportionately impacted communities and drivers. It will contribute to port, city, regional, and state decarbonization goals.

This Roadmap was developed in parallel with efforts to craft city and state policies to support the transition to zero-emission drayage and initiate demonstration projects for ZEVs in the region. It was informed by lessons from around the country, especially in and around California ports. The Roadmap is complementary to related efforts regionally and nationally to advance zero-emission trucking, including the federal government's 2024 *National Zero-Emission Freight Corridor Strategy*, which aims to catalyze investment to decarbonize the movement of freight and goods across the U.S.[1]

[1] See: https://driveelectric.gov/files/zef-corridor-strategy.pdf

The remainder of this introductory section describes the process by which the Collaborative developed this Roadmap. Section 2 lays out the context of the drayage sector serving Puget Sound ports, including key issues heard from drayage drivers and near-port communities. Section 3 outlines the fundamentals of zero-emission trucking—the vehicles, charging and fueling infrastructure, and cost comparisons with diesel trucks. Section 4 describes the principles that guided the work and the importance of getting the transition right. Section 5 provides a forecast of what the transition may look like and summarizes key priority actions to put the transition into motion.

The next sections outline the Collaborative's key recommendations related to vehicles (Section 6), charging and fueling infrastructure (Section 7), and equity and opportunity (Section 8). Section 9 estimates the cost of the transition and describes key current sources of funding. Section 10 outlines key roles and responsibilities for the many sectors and institutions that will drive the transition, and Section 11 describes the ongoing work of the Collaborative as a key place where coordinated work will continue. Section 12 concludes the Roadmap and describes the roles of Collaborative members in creating it.

Terms and Acronyms

- **ACT:** Advanced Clean Trucks rule
- **BEV:** Battery electric vehicle
- **CFS:** Clean Fuel Standard
- **Collaborative:** Puget Sound Zero Emission Truck Collaborative
- **EV:** Electric vehicle
- **FCEV:** Hydrogen fuel cell electric vehicles
- **GHG:** Greenhouse gas
- **IOO:** Independent owner-operator
- **MW:** Megawatt
- **NWSA:** Northwest Seaport Alliance
- **OEM:** Original equipment manufacturers
- **PNWER:** Pacific Northwest Economic Region
- **Roadmap:** Decarbonizing Drayage Roadmap
- **TCO:** Total cost of ownership
- **ZEV:** Zero-emission vehicle

Process

Puget Sound Zero-Emission Truck Collaborative

The idea for the Collaborative emerged from the Northwest Seaport Alliance's (NWSA) 2020 *Northwest Ports Clean Air Strategy,* which put forth a vision of phasing out emissions from seaport activities by 2050.[2] The strategy's implementation plan outlined key actions and milestones, including the creation of a regional collaborative group to guide actions for decarbonizing port-related trucking.[3] The complexity of the transition and the many organizations that would play a role necessitated engaging a broad set of stakeholders in this collaboration. NWSA secured funding from Washington State Department of Transportation (WSDOT) to launch the Collaborative and the Roadmap development process.

[2] See: https://www.nwseaportalliance.com/environment/clean-air/northwest-ports-clean-air-strategy
[3] See: https://s3.us-west-2.amazonaws.com/nwseaportalliance.com.if-us-west-2-or/2021-12/2021_12_NWSA_NWPCAS_Implementation_Plan_Stylized-LT-91CL273.pdf

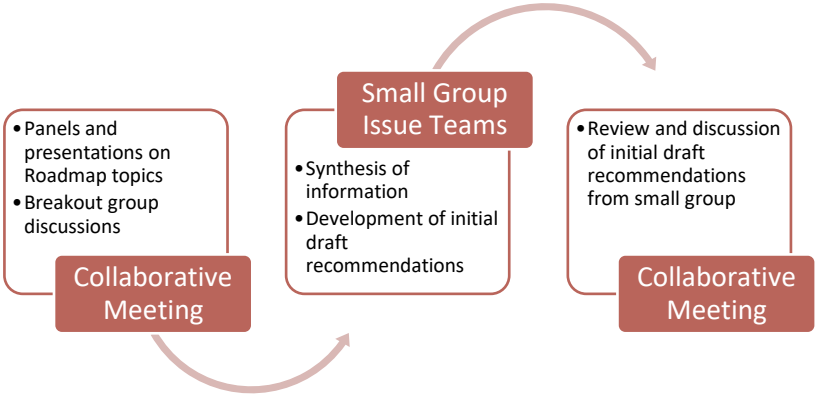
The Collaborative, whose work is ongoing, consists of members representing a diverse group of stakeholders involved in the transition to zero-emission drayage (see Appendix A). Members were identified by a small initial convening group with knowledge of key issues and sectors involved in port drayage. The full Collaborative met 11 times over approximately one and a half years (June 2023 to December 2024) to scope the Roadmap, delve into a range of issues, and identify the key findings and recommendations in this report (see Appendix B for a meeting schedule and topics).

To facilitate deeper discussion on topics considered by the Collaborative, small groups were formed on specific topics: vehicle affordability and access, infrastructure, equity, and funding. These groups met at the beginning of the process to scope priority issues, needs, and potential unintended consequences of the transition and brought these insights back to the full group. One or more small groups also met following each Collaborative meeting to refine key findings and suggest draft recommendations to the full Collaborative (see Figure 1). Small groups also convened to provide initial review and refinement of the recommendations in this Roadmap, which were then taken back to the full membership.

Members of the Collaborative represent a broad range of perspectives and interests:

- Utilities
- Tribes
- Economic development organizations
- Trucking companies
- Original equipment manufacturers (OEM)
- State, local, and regional governments
- Driver associations
- Charging and fueling providers
- Communities
- Academia and research
- Logistics
- Environmental organizations
- Ports
- Retail companies
- Environmental justice and equity organizations
- Labor interests

Figure 1. Iterative Small Group Process



For several of the Collaborative meetings, outside presenters joined discussion panels to share insights and inform the Collaborative's thinking. These included drayage drivers, trucking-as-a service providers, utilities, dealers, original equipment manufacturers (OEM), and shippers.

Driver Insights and Engagement

A key focus of the Collaborative was hearing from drivers and freight companies that would be significantly affected by the transition and are acutely aware of its potential benefits and substantial challenges. Serving on the Collaborative were representatives of the African Chamber of Commerce and Latino Metropolitan Chamber of Commerce, which represent heavy-duty drayage and medium-duty commercial drivers. They helped center discussions on the perspectives of small companies and IOOs in their communities. Collaborative members representing the Washington Trucking Associations, Mercer Logistics, and Total Transportation Services (TTSI) brought the perspective of trucking companies that have their own fleets, hire drivers, and contract out to IOOs. These members offered valuable first-hand experience of the drayage trucking business.

Early in the process, the Collaborative heard directly from a panel of drayage truck drivers in the region who shared their perspectives on the transition to zero-emission trucks. Drayage truck drivers that service the Puget Sound Gateway also participated in two driver listening sessions that were conducted in February 2024—one in Seattle and the other in Tacoma. These listening sessions focused on understanding truck drivers' perspectives on the transition to zero-emission trucks. Around 20 truck drivers attended, mostly IOOs. On average, participating drivers had over 15 years of experience in the trucking industry. Sessions were in person, with facilitators leading discussions in a relaxed setting, allowing for direct conversation. Trucker feedback covered various areas, including their awareness of zero-emission trucks, perceived benefits and challenges of the transition, needs for transitioning, and ideas to facilitate the process. These insights are discussed further in Section 2. A second set of driver listening sessions were held to review and discuss the Roadmap's draft findings.

To inform the Roadmap, NWSA also conducted an online survey of drayage drivers serving the North and South Harbors. Drivers took the survey during trucker appreciation events and through various communication channels, resulting in 129 responses. The survey aimed to inform multiple initiatives at the NWSA, such as programming for truckers and analysis of parking and driving habits. Key findings highlighted the diversity of the trucker community, particularly in terms of race and language (for example, English was not the first language of most respondents). The survey also sought to understand respondents' operations, such as fleet size and parking habits, which are further described in Section 2.

The work of the Collaborative also drew on driver engagement insights from related projects. This included presentations from the Pacific Northwest Economic Region (PNWER) and WSDOT on the design of Washington's medium- and heavy-duty ZEV incentive program, which involved extensive outreach to trucking companies, drivers, and other stakeholders. It also included presentations from the City of Seattle and the Somali Independent Business Alliance on lessons learned and engagement strategies from the City of Seattle's heavy-duty vehicle electrification incentive pilot project, which was advised by a committee of drayage trucking drivers organized by the African Chamber of Commerce.

Community Insights and Engagement

Another key focus of the Collaborative was hearing from near-port communities about how they saw potential benefits and challenges of a shift to zero-emission transportation. North and South Harbor communities were represented on the Collaborative by the Duwamish River Community Coalition (Seattle) and Communities for

Listening sessions with the following community-based organizations informed the work of the Collaborative:

- South Park Neighborhood Association
- Georgetown Community Council
- West Seattle Transportation Coalition
- District 1 Community Network
- Climate Alliance of the South Sound

a Healthy Bay (Tacoma). In an early meeting of the Collaborative, these representatives helped anchor discussion in the history and composition of near-port communities and highlight the benefits of improved air quality as well as potential challenges for communities. Meetings held by NWSA and the consulting team with several community organizations in the North and South Harbors informed the Collaborative's work (see call-out box). Issues heard from community conversations are discussed further in Section 2.

Related Research

Development of the Roadmap benefited from research presented to the Collaborative. Tetra Tech conducted a study on drayage vehicle movement and potential infrastructure needs for zero-emission drayage trucks. The study utilized Streetlight data to analyze route trends, drayage behaviors, and dwell locations to suggest potential infrastructure development areas.[4] The analysis aimed to enhance understanding of where trucks go, work, and stop long enough for potential charging. It involved a tiered analysis of truck behaviors, focusing on regional traffic patterns and port-to-port movements to determine critical locations for ZEV infrastructure. The study identified specific regions and traffic patterns, suggesting where infrastructure could be most beneficial. The Collaborative discussed the study during its March 2024 meeting. Section 2 presents key results of the study.

Throughout the process, support team member GNA (now a TRC Company) brought research and insights from the zero-emission drayage experience in California and elsewhere to the Collaborative. GNA has long been involved in West Coast clean transportation initiatives, including almost 20 years of working with the Ports of Los Angeles and Long Beach on their Clean Truck Programs and other low- and zero-emission technology programs. GNA has long-standing relationships with North America's truck manufacturers, fleet operators, trade associations such as the Pacific Merchant Shipping Association, local governments, and regulatory agencies working on major zero-emission truck and infrastructure projects and clean transportation initiatives.

GNA has been at the forefront of many of the largest zero-emission truck and infrastructure projects to date and has helped to secure nearly $2 billion in incentive funding to implement these clean fleet acquisitions in California and throughout North America. The company produces the annual Advanced Clean Transportation Expo, which is North America's largest trade show and conference that brings together more than 12,000 industry stakeholders, including the industry's top executive-level leaders, more than 400 sponsors and exhibitors of clean fuels and vehicle technologies, and top fleet operators to discuss the state of the industry and to enhance collaboration and implementation of zero-emission trucks and transportation technologies. Drawing on this comprehensive market engagement, GNA's analysis for this Roadmap included research on the types of zero-emission trucks coming into the market, analysis of total cost of ownership, the range of charging and fueling infrastructure options, how to develop secondary markets for used zero-emission trucks, the estimated cost of the transition, and more.

Roadmap Development and Review

The Collaborative took an iterative approach to developing the findings and recommendations in this Roadmap. Early in the process, Collaborative members identified key issues that informed topical programming for the Collaborative's subsequent meetings. As members focused on specific topics during each meeting, their discussions informed a set of key findings and recommendations. After approximately a year of meetings, these

[4] Streetlight is a company that specializes in providing advanced data analytics and insights for transportation planning and mobility analysis, utilizing big data and machine learning to help organizations make informed decisions about infrastructure and urban development.

findings and recommendations were synthesized into a draft Roadmap report, which was further reviewed and refined by the Collaborative and small groups and informed by driver and community input.

2. Drayage Sector Context

Port drayage is the movement of cargo containers from a port to another location, often a warehouse or rail ramp within the same local area. These short hauls are an integral component of the freight supply chain. There are approximately 4,500-5,000 drayage trucks currently serving the NWSA cargo terminals in Seattle and Tacoma.

The transition to ZEV drayage trucks is a necessary step to reduce air pollution, greenhouse gases, and environmental health disparities associated with diesel drayage vehicles at ports—as well as a significant challenge. Some aspects of drayage lend themselves to the transition because the drayage duty cycle is generally well-aligned for the performance of today's zero-emission trucks. Trips are usually short and regional in nature, so vehicles can operate all day on one charge or fill up with hydrogen. Drayage generally follows predictable routes, making optimal siting of charging and fueling infrastructure potentially less difficult than for long-haul trucking. Vehicles operating within the NWSA gateway are generally idle during the night, allowing for overnight charging. Utility infrastructure to support charging is often more well-developed in the urban and industrialized locations of ports and distribution centers compared to more remote locations (although utility infrastructure varies from site to site even in industrialized areas). These aspects of the drayage duty cycle make it an appealing place to start the overall transition to ZEV trucking.

However, the drayage market also presents significant challenges as an early focus of the ZEV transition. It is comprised of many small companies and IOOs that may not have the capital to invest in expensive zero-emission trucks and infrastructure. Drayage operators often purchase used diesel trucks from the secondary market, which creates an even larger gap between the price of their typical diesel trucks and that of a new ZEV. Markets for used ZEVs have not yet developed. Operators are also vulnerable to early uncertainty and risks related to vehicle technology, maintenance capabilities, charging and fueling access, resale value, and more limited duty cycles. Recent economic downturns in the drayage sector at the ports of Seattle and Tacoma have further hampered owners' ability to purchase more expensive vehicles.

Given these market dynamics, the ZEV transition will likely only work for a small number of large, well-capitalized fleets unless programs are in place to make ZEVs more broadly accessible. Ignoring these dynamics risks concentrating the sector in fewer, larger companies and causing losses of economic opportunity for those currently providing drayage services at the NWSA gateways. This Roadmap offers several recommendations to make ZEVs more accessible and affordable, including various types of financial incentives and accelerating markets for lower cost used ZEVs.

Profile of Drayage in the Northwest Gateway

The Ports of Seattle and Tacoma are one of the busiest cargo gateways in North America. They play a central role in the economic vitality of the Puget Sound region and the State of Washington. Cargo operations managed by the NWSA in Seattle and Tacoma support nearly 60,000 jobs and more than twelve billion dollars in economic activity. The success of these cargo operations depends heavily on the network of drayage trucking companies that provide cargo-hauling services to and from NWSA terminals. Nearly 80 percent of the cargo flowing through those terminals is moved by trucks (versus trains).

The international cargo industry in North America is highly competitive. Pacific Coast ports in Washington, California and British Columbia compete with each other, and West Coast ports compete with ports along the Gulf Coast and East Coast of the U.S. About 70 percent of the cargo flowing through the NWSA's terminals is "discretionary," meaning it is not serving local consumers but is on its way to other regions of the country, and it could flow through other ports where costs are lower. Some of these competing ports enjoy distinct competitive advantages. For example, ports in British Columbia are agencies of the federal government and therefore receive steady and significant federal government support. Similarly, California ports—due to long standing state policies and programs—receive much more state funding than has historically been the case in Washington. For these reasons, the ports and supply chain partners in the Puget Sound region and Washington state must carefully manage the overall costs of doing business to sustain competitiveness, including the cost of drayage trucking services.

The drayage sector serving Seattle and Tacoma ports is diverse, from large fleets owned by national and international companies to IOOs with a single truck. Over half of the drivers responding to NWSA's driver survey were IOOs, and the vast majority had just one truck (see call-out box). Given the diversity of the sector, there is no "one size fits all" solution to make vehicles affordable, available, and appropriate.

Nearly 90% of the trips coming in and out of the ports are in trucks newer than 2010. These model year engines were required to meet updated federal emissions standards that significantly reduced tailpipe emissions. The replacement of older diesel trucks in the NWSA gateways was a result of commitments in the *Northwest Ports Clean Air Strategy* and was encouraged by replacement and scrappage programs.

Drayage drivers participating in a panel for the Collaborative said they usually travel 100-250 miles per day for local drayage routes, which is within the range of most battery electric trucks. The majority of the drivers in the listening sessions said they visited NWSA marine terminals two to three times a day. Many drivers are paid per 'turn' or container moved. Most NWSA cargo terminals operate from 7:00 am to 4:00 pm on weekdays, and this schedule governs drayage work patterns.

NWSA Driver Survey

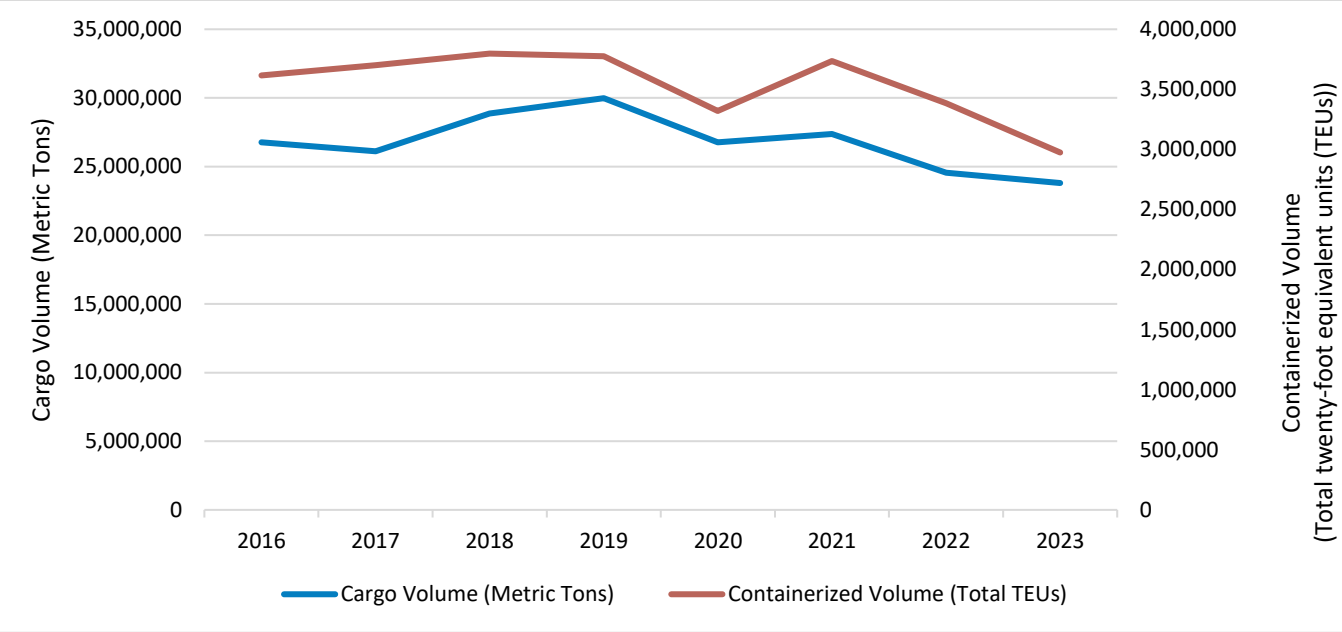
In Fall 2023, NWSA gathered information from drivers on a number of issues through an online survey and via outreach at events like Trucker Appreciation Week. NWSA received survey responses from 129 drivers. Approximately 60% were owner-operators and 40% were employee drivers. The majority (55%) had just a single truck, 35% operated fleets of 5 to 25 trucks, and 10% operated fleets greater than 25 trucks. Among other findings, the survey found that 67% of respondents park overnight in trucking company yards, warehouse yards, or secure overnight parking facilities. Twenty percent park on the street overnight and 9% at home (the remaining respondents answered "other"). The survey was not a census or scientific sample of the full population of drayage drivers serving the Gateway, but results align with other anecdotal evidence about the large number of IOOs and small businesses serving the ports, and they suggest the opportunity to charge vehicles while parked overnight in company yards and parking facilities.

Drayage trucks typically carry containers to and from warehouses in the surrounding areas, such as South Seattle, Tacoma, the Kent Valley, Sumner, Tukwila. Some drivers only conduct short haul drayage, but others conduct a mix of short- and long-haul. For example, several drivers in the listening sessions said they also do long-haul trips to and from eastern Washington (e.g., carrying agricultural products across the mountains to the NWSA gateways) and/or to and from nearby states.

Economic Trends

In driver listening sessions and Collaborative conversations, drivers and fleet owners highlighted that this is a difficult economic time for drayage—with reduced demand for services and downward pressure on rates. As shown in Figure 2, containerized volumes and total cargo volumes have declined over the last several years at the Puget Sound Gateway compared to pre-pandemic levels. This is based on a number of factors such as intense competition with other ports and Canadian rail rates as well as slow recovery of post-pandemic international trade. Economic uncertainty exacerbates concerns about taking on the new financial commitments and risks of transitioning from a diesel vehicle to a ZEV. Higher costs are passed on to customers, making services less competitive.

Figure 2. NWSA Cargo Volume History



Sources: The Northwest Seaport Alliance 5-Year Cargo Volume History: https://s3.us-west-2.amazonaws.com/nwseaportalliance.com.if-us-west-2-or/2024-06/NWSA-5-Year%20History%20YTDMay24.pdf and The Northwest Seaport Alliance 2020 Annual Trade Report: https://s3.us-west-2.amazonaws.com/nwseaportalliance.com.if-us-west-2-or/s3fs-public/2021-04/2020%20NWSA%20Annual%20Cargo%20Report.pdf

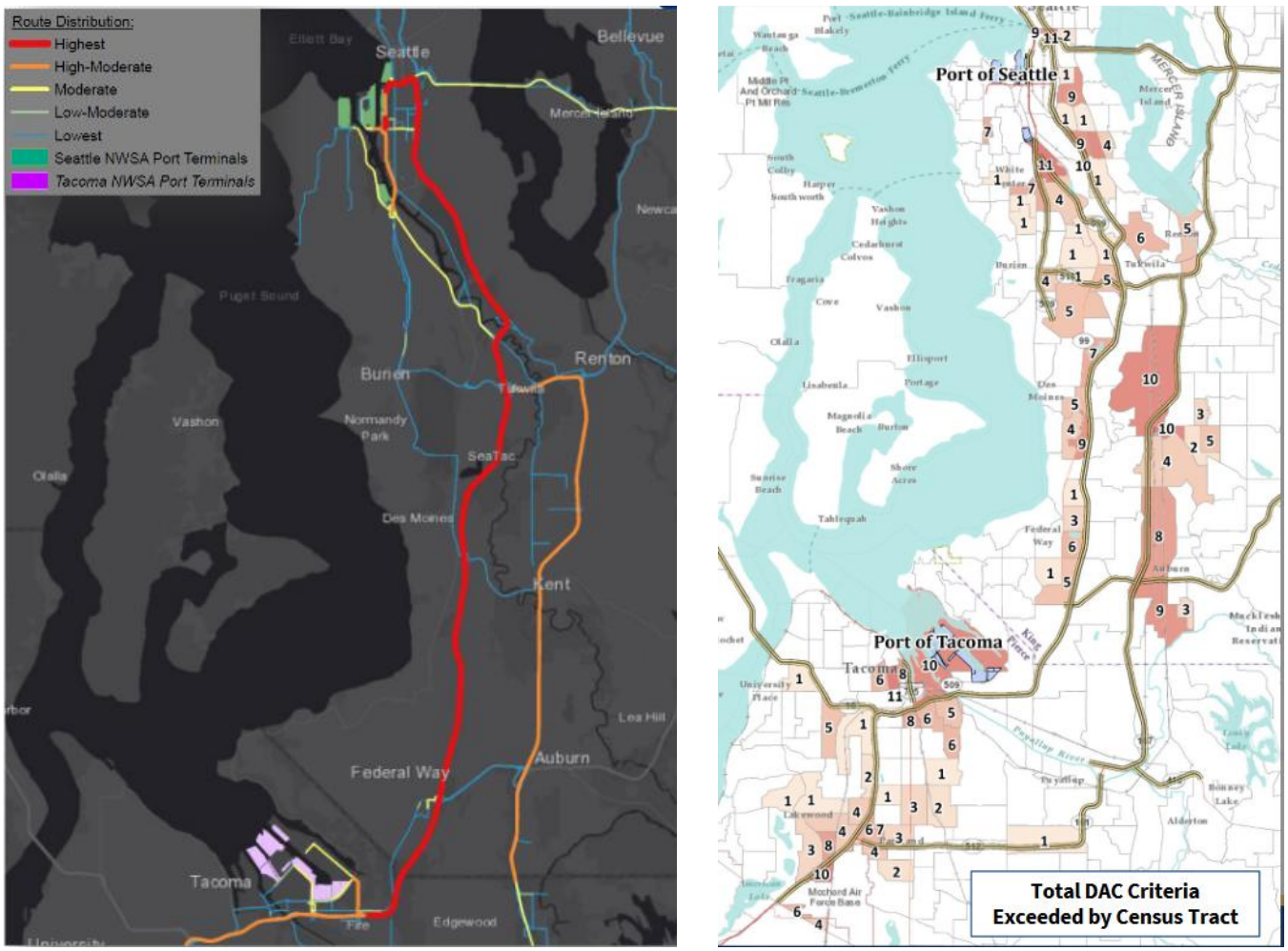
Drayage Routes

The Collaborative's understanding of drayage routes and dwell locations was informed by the Tetra Tech study, the lived experience of Collaborative members, and insights from outreach to drivers and communities.

The Tetra Tech study showed that the highest concentration of drayage traffic moves between Tacoma and Seattle ports along the I-5 corridor (see red line in Figure 3, left side). These port-to-port drayage routes run through communities where reducing criteria air pollutants would improve air quality for highly impacted communities (see shaded areas in Figure 3, right side).[5]

[5] Numbers in the map refer to the number of criteria exceeded that reflect overburdened and underserved communities using the Climate & Economic Justice Screening Tool: https://screeningtool.geoplatform.gov/en/#3/33.47/-97.5

Figure 3. Port-to-Port Travel Patterns and Census Tracts with Overburdened and Underserved Communities



Source: Tetra Tech Truck Operational Analysis, presented to Collaborative on March 27, 2024: https://www.rossstrategic.net/Zero-Emission-Truck-Collaborative/docs/Slides%20Meeting%206%20March%2027%202024.pdf

Origin and destination data, as well as information about dwell times at warehouses, distribution centers, and other facilities at the north and south ends of these routes, suggest that Fife, Sumner, and Tukwila are promising locations for public and private charging and fueling infrastructure (See Figure 4). The volume of drayage trips along the I-5 corridor also suggests opportunities for infrastructure in the Kent Valley, which hosts many warehouses and distribution facilities. During driver listening sessions and panels, drivers indicated a preference for charging on or near port properties, which would cause little disruption to their normal drayage routes and potentially provide the opportunity to charge or fuel while queuing to pick up loads. Collaborative members indicated that charging or fueling within the physical boundaries of port terminals would be impractical given hours of operation and likelihood of increased congestion. However, port properties near terminals may be appropriate for charging and fueling infrastructure.

Figure 4. Tukwila, Fife, and Sumner

Source: Tetra Tech Truck Operational Analysis, presented to Collaborative on March 27, 2024: https://www.rossstrategic.net/Zero-Emission-Truck-Collaborative/docs/Slides%20Meeting%206%20March%2027%202024.pdf

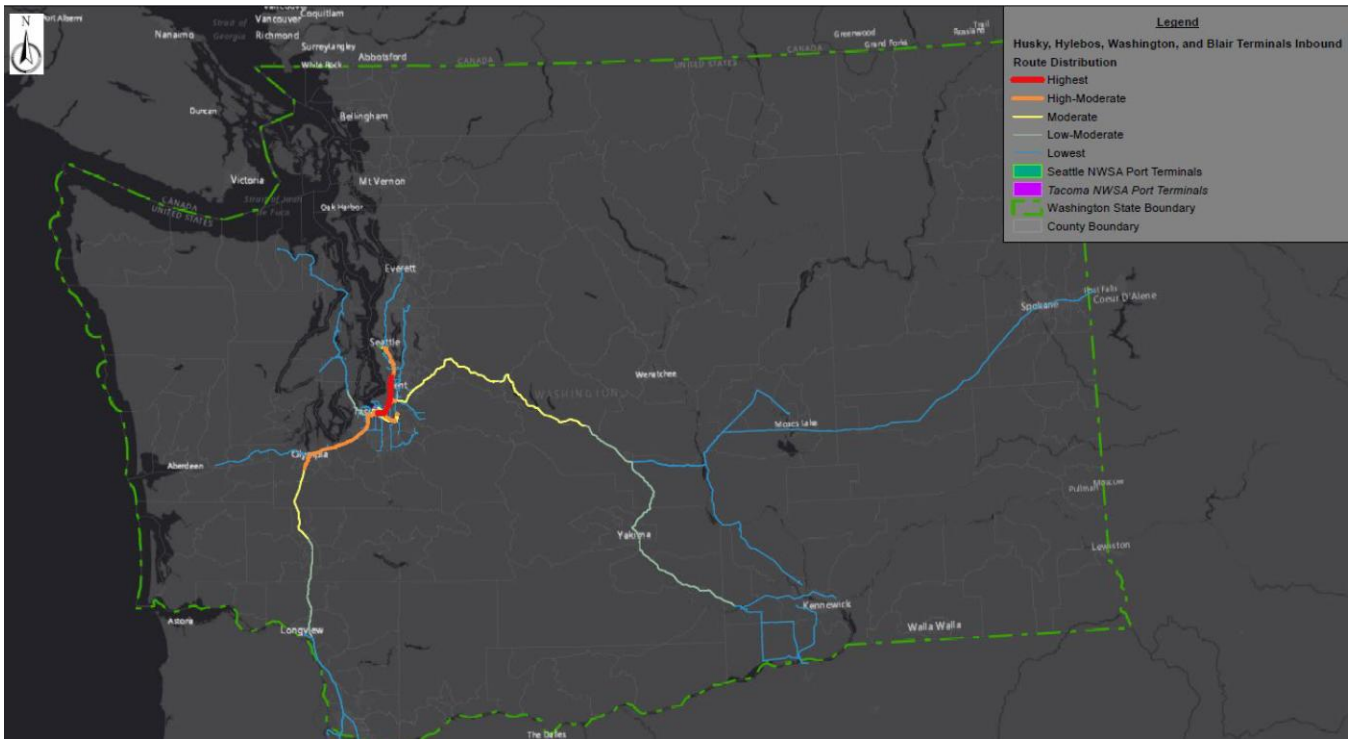
While publicly available infrastructure will be an important component of a charging and fueling network, much charging and fueling will likely take place "behind-the-fence" at privately-owned facilities on company property (mostly overnight). As noted above, most drivers responding to NWSA's survey—the majority of whom were IOOs—indicated they park overnight in trucking company yards.

At least initially, drivers utilizing other parking locations, such as street right-of-way parking, may not be well-served by public charging and fueling facilities or private facilities on company lots. Unsecured charging and fueling facilities—and the vehicles using them—may also be subject to theft and vandalism. Other solutions will be needed to serve these drivers and concerns.

Some drayage drivers and companies do both short drayage routes and broader regional travel. For those that transition to zero-emission trucks, it will be important to have both local charging and fueling as well as a broader regional network. According to the Tetra Tech study, most trips originating at Seattle and Tacoma ports

travel the I-5 corridor, with far fewer trips along other regional routes. Those that travel regional routes, typically take the I-90 and SR-18 routes heading east over Snoqualmie Pass to Ellensburg and beyond, and I-5 south to Olympia, Centralia, Chehalis, and beyond (see Figure 5).

Figure 5. Analysis of Regional Traffic Patterns from Ports of Tacoma and Seattle



Source: Tetra Tech Truck Operational Analysis, presented to Collaborative on March 27, 2024: https://www.rossstrategic.net/Zero-Emission-Truck-Collaborative/docs/Slides%20Meeting%206%20March%2027%202024.pdf

Driver Benefits and Concerns

Through driver panels, listening sessions, the driver survey, and insights from related processes, the Collaborative heard about potential benefits of the transition to ZEVs and a broad range of concerns. Drivers recognized the potential benefits of zero-emission trucks, including cleaner air, less noise, and a healthier work environment. They liked the idea of having a new, high-performance vehicle and avoiding high and volatile fuel prices. However, they also had several concerns outlined below.

Vehicle cost and availability: The cost of purchasing zero-emission trucks was the most frequently cited concern among drivers. Drayage drivers that are small business owners and IOOs typically own or lease used diesel trucks that cost $30,000-$90,000 depending on the year, mileage, and brand. New diesel trucks cost approximately $150,000-$180,000. In contrast, new electric trucks can cost approximately $400,000-$600,000, and new hydrogen-fueled trucks can cost approximately $500,000-$700,000.

In addition to the upfront cost of a ZEV, there are additional (and uncertain) related costs, including:

- *Higher insurance costs* due to the higher value and specialized maintenance requirements of zero-emission trucks. For the insurance industry, risk calculations are difficult because there is not yet much experience with ZEVs, which impacts the availability of insurance and its cost.

- *Maintenance and repair costs*, which are uncertain due to new technologies. Some drivers expressed concern that while routine maintenance needs may be less frequent, repair costs will be high due to specialized equipment and may take longer, impacting business while vehicles are in the shop.
- *Ambiguity about how charging and fueling costs will be passed on to shippers*. Currently, diesel costs are passed on to shippers as a fuel surcharge.
- *Uncertain charging and hydrogen fueling costs*. While these could be less costly and less volatile than diesel fuel, there is no experience yet in the region about actual costs. Hydrogen vehicle fuel in California has been significantly more expensive than gasoline and diesel.
- *The cost of various fees and permits* that may be required due to additional weight or other characteristics of zero-emission trucks.
- *State and federal sales taxes and potential tax impacts from financial incentive programs* that may be taxed as additional ordinary income. For example, should an operator receive a $400,000 grant for a zero-emission truck, the tax liability could be more than $125,000. Additionally, the higher tax rate on this "additional income" will then likely also be applied to the operator's base drayage income.

Along with high cost, limited maintenance and repair resources exist in the region for ZEVs and will need to be developed as ZEV deployments grow.

Drayage sector disruption in challenging economic times: Generally, drivers indicated unease with the cost and potential disruption of the transition to ZEVs and the potential loss of livelihoods for independent drivers and small businesses. Many drivers are immigrants looking to establish an economic foothold in the U.S. They turn to drayage as a sector providing a clear point of entry for small operators to own a business that can support their families.

These IOOs and small businesses are particularly vulnerable to changes in the cost of doing business and operational disruptions that may limit their ability to deliver loads during the day. Several drivers expressed concern that the shift to ZEVs would favor larger, well-capitalized companies and lead to industry consolidation that forces independent and smaller operations out of the business. Some of the driver's caution comes from a historical lack of trust in the ports and government agencies and strained relationships over other operational concerns and past programs requiring cleaner diesel trucks.

Lack of information and training: Because there are currently no zero-emission drayage vehicles operating in the NWSA gateway, most drivers don't have direct experience with them, nor with the process for charging or fueling. Many approach the issue with skepticism and lack of confidence in the performance of new technologies and new operational requirements.

There is little direct experience to answer key questions drivers have about operating ZEVs. This includes what maintenance needs are, the useful life of batteries, and how well ZEVs will operate on their typical routes. There are also significant questions about what kind of maintenance these new technologies require, and how much – if any – of this maintenance can be performed by the drayage operators themselves (a common practice) rather than having to use more expensive outsourced maintenance services provided by large truck brand dealers.

Several drivers said they would like to hear lessons directly from people using ZEVs in practice rather than the companies selling them. They suggested training (multi-lingual) and demonstration programs to increase familiarity and understanding.

Risk for early adopters: IOOs and small business expressed concern about them taking on the risk of new technology and business operations. They said larger trucking companies should bear these risks. If the zero-

emission trucks work for the bigger companies and the infrastructure is in place, IOOs and smaller operations will be more likely to adopt them. Also, when they start seeing them on the road, they will feel more comfortable with the technology.

Value of ownership: The Collaborative heard that some drivers strongly prefer to own their trucks and others were open to other models like leasing if that would be more cost-effective. Those preferring ownership said it provides flexibility and independence. For IOOs and small businesses, trucks are often their largest capital asset. Some expressed concern about the cost of leasing or related models and the challenge of having fixed payment obligations when drayage income is uncertain and fluctuating.

Other drivers were more open to alternatives to ownership, like leasing. They indicated that they look at the total cost of ownership over time and will choose the lowest cost option regardless of whether it involves ownership.

Financing: Drivers noted concerns about securing financing for purchasing electric trucks, including issues related to:

- Availability of appropriate and accessible loans at the levels required to afford zero-emission trucks
- Complexity of incentives and financing opportunities
- Eligibility for financing due to low credit ratings
- Concerns about predatory loans
- Cost of early termination of financing for current vehicles
- Tax implications of vehicle financing approaches (e.g., taxes on large grants or incentives and potential increased tax rates on base income)

Drivers advocated for accessible financing with low or zero interest rates. For some, financing challenges made leasing or other non-ownership arrangements more attractive.

Impact on routes, timing, and logistics: Drivers cited the potential inconvenience and constraints on route planning and delivery schedules due to vehicle range limitations, charging and fueling location, and charging and fueling times. They were concerned about the time it takes to charge versus fill up with diesel fuel—especially if charging needs to happen during the day. Longer charging times impact operational efficiency and scheduling. Terminal schedule and operations not only limit the time available during the workday for charging between runs but also influence the number of turns drivers can complete. For drayage drivers, waiting time is a significant factor that impacts overall efficiency. Restrictions on driver work hours also constrain time available for charging.

Availability, accessibility, and security of charging and fueling infrastructure: Drivers emphasized that charging and fueling infrastructure needs to be convenient to access and provide security for vehicles while they charge or fuel. Parking is already a challenge for drivers and communities, which can either be assisted or exacerbated by charging and fueling infrastructure. Drivers expressed significant concern about the security of charging and parking sites to avoid things like vandalism and cable thefts. The smaller the operations, the more vulnerable they are to recover from theft or vandalism.

Vehicle range and regional access to charging and fueling: Long-haul routes can be a significant source of income for some drayage drivers. Drivers that do drayage and long-haul routes expressed concern about regional availability of charging and fueling infrastructure. Without infrastructure in place for charging beyond

the areas of Puget Sound ports, they have concerns about how far they can go before needing to charge or refuel and where they would do it.

If longer routes aren't served by charging infrastructure, drivers and freight companies are worried they may need to replace one current vehicle with two—having a ZEV for drayage and a diesel truck for long-haul. This concern is exacerbated if scrappage of older diesel vehicles is required as part of incentives to adopt a new ZEV. If ports only allow access to ZEVs at some point, this may push those that can't make the transition into doing long-haul routes.

Maintenance and emergency services: Maintenance costs and down time were a large concern for drivers. Some drivers currently maintain their own diesel vehicles and others use third-party servicing. In the panel and listening sessions, many drivers were concerned about lack of familiarity with maintenance needs for ZEVs and lack of confidence in new truck technologies. Concerns included:

- The extra weight of zero-emission trucks may lead to more wear-and-tear on trucks and tires.
- Batteries may wear out and need to be replaced. Other specialized technology like heavy-duty electric motors and fuel cells will likely be more costly to replace as well.
- If maintenance is highly specialized, it will need to be done by dealers or other certified operations, which can be costly and take time.
- High-voltage systems raise safety concerns.

Drivers wondered if emergency services would be feasible for electric trucks, especially considering their weight and insurance policies. Lack of emergency services for ZEVs at ports may create operational bottlenecks if a truck runs out of charge or needs repair on port property.

Weight of ZEVs: With legal load limits, the additional weight of zero-emission Class 8 diesel day cabs, which are commonly used by drayage drivers, may limit the weight of containers that drayage drivers can carry or the routes they can take. Heavy-duty electric vehicles can add 3,000 to 5,000 pounds to the total gross vehicle weight, potentially bringing the combined weight above the legal limit of 82,000 pounds on roads.

Community Issues and Characteristics

The ports of Seattle and Tacoma are located in highly urbanized areas of these cities, where residential neighborhoods sit alongside industrial facilities and major economic infrastructure. These communities have been impacted for years by air pollution, traffic, and other challenges of living among industry. They are historically underserved.

In the North Harbor, the South Park and Georgetown communities are some of the most diverse areas of Seattle. English is not the primary language for many residents. Approximately 70% of residents live well below the poverty line. These communities are considered vulnerable and have limited access to green spaces, with only 40 square feet of green space per resident, compared to nearly 400 square feet on average for other Seattle residents.

These communities are heavily impacted by drayage trucks due to their proximity to ports and warehouses. Diesel drayage trucks contribute to significant health issues, including high cancer rates, premature birth rates, and asthma. South Park and Georgetown experience a 13-year gap in life expectancy compared to other areas in

Seattle.[6] The lack of designated parking means drayage trucks often idle in front of homes as they wait for port access, releasing exhaust fumes and contributing to congestion.

In the South Harbor, near-port neighborhoods face many of the same types of health impacts, equity concerns, and congestion as the North Harbor. Tacoma has some of the worst health disparities in Washington, with certain areas experiencing a 25-year gap in life expectancy compared to other neighborhoods.[7] The Tacoma tide flats are home to the only privately-owned state detention center in Washington,[8] which houses up to 1,600 individuals in an area that is highly susceptible to harmful air pollution from drayage trucks and shipping.

A major benefit of the transition to zero-emission drayage is improved air quality for surrounding communities. Air quality and health (e.g., asthma risk) is a long-standing interest of near-port communities that have suffered from the health impacts of diesel pollution as well as noise and other impacts. According to a tool developed by the Clean Air Task Force, Washington lost 7,290 days of work and faced monetized health damages of over $1.3 billion in 2023 due to health impacts of diesel emissions.[9] Community members encouraged the Collaborative to advocate for reducing emissions as quickly as possible and to make sure that benefits are targeted to address historic economic and environmental injustices. Community members also appreciated that ZEVs would be quieter than their diesel counterparts. Some groups queried how community-based organizations and community members could help support the transition to zero-emission trucks.

While community members say they have waited a long time for air quality improvements, they are also concerned that moving forward without thoroughly considering community issues and concerns could perpetuate existing or historical injustices. These concerns stem from past experiences where a lack of support and funding resulted from insufficient community engagement. Key concerns are outlined below.

Impacts of infrastructure and traffic in areas that are already overburdened: Hosting charging and fueling infrastructure for zero-emission trucks is concerning to community members, given the amount of infrastructure already present in these neighborhoods. For example, Seattle's South Park community has a school bus barn and landfill. Near-port residents in Tacoma are concerned about the Bridge Industrial Warehouse project, which could introduce new sources of diesel emissions. Community members would like to see more green spaces and parks, as well as more sidewalks and improved transit infrastructure.

Traffic and congestion: Residents are concerned that new zero-emission truck travel patterns could increase traffic, congestion, and illegal parking. They suggest developing infrastructure that encourages truck routes that don't go through near-port neighborhoods or create more parking challenges.

Recycling and disposal: Community members encouraged the Collaborative to be mindful of environmental impacts throughout the battery lifecycle – from mining of lithium to disposal. They also encouraged environmentally safe truck tire disposal methods.

Opportunities for IOOs and small companies: Community organizations noted that many drivers who own and operate their own vehicles or work for small companies are also residents of these near-port communities. They want drivers to have equitable access to zero-emission trucks. Community members echoed driver concerns about the cost of ZEVs for drivers lacking capital to purchase a new truck and the concern that they bear the risk

[6] Washington State Department of Health: https://doh.wa.gov/data-and-statistical-reports/data-systems/geographic-information-system/interactive-maps
[7] Tacoma Pierce County Health Department - Life Expectancy at Birth by Census Tract Pierce County, 2011: https://tpchd.org/wp-content/uploads/2023/12/Life-Expectancy-at-Birth-by-Census-Tract.pdf
[8] State inspectors denied entry to privately-run immigration detention center in Tacoma: https://washingtonstatestandard.com/2024/01/24/state-inspectors-denied-entry-to-privately-run-immigration-detention-center-in-tacoma/
[9] Clean Air Task Force: https://www.catf.us/deathsbydiesel/

for uncertain new technologies. Community organizations would like to see the ports and others incentivize the adoption of ZEVs for these drivers through financial incentives and non-financial incentives like preferred gate times or preferred terminal access. They wondered whether Seattle and Tacoma ports could be informed by leading practices at other ports.

Alternative fuels: Community members encouraged greater use of alternative fuels that are already available, such as natural gas and biofuels.

Lack of community trust: Discussion about ZEVs occurs within the context of a lack of community trust in government institutions and skepticism that communities will benefit from the transition.

Community groups also highlighted benefits they would like to see from the transition, outlined below.

Jobs and economic opportunity: Community members want to ensure that the ZEV transition leads to new high-quality job opportunities for residents and economic opportunities for local small businesses (e.g., maintenance and repair). This includes creating new green jobs and funding for workforce training. Residents suggested that funds for the ZEV transition should be invested in impacted communities and foster collaboration between communities, the ports, and state/local agencies. Efforts to protect communities from gentrification should accompany new economic opportunities.

Broader clean energy transition and efficient land use: Some community members wondered if the shift to ZEVs could be complemented with other clean energy solutions, such as solar arrays on the roof of charging stations to provide cover for vehicles and generate power for charging. Some offered innovative land use ideas, such as using big box store parking lots for charging overnight, when these lots are mostly empty.

Finally, community representatives in near-port neighborhoods in the North and South Harbors stressed the importance of proactively engaging with communities to understand their concerns and needs. This engagement can help ensure that the transition to ZEVs helps address long-standing community concerns about health, parking, traffic, noise, and safety, rather than exacerbate them.

3. Zero-Emission Drayage Truck Fundamentals

Zero-Emission Vehicles

Zero-emission trucks include both battery electric vehicles (BEVs) and hydrogen fuel cell electric vehicles (FCEVs). Each technology has unique strengths, limitations, and infrastructure needs that can help inform the best applications for drayage operations in the Puget Sound Gateway.

BEVs are powered by electricity stored in large onboard batteries that are recharged using electrical charging infrastructure. In Washington, where around 80% of Washington's electricity currently comes from renewable or clean energy (and where the state is set to reach 100% clean energy by 2045), BEVs offer immediate emissions reductions compared to diesel, helping to meet regional air quality and greenhouse gas reduction goals.[10]

- **Range and weight**: The distances that BEVs can travel on a single charge varies with battery size and use of the vehicle, but typical drayage applications can expect ranges of 120-250 miles on a full charge with current technologies. However, a battery adds substantial weight to the vehicle, often increasing the

[10] See: https://climate.wa.gov/washington-climate-action-work/big-seven-washingtons-biggest-climate-policies.

curb weight by 5,000-10,000 pounds compared to diesel trucks. Washington has adopted federal rules providing a 2,000-pound weight exemption for BEVs travelling on or near interstate highways, which partially offsets this weight increase.[11]

- **Optimal applications**: In the near term, with current vehicle and charging technology, BEVs are best suited for short-haul and urban routes where range requirements are modest, and vehicles can be charged overnight at depot locations.

Hydrogen FCEVs use hydrogen fuel cells to generate electricity onboard, providing a zero-emission option particularly suitable for longer routes, high-payload operations, and/or where quick refueling is valuable. They are currently more expensive than BEVs. Current hydrogen supplies are not low-GHG, but low-carbon hydrogen may become increasingly available due to substantial investment and innovation in the region (e.g., through the Pacific Northwest Hydrogen Hub[12]). Currently, green hydrogen—produced by the electrolysis of water, using renewable electricity—is significantly more expensive than electricity or diesel.

- **Range and weight**: FCEVs generally offer extended ranges of 300-500 miles per fueling, with lighter fuel tanks compared to BEV battery packs offering similar range. This makes them technologically advantageous for applications that require more range or payload capacity.
- **Optimal applications**: With their faster refueling times, longer-range capabilities, and lower weights, FCEVs are well-suited for longer routes and heavier loads.

It must be noted that these are broad characterizations and that the best-fit technology for a specific fleet or operation will depend on many factors. Additionally, the state of the art for each technology is rapidly evolving and will likely expand the range of feasible use cases for both technologies.

Total Cost of Ownership Comparisons Between ZEVs and Diesel Vehicles

Currently, the upfront price of a new heavy-duty ZEV is higher than a comparable new diesel truck (and much higher than a used diesel truck). However, ZEVs can have a lower total cost of ownership (TCO) over the lifetime of the vehicle when lower operating costs and/or incentives combine to offset their higher upfront cost. TCO cost elements comparing a diesel vehicle with BEVs are summarized in Table 1 and detailed below (similar issues apply to hydrogen FCEVs, although dollar amounts vary).

Table 1. Comparison of Elements of Total Cost of Ownership

TCO Cost Element	Diesel	Battery Electric ZEV
Purchase Price	Lower	Higher
Residual Value	Understood	Uncertain
Marginal Infrastructure Cost	Low	High
Infrastructure Monitoring	Low	Higher
Fuel Cost	Higher	Lower to Higher
Maintenance	Higher	Lower, but uncertain

[11] Only the federal government can raise the total weight cap for travel on inter-state highways or allow options like triple-trailering. See: Compilation of Existing State Truck Size and Weight Limit Laws - FHWA Freight Management and Operations.
[12] See: https://www.energy.gov/oced/pacific-northwest-hydrogen-hub-pnwh2

TCO Cost Element	Diesel	Battery Electric ZEV
Tire Wear	Lower	Higher
Battery replacement and recycling	None	Higher, but uncertain
Insurance	Lower	Higher
Purchase Incentives	None	Often Significant
Carbon Credits	None	Significant

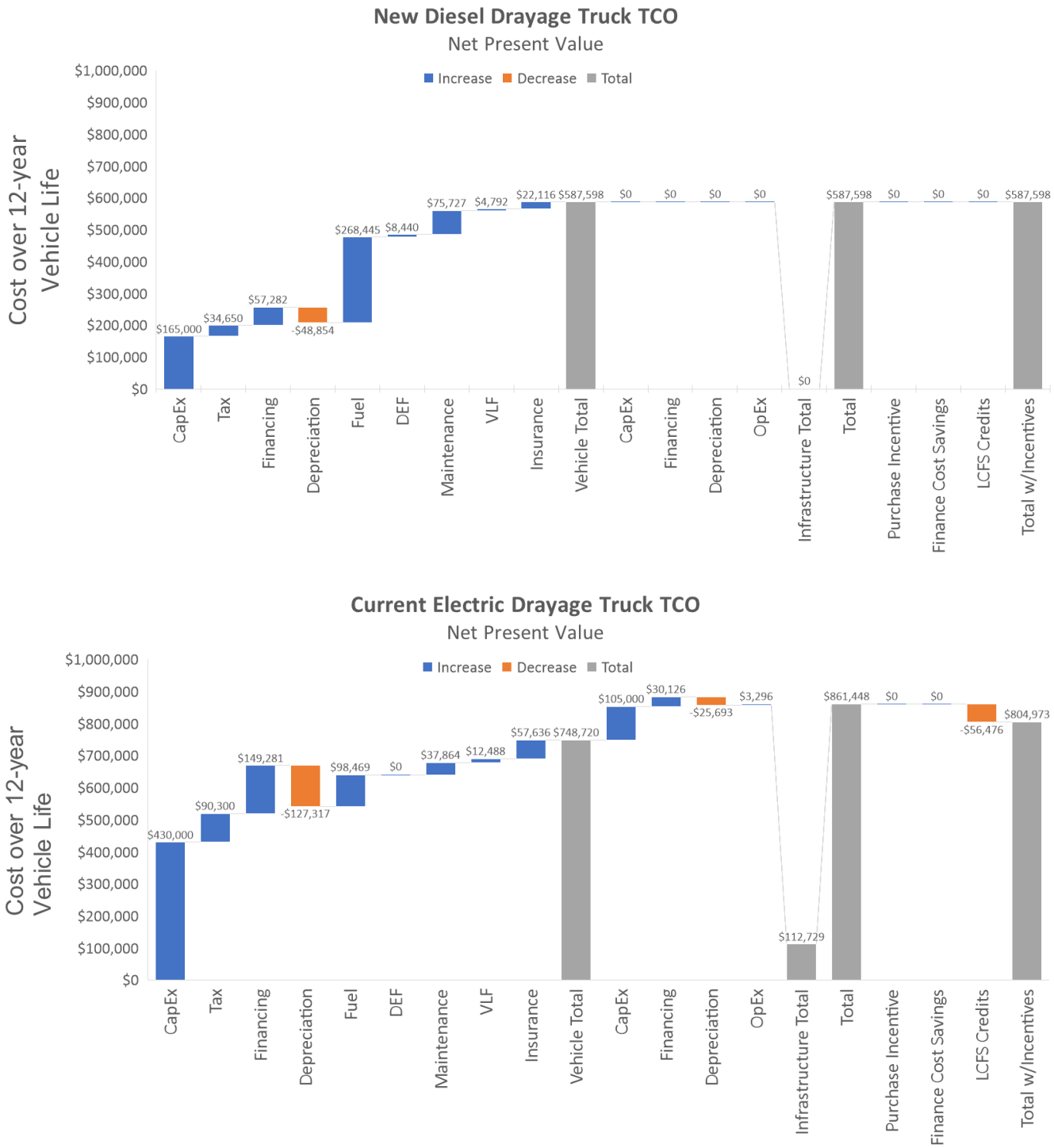
- **Purchase price:** New electric trucks can cost approximately $400,000-$600,000, and new hydrogen-fueled trucks can cost approximately $500,000-$700,000. This compares to $150,000-$180,000 for a new diesel truck and $30,000-$90,000 for a used diesel truck, which is often what single owner-operators and small fleets purchase for drayage.
- **Residual value:** The resale value of diesel trucks is known and easily incorporated into financing calculations (often around $40,000). The resale value of ZEVs is uncertain because of the current lack of a used ZEV market and lack of experience with technologies like battery life over time. Given the uncertainty and lack of ZEV secondary market, the residual value of a used ZEV may be valued at zero for purposes of financing (or valued using an imprecise proxy, such as the price of a used diesel vehicle.) Additionally, as ZEVs improve with respect to range, weight, and purchase price, these improvements place downward pressure on the residual value of used ZEVs.
- **Marginal infrastructure cost:** While the large-scale build-out of publicly available diesel fueling represented a significant cost at the time, it is now ubiquitous, so there is essentially no marginal infrastructure cost for fleets. By contrast, charging and fueling infrastructure for heavy-duty ZEVs is currently non-existent in the Puget Sound region. Fleets must either build their own behind-the-fence charging or access publicly available facilities (paying some of the capital cost of these facilities through charging fees). An overnight charging facility with 50 chargers, each dedicated to one vehicle, could cost approximately $13 million to $26 million over 10 years. A small publicly available charging facility with eight chargers may cost approximately $4 million to $6.5 million over 10 years.
- **Infrastructure monitoring:** Ensuring the availability and reliability of ZEV charging and fueling infrastructure requires regular monitoring, maintenance, and timely repair when needed. While necessary, these activities add operational costs to charging and hydrogen fueling facilities.
- **Fuel cost:** Diesel fuel prices have been increasing and can be volatile, typically ranging from $3 to $5 per gallon over the past five years. In the Puget Sound region, electricity costs are fairly low and stable, and Washington ranks tenth amongst states with the lowest average retail electricity rates in the U.S.[13] BEV charging costs are often substantially impacted by the time and speed of charging and average utilization of the grid connection.
- **Maintenance:** Diesel vehicles require more frequent maintenance than ZEVs, which have fewer regular maintenance items and no emissions aftertreatment systems. However, individual repairs or replacements of ZEV components can be more expensive because of component costs and the need for specialized equipment and training that are not yet commonly available within the heavy-duty fleet maintenance ecosystem.

[13] www.eia.gov/electricity/state

- **Tire wear** and **battery replacement and recycling:** Due to heavier vehicle weights and higher torque, battery electric EVs can wear through tires faster, incurring replacement costs more frequently. BEVs may also incur costs if batteries need to be replaced and recycled, although battery life and associated costs of replacement are uncertain until there is more experience with these vehicles on the road.
- **Insurance:** Because of the higher purchase price and uncertainty about the repair costs of new technology, insurance rates for ZEVs are generally higher.
- **Purchase incentives:** Substantial purchase incentives are becoming available for ZEVs through federal, state, and local sources.
- **Carbon credits:** Carbon credits can be available for ZEVs, for example through Washington's Clean Fuel Standard (CFS) credits for BEV charging and hydrogen fueling. The CFS allows revenue to be generated through credits created by installing charging or fueling infrastructure and reporting the electricity or hydrogen used to displace fossil fuels. These credits are currently worth about $0.06 per kilowatt-hour (kWh) in BEV heavy-duty trucks and $0.34 per kilogram in hydrogen FCEV heavy-duty trucks, but credit prices change based on market forces. Assuming a drayage truck travels 50,000 miles per year, the annual value of CFS credits would be $7,100 for a BEV truck (assuming it consumes 2 kWh per mile) and $2,400 for a FCEV truck (assuming it travels 7 miles per kilogram). Revenues may be higher if lower carbon electricity or hydrogen sources are used. Participation in the CFS program is complex and may not be cost effective for small fleets or difficult to claim for those who don't own infrastructure.

Figure 6 compares the TCO for a diesel vehicle priced at $165,000 to the TCO of a new battery electric ZEV priced at $430,000 (incorporating several assumptions about the other TCO elements above). Without financial incentives, the TCO of the new ZEV is higher than the new diesel by approximately $273,000 over a 12-year useful life; on their own, lower fuel and maintenance costs do not offset the higher capital cost of the vehicle and infrastructure. CFS credit revenue at current credit prices reduce the TCO of the BEV drayage truck scenario by approximately $56,000 over its useful life. To help mitigate the higher TCO between diesel and battery electric vehicles in the short term, additional purchase incentives for the vehicle and/or infrastructure of approximately $217,000 are needed to bring the TCO of the vehicles into parity.

Figure 6. Comparison of New Battery Electric ZEV TCO to New Diesel Truck



Note: DEF = Diesel Exhaust Fluid (required for proper after-treatment operation of emissions system). VLF = vehicle license fee.

Current and anticipated state and federal incentives for ZEV vehicles and infrastructure in Washington would bring many ZEVs into cost parity (or below) with diesel vehicles. Key financial incentives, several of which are described later in the Roadmap, include:

- $150,000-$198,000 stackable purchase vouchers for new vehicles (with modifier for drayage plus other possible modifiers) and $75,000-$99,000 for used ZEVs through Washington's Medium- and Heavy-Duty Zero-Emissions Vehicle and Infrastructure Incentive Program. This program also includes a $60,000 voucher for charging infrastructure
- A yet-to-be-determined per vehicle incentive amount from the NWSA ZEV Pilot Program, which is still under development to finalize incentive amounts, eligibility criteria, and stackability with other programs
- Up to $40,000 for purchase of new ZEV Class 8 vehicles from the Federal Commercial Clean Vehicle Credit
- $100,000 or more from the Federal Alternative Fuel Vehicle Refueling Property Credit for charging or fueling infrastructure located in low-income and rural areas. The program pays for up to 30% of the cost of each single qualified item that goes into making a charging or fueling station operable with up to $100,000 maximum per item of property.
- Carbon credit through the state Clean Fuels Program (which could total $7,100 per year for a battery-electric ZEV or $2,400 per year for a hydrogen fuel cell ZEV, as noted above)
- Additional utility incentive programs (see Section 7)

Charging and Hydrogen Fueling Infrastructure

Along with vehicles, charging and fueling infrastructure is a major piece of the ZEV transition strategy. This infrastructure needs to be in place when ZEVs arrive in the region. Just as there are currently no zero-emission drayage vehicles operating in the Puget Sound Gateway, there are currently no heavy-duty charging or hydrogen fueling facilities that could serve drayage fleets. Major new infrastructure can be costly and could take a long time to get in place, especially for facilities requiring large amounts of electricity and potential upgrades to utility infrastructure.

Ultimately, the region will need to develop a network of charging and fueling infrastructure consisting of private infrastructure on company lots, publicly available facilities, and probably subscription-type charging-as-a-service facilities. Each has distinct characteristics, as outlined below:

Private charging and fueling is "behind-the-fence" infrastructure for private or contracted fleets. For BEVs, it is conducive to charging overnight when vehicles are at their home facilities for extended periods of time. In this case, a single parking stall is needed for each vehicle and typically has a dedicated charging port. (Because of their faster fueling times, hydrogen vehicles would not need dedicated dispensers in each parking stall.) Expense and land use requirements make private behind-the-fence infrastructure most appropriate for large fleets that own the land (vs. short-term leases, which disincentivize fleet investments in the property and require cooperation from the property owner to make improvements).

These private facilities can be more cost-effective than public-access facilities because they make use of land already devoted to vehicle parking, and infrastructure can generally be sized to match the available charging and fueling windows for the fleet, leading to better utilization. Infrastructure may also be more regularly inspected and maintained due to the regular presence of fleet staff compared to remote, unattended charging and fueling facilities. Behind-the-fence charging facilities can be owned and maintained by the fleet but may also be owned and/or maintained by third-party service providers. Owners and operators contracted with motor carriers that have access to private charging have the advantage of accessing the facility, but they can be disadvantaged by dependence on the motor carrier whose infrastructure they require.

Publicly available charging and fueling (or "opportunity" charging and fueling) is accessible to anyone to use for a fee. These facilities are usually long-term investments with significant land area requirements dedicated to charging or fueling activities, comparable to truck stops. Charging facilities will have high-power requirements and provide faster charging than overnight charging facilities, allowing a single charger port to service multiple vehicles over the course of a 24-hour period. However, drayage duty cycles may not lend themselves well to stopping and charging during the day unless very high-power charging (i.e., "megawatt" charging) allows for short charge sessions. Depending on their location, these publicly available charging or fueling facilities may create new or increased truck traffic and vehicle dwelling at their locations, which can negatively impact communities where facilities are located if poorly sited.

Charging-as-a-service typically offers charging for a fixed fee on a per-month and/or per kWh basis. These fees are inclusive of the cost to construct and maintain the charging facility, meaning that fleets do not need to spend the significant upfront capital required to develop facilities themselves. Facilities may be constructed on private property and managed for the site host or constructed in shared access locations and open to those who sign up for the service. These services may also be accompanied by "rental" of ZEVs typically billed on a per-mile or per-month basis (in which case they are categorized as trucking-as-a-service).

Construction and operating costs vary by the type of facility and number of chargers or fuel dispensers. For example, a small publicly available charging facility with eight chargers serving 12 vehicles per charger during the day and night may cost around $4 million to $6.5 million over 10 years. A large overnight charging facility with 130 chargers, each dedicated to one vehicle, could cost around $40 million to $75 million. These construction and operating costs would contribute around $0.20 per kWh to the dispensed cost of electricity for the publicly available charging example while the contribution to the dispensed cost of private behind-the-fence charging is higher (in the $0.36 to $0.47 range) due to lower utilization and the larger number of dedicated chargers required. See Table 2 for cost comparisons of some examples.

Table 2. Example Infrastructure Costs for Different Types of Charging Facilities[14]

Site Type	Number of Chargers	Construction Cost	Operating Cost	Trucks per Charger	Implied Cost per kWh*
Opportunity	8	$2.4-4.8M	$1.74M	12	$0.20
Overnight	50	$12.9-$25.7M	$1.0M	1	$0.44
Opportunity	55	$14.3-28.6M	$9.5M	12	$0.16
Overnight	200	$49.4-98.7M	$2.7M	1	$0.36
Opportunity	40	$11.4-22.9M	$8.3M	12	$0.19
Overnight	130	$35.8-$71.5M	$2.8M	1	$0.47

Reference: https://thehelm.polb.com/download/379/zero-emissions/12744/final-polb-charging-study-12-sep-2021.pdf

Hydrogen fueling, because it is faster and has fuel stored on-site, is more akin to the traditional diesel truck stop model. While hydrogen infrastructure avoids some of the challenges of charging infrastructure related to utility

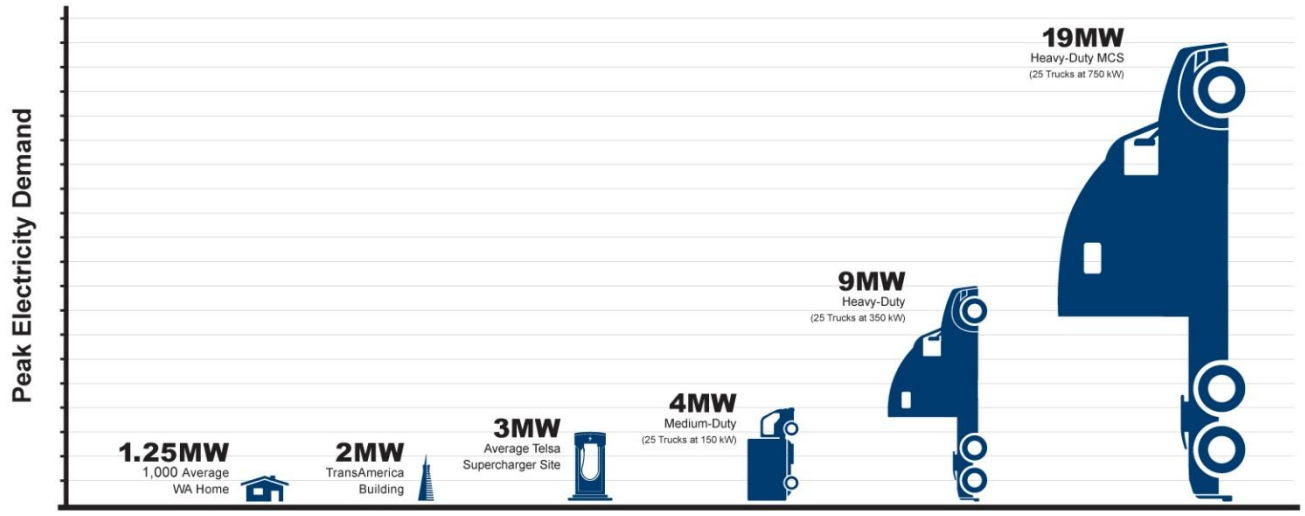
[14] Construction and operational costs are averaged over a 10-year operational period.

capacity, charging times, and parking, hydrogen has its own challenges including the need to establish sources and supply chains for hydrogen and potential for leakage.[15]

The timing and location of charging and fueling infrastructure raises a number of issues, outlined below:

- **Utility infrastructure planning and investment.** Fast charging of heavy-duty vehicles requires high power grid connections, which are typically much larger than would be required by a vehicle fueling facility (see Figure 7). New distribution infrastructure, such as substations, may be needed, requiring investment and land. Utilities face several constraints for the type of proactive planning and investments that may be needed as well as important questions about who pays.

Figure 7. Comparison of Charging Capacity Needs



Source: GNA

- **Community and land use issues:** Charging and fueling facilities require large land areas for trucks to park and move around, with potentially limited real estate opportunities in dense urban areas like greater Seattle and Tacoma. Many of the communities where drayage vehicles operate have been highly impacted by industry, transportation-related pollution, and other stressors. While the zero-emission transition promises cleaner air and quieter streets, it also potentially brings new industry-scale facilities to neighborhoods and new traffic and parking patterns that exacerbate community burdens.
- **Routes and schedules:** Charging and infrastructure facilities need to be located where they are conducive to drayage routes and schedules, and appropriate for vehicle ranges between charging and fueling times. For drayage, terminal schedules and operations limit time available during the workday for charging. New inconveniences and constraints that threaten delays or create unwanted changes in travel patterns will create more barriers for drivers and fleets to transition to ZEVs. Charging and fueling infrastructure will also need to be more fully developed along frequently traveled longer-distance freight routes that may be served by vehicles that also provide drayage services.

[15] Hydrogen has some global warming potential, although it is relatively short-lived as a climate pollutant in the atmosphere. See, for example, https://www.nature.com/articles/s43247-023-00857-8

- **Parking:** Charging facility type and location is linked to long-standing challenges of parking heavy-duty vehicles. The lack of dedicated parking already impacts near-port communities. Drivers often have limited parking opportunities, resulting in parking within residential neighborhoods and in the right-of-way. Drayage trucks parking overnight at motor carrier yards or paid parking spots may have access to overnight charging. Those parking at home or on the street are more likely to need publicly available charging or charging-as-a-service—or future solutions such as right-of-way charging.
- **Safety and security:** Drivers emphasize the importance of having safe and secure places to park and charge, especially overnight, so they are not impacted by vandalism and theft. Charging facilities also need to be secure to prevent acts of vandalism to facilities and theft of infrastructure (e.g., copper wire), which are costly and threaten reliability. Grid infrastructure and supply chains supplying facilities need to be reliable, especially as transportation becomes more dependent on these sources of energy. Disruptions create additional costs and potential delays throughout the freight system.
- **Workforce and supply chains:** It will be important to have trained and certified technicians to work on charging and fueling facilities, as well as upstream work on utility upgrades and hydrogen production. Sufficient production and supply chains of charging and fueling equipment will be needed to prevent project delays and reliable repair.

Forecast of Infrastructure Needs

To provide a rough estimate of the amount of charging and fueling that could be needed to serve approximately 4,500 drayage trucks serving the Puget Sound gateways, two analyses were conducted—one assuming that all drayage trucks are transitioned to battery electric ZEVs and another assuming they are all transitioned to hydrogen ZEVs. These analyses were further broken down into scenarios based on the type of infrastructure developed.

For battery electric ZEVs, the scenarios examined were:

- A high-power scenario, which assumes all 4,500 drayage ZEVs would be charged with high-power rapid charging (350 kilowatts (kW)) at publicly available sites with 20 charging points each.[16]
- A mixed low- and high-power scenario, which assumes a mix of low power behind-the-fence charging (50 kW) and high-power rapid public charging (350 kW) at sites with 20 charging points each.
- A simplified average power scenario, which assumes all ZEVs would be charged with medium-power (180 kW) chargers at sites with 20 charging points each.

Across these scenarios, the number of charging facilities needed to fully serve 4,500 battery electric ZEVs ranges from 34 large high-power facilities (high-power scenario) to 190 facilities (composed of 20 high-power facilities and 170 low-power overnight charging facilities in the mixed low- and high-power scenario). Because the high-power scenario would involve new large facilities (or facilities converted from other uses) that could accommodate many trucks coming in and out, it would require the most amount of new land space devoted to charging—100 acres. The mixed low- and high-power scenario would require the least amount of new space devoted to charging—60 acres—because the low-power charging points would be installed in company lots or areas already used for parking where vehicles could charge overnight. The simplified average power scenario

[16] More powerful megawatt charging systems (MCS) are in early pre-commercial deployment. These can supply up to 3 MW of power that can theoretically fully charge vehicle battery packs in 20 to 60 minutes depending on the size and technology of the pack. The potential for MCS is not assessed here because commercial deployment is several years away and there are uncertainties about the technology. If deployed, MCS would likely reduce the number of charging facilities and land requirements compared to the scenarios evaluated here.

falls in between, requiring 50 sites and 75 acres. Across the three scenarios, new power requirements would range from 180 to 310 megawatts (MW) of electricity. See Table 3 for a summary.

Table 3. Electrification Infrastructure Scenarios

Scenario	Total Charging Points Required for 4,500 ZEVs	Charging Points Per Facility	Number of Charging Facilities	Total Land Requirements for New Charging Facilities	Total Power Requirements
High-Power	670 high-power (350 kW)	20 high-power	34	100 acres	235 MW
Mixed Low- + High-Power	3,400 low-power (50kW) + 400 high-power (350 kW)	20 low-power or 20 high-power per site	170 low-power + 20 high-power	60 acres	310 MW
Simplified Average Power	1,000 medium-power (180 kW)	20 medium-power	50	75 acres	180 MW

For hydrogen-powered ZEVs, the analysis looked at two scenarios:

- A small station scenario, with each fueling station supplying 2,000 kg of hydrogen per day at a facility with one fueling lane.
- A large station scenario, with each fueling station supplying 6,000 kg of hydrogen per day at a facility with two fueling lanes.

For a fleet of 4,500 hydrogen-fueled trucks, hydrogen demand could range from 74,000 to 224,000 kg per day, depending on the utilization and efficiency of the vehicles. Smaller hydrogen stations with a capacity of 2,000 kg per day would require between 40 and 110 new fueling facilities, while larger stations with a 6,000 kg/day capacity would reduce this need to 10 to 40 new facilities. Across the two scenarios, new fueling facilities would require up to 10-15 acres of land. Table 4 summarizes the scenarios.

Table 4. Hydrogen Fueling Infrastructure Scenarios

Scenario	Total Fueling Points Required for 4,500 ZEVs	Fueling Points Per Facility	Number of Fueling Facilities	Total Land Requirements for New Fueling Facilities
Hydrogen Fueling: Small Stations (2,000 kg/day)	Up to 110 stations	1 station, 1 lane	110 stations @ 2,000 kg/day	Up to 15 acres
Hydrogen Fueling: Large Stations (6,000 kg/day)	Up to 40 stations	1 station, 2 lanes	40 stations @ 6,000 kg/day	Up to 10 acres

Ideal locations for ZEV charging and fueling infrastructure include areas near the Ports of Seattle and Tacoma, which serve as central hubs for drayage operations, as well as high-traffic corridors like I-5, I-90, and SR-167, which would allow flexibility for IOOs and long-haul transport. Industrial zones in the Kent Valley, Tukwila, Sumner, and Fife offer opportunities for both private behind-the-fence depot charging or fueling and shared access facilities suitable for a variety of fleet needs.

For the electrification scenarios, securing the estimated 60-100 acres needed to develop new charging facilities or convert other facilities to charging presents challenges, particularly in densely populated near-port locations where industrial land is in high demand. For comparison, Lumen Field in Seattle occupies 30 acres. Addressing these challenges will require a collaborative approach. Public-private partnerships involving port authorities, local governments, and private stakeholders such as OEMs and utilities will be crucial for securing land and attracting investment. Engaging local communities throughout the planning process will be essential to address concerns around traffic, noise, and land use. Adjusting zoning laws, particularly in high-priority corridors, may also be necessary to facilitate zero-emission infrastructure development.

Fully built-out charging infrastructure also has large power requirements—up to 310 MW in the mixed low- and high-power scenario. This is roughly equivalent to the installed capacity of 100 new wind turbines or a medium-sized gas plant. Engaging utilities early can help identify sites with sufficient grid capacity and facilitate phased infrastructure upgrades, ensuring that new charging and fueling facilities align with regional energy goals.

Interim Strategies

While ZEV markets and pathways are being established, interim strategies can contribute to achieving the goals of reduced GHG emissions, cleaner air, and reduced disruption to the drayage sector. These interim strategies are most valuable where they can utilize existing equipment and minimize the need for additional investments.

For fuels, the use of renewable diesel is a currently available solution that can reduce GHG emissions and other air pollutants.[17] Renewable diesel is a "drop in" fuel that does not require new engine technologies; it is chemically identical to petroleum diesel and meets the same standard specification. As a result of Washington state's adoption of a Clean Fuel Standard, renewable diesel has become available in Washington. Because of the credits that can be generated under the state's program, renewable diesel has generally been slightly less expensive than petroleum diesel for fleet operators where it has been available. Exploring the potential for renewable diesel is an action called out in the *Northwest Clean Ports Strategy Implementation Plan*.[18] In community conversations about the Roadmap, participants highlighted the value of advancing use of alternative fuels such as renewable diesel, which are already available to improve air quality in the near term while the longer-term ZEV transition takes place.

Other interim strategies are referenced in recommendations later in the Roadmap, such as consideration of converting existing diesel vehicles to zero-emission drive trains as conversion technologies improve and costs decline (see Recommendation 6.16 in Section 6).

4. Principles for Decarbonizing Drayage

To craft a strategy that achieves the imperative of improving air quality and health while addressing key issues of drivers and communities and the realities of ZEV technologies, the Collaborative followed a set of guiding principles agreed upon early in the process. While these principles may not represent the work of all members individually, they guided the work of the full group collectively.

[17] Renewable diesel fuel use results in as much as a 70%-85% reduction in CO_2 emissions. According to the U.S. Department of Energy's National Renewable Energy Laboratory, renewable diesel also reduces harmful nitrogen oxide (NO_x) emissions.
[18] See: https://s3.us-west-2.amazonaws.com/nwseaportalliance.com.if-us-west-2-or/2021-12/2021_12_NWSA_NWPCAS_Implementation_Plan_Stylized-LT-91CL273.pdf

Principles include:

- Emphasize voluntary, non-regulatory, and partnership-based solutions
- Achieve GHG and air pollution emissions reductions at the scale and pace needed to meet port, local, and state decarbonization goals while also ensuring the continued economic vitality of the Northwest ports gateway and region
- Embrace multiple technology pathways, including electricity, hydrogen, and retrofits[19]
- Facilitate a just and equitable transition to zero-emission trucking, with an emphasis on solutions that make zero-emission trucks affordable and available for a range of operators, large and small
- Assess the potential role of secondary vehicle markets to provide an affordable option for used trucks and bolster the business case for new vehicles by enhancing their resale value
- Explore alternative business models such as 'trucking as a service' or other alternative financing and service approaches to accelerate and support a successful zero-emission transition
- Identify and provide collaboration and support for development of necessary infrastructure by utilities, charging providers, and sales and servicing entities
- Use a data-driven and learning-by-doing process, informed by regional demonstration projects and related efforts
- Retain a regional/state-wide perspective, recognizing that ports can be catalysts for accelerating a broader transition to zero-emission medium- and heavy-duty transportation in other sectors

The Collaborative recognized that how to achieve a zero-emission drayage transition is as important as the transition itself. There are many potential unintended consequences of not getting it right. The following complexities illustrate the delicate balance that must be considered as the transition to zero-emission drayage moves forward:

- The cost of ZEVs makes them more accessible to larger and well-capitalized companies, so a transition that doesn't adequately bring ZEVs into cost-parity with comparable diesel vehicles (and charging and fueling accessible) may force out smaller and less well-capitalized drivers and companies. It was important to the Collaborative that the ZEV transition not displace current drayage operators due to cost or complexity. Some increased costs may not be immediately obvious, such as increased insurance rates and the tax consequences of financial incentives.
- IOOs and small businesses are particularly vulnerable to business disruptions related to charging and fueling access and time, lack of maintenance services for ZEVs, parts availability, and other factors. While it is important that these drivers and smaller companies have equitable opportunities to obtain zero-emission trucks, they shouldn't have to bear disproportionate technology or business risk of the ZEV transition.
- The design of incentive programs intended to lower the cost of ZEVs may create barriers for smaller businesses and IOOs due to the complexity of programs and/or lack of technical support. Approaches to financing could exacerbate predatory lending practices.
- Alternative business models to ownership—such as leasing or trucking-as-a-service—promise to increase access to zero-emission trucks and perhaps bring them to the region quickly, but these models could also be beyond the reach of IOOs and smaller companies unless thoughtfully designed with equitable access as a priority.

[19] The Roadmap primarily focuses on battery electric and hydrogen-fueled ZEVs, but also references retrofits that would convert diesel vehicles to battery or hydrogen fueling (see Section 5 on vehicle recommendations).

- Inequitable access to—and cost of—charging and fueling may result in inequitable economic impacts. For example, drivers without a safe and secure place to charge overnight may end up paying more for charging or hydrogen fueling or incur greater risk of vandalism. IOOs and small businesses relying on their client's private infrastructure for charging may be put at a business disadvantage because of this reliance.
- Inadequate coordination with utilities in infrastructure siting and planning may lead to delays in getting charging facilities online. The cost of new utility infrastructure to support vehicle charging, if rate-based, could lead to increased electricity cost and energy burden for lower-income utility customers.
- The location of charging and fueling infrastructure in communities and the related travel patterns of vehicles may create new and disruptive traffic and parking patterns in near-port communities.

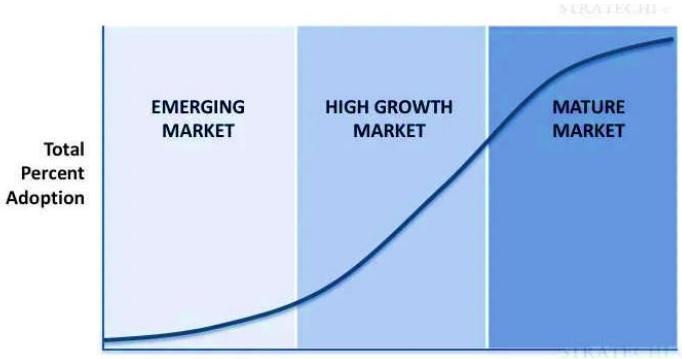
5. Transitioning to ZEVs: Priorities for Action

This section outlines what the transition to ZEVs for drayage may look like over near, medium, and longer terms and what factors are driving the pace of change. Drawing on the report's recommendations (detailed in sections 6 to 8), this section also highlights priority strategies for the near term to catalyze the transition.

Phases of Transition

The transition to zero-emission drayage is likely to proceed through phases that track the common "S-Curve" of technology adoption—from emerging markets to high-growth and then to mature markets (See Figure 8). The discussion below sketches out what this may look like in the region—if we have supportive policies, programs, and funding, and if key players in the market take actions to accelerate it.

Figure 8. Technology Adoption "S-Curve"



Near-Term Phase: Emerging Market (2025-2027)

Over the next three years, the first round of zero-emission drayage trucks (and other heavy-duty ZEVs) will begin to come into the region for testing and learning. This initial deployment near the ports is in line with the federal government's Phase 1 outlined in the *Zero-Emission Freight Corridor Strategy.*

New vehicles will likely be available first. Then, used vehicles will become available—most likely as companies sell vehicles from initial deployments in California. Incentives and demonstration projects will help attract new and used vehicles to the region.

Well-capitalized large- and medium-sized fleets will probably be the first to pilot the use of ZEVs in their fleets and invest in behind-the-fence charging at their facilities. Initial publicly available heavy-duty charging and fueling will likely also be developed during this period, led by public investment and trucking as-a-service type companies. Utilities will play an important role in providing needed infrastructure for charging and will continue planning for future investments. We are likely to see partnerships across different sectors of the ZEV market emerge to support early deployments of vehicles as well as charging and fueling infrastructure.

Business models with a lower barrier to entry than ownership, such as leasing and trucking-as-a-service may also emerge during this early period. This will facilitate awareness as well as experimentation and learning about new business models.

Medium-Term Phase: High Growth Market (2028-2035)

During this phase, the transition to ZEVs accelerates and rapidly scales. New heavy-duty ZEVs become readily available from dealers. They achieve TCO parity with diesel vehicles by the end of period,[20] reducing the need for purchase incentives for the mass market. Federal and state regulations like Advanced Clean Fleets and federal emission standards may create additional incentives or requirements for ZEV adoption. Well-capitalized large- and medium-sized fleets will increasingly adopt new ZEVs where it makes the most sense for duty cycles like drayage.

During this phase, secondary markets also mature and grow, creating more affordable opportunities for smaller companies and IOOs to adopt used ZEVs. Dealers actively market, finance, and maintain new and used ZEVs. Trucking-as-a-service, leasing, and other business models settle into a sustainable market niche. Additionally, the aftermarket for batteries and end-of-life management becomes increasingly significant. Battery recycling and repurposing will create new economic opportunities and support grid stability through applications like energy storage.

Behind-the-fence and public charging and fueling infrastructure expands locally for drayage, and regional infrastructure is built out to support heavy-duty ZEVs for long haul. Utilities make significant investments in infrastructure to support charging. These efforts may be accelerated by the maturity of vehicle-to-grid integration, giving utilities greater ability to manage loads and creating a new revenue stream for fleets or charging operators. Low-carbon hydrogen, specifically electrolytic or green hydrogen produced through renewable energy sources, increases in the region, along with greater availability of hydrogen-powered trucks.

Maintenance and other service businesses grow and create jobs during this phase, supported by workforce training. Communities benefit from improvements in air quality.

Longer-Term Phase: Mature Market (2036 and beyond)

In a mature market, ZEVs dominate the new vehicle market and used ZEVs are readily available—both at prices that outcompete diesel. Charging and fueling infrastructure is ubiquitous, along with maintenance and other services to support ZEVs. Policy and investments shift from a focus on scaled adoption of ZEVs to replacing the remaining aging diesel vehicles in the fleet.

[20] Source: https://www.nrel.gov/docs/fy22osti/82081.pdf

Forecasted ZEV Deployments and Infrastructure

While the pace of future ZEV deployments is unknown, two scenarios illustrate what the trend of ZEV deployments and associated infrastructure may look like as the market matures to one where all drayage vehicles serving the Ports of Seattle and Tacoma are ZEVs:

- Scenario 1: Natural Turnover with regulatory requirements – In this scenario, ZEV deployments occur as the result of natural turnover of the fleet where new trucks are assumed to be subject to Advanced Clean Trucks (ACT) regulations. Consistent with ACT, 7% of new trucks in 2025 are assumed to be ZEVs, increasing to 40 percent by 2031. In 2036 100% of new trucks are assumed to be ZEVs to reach a fully zero-emission drayage fleet between 2040 and 2050.
- Scenario 2: Incentivized Deployments – This scenario estimates the number of zero-emission drayage trucks that could be deployed based on the funds available in Washington State and NWSA incentive programs.

Using these scenarios, the number of zero-emission drayage trucks anticipated to be deployed in Phase 1 (2025-2027) ranges from 29 to 217 trucks (See Table 5). Incentives from the Federal Highways Administration (FHWA) and WSDOT programs are the primary drivers of the upper end estimate. By the end of Phase 2 (2028-2035), the number of deployed ZEVs ranges between 473 and 712 trucks. Beginning in 2036—the Mature Market phase—the number of annual ZEV deployments increases significantly as all new trucks are assumed to be ZEVs and many ZEVs are assumed to exist in the used truck market.

Table 5. Scenario Estimates of ZEV Deployments

Phase	Scenario 1 Natural Turnover – ZEVs Deployed	Scenario 2 Incentivized Trucks – ZEVs Deployed	Combined Scenarios 1 + 2
Emerging Market (2025-2027)	29	188	217
High-Growth Market (2028-2035)[21]	473	239	712
Mature Market (2036+)	Full fleet (~4,500)		

Table 6 translates these ZEV deployments into infrastructure requirements. Consistent with the discussion in Section 3, the figure describes the "edge" cases where either all new ZEVs are battery electric, or all new ZEVs are hydrogen fueled. For illustration purposes, the figure shows the number of "simplified average power" charging ports (180kW) for each phase and the number of "small station" hydrogen fueling (2,000 kg/day) for each phase. In reality, infrastructure will likely be a mix of charging and hydrogen fueling in various configurations and sizes. Appendix C provides more information on different charging and fueling options.

[21] Assumes vehicles from previous period still in use.

Table 6. Scenario Estimates of ZEV Charging and Fueling Infrastructure

Phase	Charging Infrastructure Simplified Average Power (180 kW) Charging Points	Fueling Infrastructure Small Stations (2,000 kg/day)
Emerging Market (2025-2027)	6 to 48	1 to 5
High-Growth Market (2028-2035)	105 to 158	12 to 17
Mature Market (2036+)	1,000	110

A more thorough description of assumptions and the analysis is included in Appendix C.

Factors Affecting the Speed of Transition

The speed of the ZEV transition in drayage markets will be largely determined by policies, programs, funding, and engagement of the types highlighted above. It will also be influenced by the pace of technical improvements, cost reductions, infrastructure deployment, and regulation as outlined below.

Technology and cost trends bringing greater parity between zero-emission and fossil fuel vehicles. Over time, decreasing battery pack prices and innovations in technology will translate into lower ZEV purchase prices. Additionally, increasingly stringent federal and California emissions regulations on new combustion engines will increase the cost of traditional vehicles and further narrow the gap in purchase price between ZEVs and diesel trucks.

Truck manufacturers are also increasing the range of their battery electric platforms. Some of these range improvements are achieved by increasing battery capacity while others are achieved through improved efficiencies from better aerodynamics, weight reduction, regenerative braking, and other technologies. The result is that while zero-emission platforms remain expensive, the relative performance of these platforms is improving at the same price points. Further, the anticipated availability of platforms like the Tesla Semi could set much higher performance-to-price ratios in the market, forcing less capable platforms to reduce their purchase price.

Improved range reduces some operational impacts but may exacerbate others. Improvements in range for newer zero-emission platforms will increase the applicability of ZEVs to more drayage routes. Some platforms are claiming ranges as high as 500 to 600 miles, which would be expected to satisfy most drayage routes and daily truck operations. However, increased range currently comes mainly from larger battery packs that increase the curb weight of the truck. As the curb weight of the vehicle increases, more loads are likely to be overweight, increasing the complexity of managing the use of these vehicles and limiting their operations. Technology improvements will need to allow for increased range while keeping incremental weights at or below the lower end of the currently observed range of incremental weights. This may be achieved with advanced battery technologies and better vehicle systems and motor efficiency, which is beginning to be seen in light duty BEVs. Some light duty models like Kia, Hyundai, and Lucid are achieving higher ranges with smaller and lighter batteries.

Charging and hydrogen fueling infrastructure improvements in availability, cost, and speed. While there are several evolving business models to support infrastructure deployment and operations, the cost of charging and

fueling infrastructure remains significant and typically dependent on incentives to reduce costs.[22] Relative to other markets like California, the Puget Sound gateway enjoys lower electricity rates that help improve the cost-effectiveness of ZEV charging and hydrogen fueling costs.

Both charging and hydrogen fueling infrastructure have shown mixed-to-poor performance with respect to reliability, particularly at public-access facilities. Poor reliability not only creates significant operational risks to the fleets that rely on this infrastructure, it also increases the cost of the energy delivered by this infrastructure. As manufacturers of vehicles and infrastructure and infrastructure operators gain experience with Class 8 vehicle and drayage deployments, they are able to refine their products and their implementation of standards to improve the reliability of charging and fueling. Fortunately, the experience from deployments occurring around the U.S. at varying scales is transferrable to the Puget Sound region, and infrastructure reliability should improve over the next several years as the market gains experience.

Charging and fueling speed are also important enablers of the ZEV transition in the drayage market. While there are significant portions of the drayage fleet that have several hours of dwell time at fleet yards to allow for lower speed charging or fueling, fleets that rely on public access fueling will need the ability to charge or fuel in times like diesel fueling today or face operational impacts. Further, as ZEV range increases to address more of the drayage market, more energy will need to be transferred during charging and fueling events. New charging and fueling standards and strategies are needed and beginning to appear in the market.[23] Inductive charging and battery swapping[24] may also enable reduced operational impacts from charging events. These technologies will take time to become standard offerings on new commercial vehicles and infrastructure but are expected to significantly increase in availability over the next five years.

Policy and regulations are important drivers of technology adoption but can also create market confusion and act as barriers. Several state and federal regulations have been adopted that seek to reduce emissions from combustion engines while supporting a transition to lower carbon, ZEVs. Regulations on vehicle manufacturers, including the Advanced Clean Trucks (ACT) zero-emissions vehicle sales requirements and federal new engine emissions standards and GHG standards are key examples of such regulations. Supportive policies such as Washington's Clean Fuel Standard and various incentive and grant programs provide additional funds to reduce the upfront and operational costs of ZEVs.

Many of these regulations are pushing the goods movement market into new territory with respect to technology. Early acting states like California have encountered implementation challenges and uncertainties with policies such as Advanced Clean Fleets (ACF), which mandates that new trucks added to California's drayage registry must be zero-emission as of January 2024, leading to legal challenges.[25] Despite these early challenges, policy and regulation remain important tools to accelerate the transition to ZEVs, and will likely evolve over the next several years as they come into alignment with the state of ZEV technologies.

Washington has adopted the California ACT rule and has become a participant in a memorandum of understanding (MOU) between 15 states and the District of Columbia committing to ensure that 100% of sales

[22] As noted above, Washington's Clean Fuel Standard provides credits that can be monetized for charging infrastructure placements, and the state's Climate Commitment Act provides a funding source for incentives for lower carbon transportation projects.
[23] The Megawatt Charging Standard (MCS), for example, currently enables charging speeds up to 1.5 MW and could eventually support charging speeds of up to 3 MW. In the hydrogen market, the new SAE standard J2601-5 enables high flow fueling at rates up to 18 kg per minute for vehicle fuel tank capacities up to 120 kg. In effect, this enables fueling rates of 10 minutes or less for Class 8 trucks with ranges of 500 to 1,000 miles.
[24] Battery swapping is gaining traction in China. However, no major truck manufacturers in the U.S. are currently building battery swapping capability into vehicles.
[25] Source: https://environmentalenergybrief.sidley.com/2024/05/23/17-states-file-complaint-challenging-constitutionality-of-californias-advanced-clean-fleets-regulation/

of new medium- and heavy-duty diesel vehicles are zero emission by 2050, with an interim target of 30% of sales by 2030. While Washington state has not adopted California's ACF rule, it is identified in Washington's Transportation Electrification Strategy as a possible pathway needed to meet the state's GHG targets for transportation.

Overall, the transition is going to be significantly driven by the pace of technology change, market development, and policy and regulatory approaches. There may also be bumps in the road that slow the pace of the transition. Public sector funding may not be adequate to catalyze the early stages of the transition, and private sector funding may not materialize at the levels needed. Competition and conflict over land uses may hamper infrastructure development. Supply chains may not be able to keep up with the need for vehicles or be adequate to provide adequate charging or fueling.

Priority Near-Term Actions to Catalyze the Transition

To set the region on a sustainable path for the ZEV transition described above, there are several near-term priorities for action drawn from the recommendations of this Roadmap. They are categorized below as those that are the most critical first steps to begin the transition and those that are also valuable for accelerating and shaping the first phase of the transition.

Critical first steps are:

- **Effectively implement sustainable local, state, and federal vehicle and infrastructure incentive programs.** Through Washington state's medium- and heavy-duty vehicle incentive program, the Northwest Seaport Alliance's incentive program, and others, ensure that stackable point-of-sale rebates and other tax reforms and innovative financing are helping to make new ZEVs competitive with the purchase of new diesel vehicles and reducing the upfront cost of charging and fueling infrastructure. Aggressively pursue long-term sustainability and predictability of state funding for financial incentives.
- **Get ZEVs and infrastructure deployed in the region via demonstration projects.** Implement ZEV demonstration projects to gain experience with ZEVs in the region and catalyze early investments in vehicles and infrastructure. As part of this work, identify and engage "first movers" among supply chain partners and private sector entities who are most interested in helping to advance the transition to zero-emission drayage trucking.
- **Develop initial public charging infrastructure.** Provide opportunities for early adopters, including IOOs and small companies that do not have the capital to establish their own charging infrastructure.
- **Engage in proactive utility planning.** Analyze and plan for future charging infrastructure needs. Advocate for policies that allow utilities to proactively develop infrastructure and programs that provide grid benefits from transportation electrification. Support initiatives that create a more robust grid to support large-scale electrification.
- **Actively engage drivers and communities.** Work with drivers to design and learn from incentive programs and demonstration projects. Engage communities about how to maximize local benefits and minimize impacts.
- **Provide technical assistance to fleets for vehicle adoption and infrastructure.** Support fleet managers and others to understand where shifting to ZEVs makes the most sense, how to transition fleets and build or access infrastructure most effectively, and how to connect with funding and programs that support the transition. Ensure that drivers and small companies have technical support to access financial incentives.

Additional actions valuable for accelerating and shaping the first phase of the transition are:

- **Lay the groundwork for secondary vehicle markets.** Implement used vehicle incentives and coordinated approaches for attracting used vehicles from California. Highlight opportunities through pilot deployment of used ZEVs in the region.
- **Provide opportunities for drivers to test out ZEVs.** Launch education, demonstration, ride-and-drive, and loaner programs for drayage drivers and smaller fleets to increase familiarity and reduce uncertainty about ZEVs.
- **Build local capacity for technical ZEV support.** Catalyze training and certification for ZEV maintenance, repair, and emergency services.
- **Advocate for operational and supply chain incentives for ZEV drivers.** Bolster financial incentives with operational incentives that improve access to terminals and warehouse. Help create buy-in and support from shipping and logistics companies that use the Puget Sound gateway.

6. Vehicles: Recommendations

This section outlines recommendations related to vehicle availability, affordability, and maintenance, describing actions to:

- Bring ZEVs into cost-parity with diesel through financial incentives
- Pilot and demonstrate deployment of ZEVs and charging and fueling infrastructure in the region to test, educate, and learn
- Catalyze a secondary ZEV market
- Provide alternatives to vehicle ownership
- Mitigate impacts of additional vehicle weight on drayage operations
- Ensure adequate vehicle maintenance and services
- Advance programs for residual battery and tire recycling and disposal
- Provide non-financial benefits for ZEV drivers at ports

Bring ZEVs into Cost-Parity with Diesel through Financial Incentives

As noted above, the gap in total cost of ownership between ZEVs and diesel vehicles is large. The primary contributor is the upfront cost of each, comparing a new diesel truck costing $155,000–$175,000 to a new battery electric truck costing $400,000–$600,000. While a 2023 study by the International Council on Clean Transportation (ICCT) forecasted retail price parity between diesel and battery electric trucks in the early 2030s[26], dealers speaking to the Collaborative indicated that the sales price of new zero-emission trucks is unlikely to come down until we reach a point of high-volume sales and competition (although the value of the vehicles may increase with technology improvement). This has been the experience so far in the California market, which is the first location in the U.S. to see a substantial number of zero-emission trucks entering the market. Even with substantial incentives in California, some of these incentive programs remain under-subscribed for various reasons including price gaps and wariness about being an early adopter of new technology.

[26] Purchase costs of zero-emission trucks in the United States to meet future Phase 3 GHG standards": https://theicct.org/publication/cost-zero-emission-trucks-us-phase-3-mar23/

Key California Zero-Emission Vehicle and Infrastructure Programs

Hybrid and Zero-Emission Truck and Bus Voucher Incentive Project (HVIP). Funded by the California Air Resources Board and implemented by CALSTART, HVIP provides point-of-sale vouchers for zero-emission trucks and buses. Vouchers for Class 8 trucks are currently $120,000 for battery electric ZEVs and $240,000 for hydrogen fuel cell ZEVs, with a 25% additional incentive for ZEVs used in drayage. For more information, see: https://californiahvip.org/vehicle-category/heavy-duty/.

Energy Infrastructure Incentives for Zero-Emission Commercial Vehicles (EnergIIZE). Funded by the California Energy Commission and implemented by CALSTART, EnergIIZE provides reimbursement-style grants for the development of charging and hydrogen fueling infrastructure for medium-duty, heavy-duty, and off-road ZEVs. Funding covers 50-75 percent of eligible project costs (up to maximum grant amounts), and up to 100% for some projects that meet equity criteria. EnergIIZE includes a drayage set-aside funding lane available to drayage vehicles that receive HVIP funding. For more information, see: https://www.energiize.org.

Currently, to reach cost parity with a used diesel truck, new electric trucks need to be subsidized 80% to 90%. Higher costs for insurance and other factors further widen the gap. Amounts of proposed state incentives of $150,000 to $190,000 for new vehicles and $75,000 to $99,000 for used vehicles are not enough on their own to reach TCO parity with used diesel vehicles for most drayage customers, so incentives need to be increased and/or made "stackable" with other programs.

Recommendations

Recommendation 6.1: Fully and effectively implement Washington's Medium- and Heavy-Duty Zero-Emissions Vehicle and Infrastructure Incentive Program and NWSA's drayage vehicle incentive program.

Recommendation 6.2: Advocate for additional incentive programs for ZEVs and infrastructure that support the transition to zero-emission drayage, aiming for a range of well-designed and effective programs that bring ZEVs into TCO parity with diesel vehicles. Align new ZEV incentive programs with the Washington and NWSA programs and adopt best practices outlined in the "Washington State Medium- and Heavy-Duty Zero-Emission Vehicle and Infrastructure Incentive Program Design Strategy," especially:[27]

- Third-party administered point-of-sale vouchers for ZEVs and charging and fueling infrastructure
- Voucher amount plus-ups, or modifiers, for select fleet types, vehicles, or environmental impacts, such as vehicles operating in disadvantaged communities and those owned by small, minority-owned businesses (see Figure 9)
- Incentives for secondary market vehicles
- Vouchers that are stackable with other federal, state, and local incentives
- Adaptability over time to new technology progress and market dynamics, informed by a process of regular program evaluation and revision

[27] "Washington State Medium- and Heavy-Duty Zero-Emission Vehicle and Infrastructure Incentive Program Design Strategy," CALSTART, PNWER, S Curve Strategies (February 15, 2024).

Figure 9. Summary of Recommended Washington State Vehicle Incentive Voucher Amounts

New Class 8 drayage vehicle voucher: $150k-$198k
Used Class 8 drayage vehicle voucher: $75k-$99k

Vehicle Voucher Amounts

Vehicle voucher amounts consistent with HVIP funding levels. Modifiers are unique to Washington State needs and program goals.

GVWR (lbs.)	Vehicle Class	Incentive Amount
8,501-10,000	Class 2b	$7,500
10,001-14,000	Class 3	$45,000
14,001-16,000	Class 4	$60,000
16,001-19,500	Class 5	$60,000
19,501-26,000	Class 6	$85,000
26,001-33,000	Class 7	$85,000
33,001+	Class 8	$120,000

Modifier Type	Amount Above Base
Class 8 Drayage	+ 25%
More Impacted Environmental Risk	+ 15%
Small or minority-owned fleet	+ 25%
In-Use Converted/Remanufactured	- 50%
Used Vehicle	- 50%
EV Charging and Infrastructure	+ 50%

Recommendation 6.3: Advocate for stable federal and state funding for regionally available ZEV and infrastructure incentive programs to provide long-term funding certainty for fleets and infrastructure providers.

Recommendation 6.4: Advocate for additional incentives that can be combined with point-of-sale rebates to reduce total cost of ownership, including grants, low-interest loans, and tax incentives. For tax incentives:

- Reduce or exempt zero-emission drayage trucks from the 12% federal excise tax on the purchase price of Class 7 and 8 vehicles (assessed before incentives) or offer a tax credit equal to the excise tax amount.
- Expand the Washington state light duty vehicle sales tax exemption to include medium- and heavy-duty ZEVs and extend the exemption beyond its current expiration date (July 31, 2025).
- Generally, bring taxes down at least to parity with taxes on an equivalent diesel vehicle, for example through a lower sales tax percentage assessed on a higher cost ZEV.

Recommendation 6.5: Design incentive and financing programs to avoid adverse income tax consequences for IOOs and small companies. For example, the proposed Washington state incentive would go through dealers, so it is not counted as income for purchasers.

Recommendation 6.6: Educate dealers and their sales teams on available incentives and stackability of incentives to enable them to inform customers and aggregate incentives in the sales process.

Recommendation 6.7: Provide technical assistance to drivers and fleets to access incentive programs and encourage ZEV adoption, including:

- Fleet advisory programs integrated into voucher programs
- Guidance on tax credits, grants, and rebates available to overcome financial barriers
- Free or subsidized legal advice on transportation contracts and documentation

The Washington State Medium- and Heavy-Duty Zero-Emissions Vehicle and Infrastructure Incentive Program requires that participants utilize technical advisory services. Other fleet advisory services are available regionally, such as Seattle City Light's fleet and charging assessments through its comprehensive advisory services[28] and the Breaking Barriers Collaborative, which works with regional organizations to develop fleet decarbonization plans.[29]

Recommendation 6.8: Design programs with a simplified, accessible, and supported application process, including:

- A single online portal for fleet applicants
- Streamlined application processes without unnecessary complexity and lengthy requirements—ideally implemented through dealers to simplify and reduce burden for purchasers
- Technical support in multiple languages to ensure drivers and owners understand the application process
- A front-end pre-approval process and paperwork verification

Recommendation 6.9: Provide tailored education and outreach to drivers and small fleets to encourage use of incentive programs, including:

- Targeted outreach campaigns tailored to address specific concerns and misconceptions and promote community engagement
- Training on ZEV benefits for air quality and public health, addressing emissions concerns
- Educational workshops on reduced maintenance needs of ZEVs, emphasizing cost savings
- Partnerships with local organizations for outreach and engagement
- Training for community-based organizations to ensure they are equipped with the knowledge and resources needed to support drivers in transitioning to electric trucks effectively

Pilot and Demonstrate Deployment of ZEVs and Charging and Fueling Infrastructure in the Region to Test, Educate, and Learn

An underlying theme of Collaborative discussions and conversations with drivers, dealers, and others was lack of understanding about how ZEVs (and their charging and refueling) could fit into drayage operations in the Puget Sound region. A first step is to operate ZEVs here to demonstrate how they work for drayage duty cycles in Tacoma and Seattle and understand the suitability of different types and locations for charging and fueling infrastructure. These efforts can raise awareness and begin to reduce some of the uncertainty that hinders ZEV uptake and market development.

Recommendations

Recommendation 6.10: Fund and implement near-term demonstration projects that bring zero-emission trucks to the region and catalyze initial charging and fueling infrastructure as the initial stage of the broader transition. These demonstration projects should test a variety of models—including secondary market sales, ownership, leasing, and trucking-as-a-service—as well as different types of charging and fueling, including publicly available, charging-as-a-service, and private facilities on company lots.

[28] See: https://www.seattle.gov/city-light/business-solutions/renewable-energy-services/fleet-electrification-program
[29] See: https://www.breakingbarrierscollaborative.org/about

Recommendation 6.11: Ensure that lessons from demonstration projects are developed and shared to inform future project design and implementation, by:

- Incorporating intentional data collection and evaluation into projects.
- Centrally tracking drayage-related deployments of ZEVs and infrastructure in a regional clearinghouse.
- Sharing and discussing lessons in a collaborative forum to foster shared learning and best practices. This could draw on experience in the Puget Sound region as well as efforts in California and other parts of the country.

Catalyze a Secondary ZEV Market

Making used ZEVs available to the drayage sector via a secondary market is a vital strategy for bringing them closer to parity with the total cost of owning a comparable diesel truck. A secondary market can potentially provide used ZEVs on the market at around 30% of their new truck price—approximately $160,000 for a battery-electric ZEV. This provides drayage operators access to ZEVs at a lower cost. Other costs, like insurance, will also be lower.

Smaller purchase incentives (in the range of $100,000) would be required for used trucks to reach cost parity with used diesel vehicles, reducing the overall cost of incentive programs and supporting more truck deployments, as well as reducing tax impacts for the purchaser. A secondary market would allow other businesses, such as trucking-as-a-service, to provide lower cost options to drayage drivers. As markets mature, incentive amounts can be re-evaluated.

A secondary market would also significantly help accelerate markets for new trucks by providing a clear resale value for the primary buyer, which reduces the overall TCO. Without a secondary market for used trucks, the resale value is likely in the low tens of thousands of dollars. For dealers and OEMs, the opportunity for customers to return used vehicles will very likely help spur new vehicle sales to well-capitalized primary fleet buyers.

It will take time for a secondary market to emerge. For Washington, used zero-emission trucks are likely to first become available from California in the next one to three years.

There are significant uncertainties about the development of a secondary market:

- Well-capitalized over-the-road and regional trucking companies will often use new diesel trucks for three to five years before the truck is sold into the secondary market. However, it is uncertain whether purchasers of new ZEVs will hold onto them longer due to low annual mileage, different economics, compliance with regulations, or other factors.
- The condition of ZEVs sold into secondary markets is uncertain, as well as how long they can then be used (although OEMs currently have projections on anticipated useful life for zero-emission trucks). Battery life and general wear and tear on heavier vehicles may affect maintenance and insurance costs. OEM and dealer reconditioning and certification programs can help ensure used vehicle quality.
- Technology improvements and lower purchase prices for new vehicles may degrade the value of "first generation" used vehicles as buyers wait for higher quality vehicles to emerge in used vehicle markets. Similarly, market developments influencing the relative roles of battery electric and hydrogen-fueled ZEVs may influence the value of one technology over the other.

- The expected residual value of used vehicles at the end of their life is uncertain, including the value of batteries that may be reused or recycled. New approaches to determining appropriate financing and leasing costs may be needed for ZEVs.
- Without adequate policy design, used vehicles may not end up in the drayage sector.
- Even as the availability of used vehicles lowers the cost of adoption, infrastructure for charging and fueling is still required. Delays in infrastructure will also delay the development of secondary markets.

Recommendations

Recommendation 6.12: Advocate for cost-competitive incentive funding to jump start a secondary market purchase program within the next one to three years. New state and federal medium- and heavy-duty ZEV incentive programs should allow for used vehicle incentives in their funding programs, following the design of the Washington state purchase incentive program.[30] Used vehicle incentives should:

- Help cover the cost of used ZEVs and the infrastructure required for charging and fueling.
- Be designed to be accessible to IOOs and small fleets.
- Be available to a wide variety of business models, including trucking-as-a-service.

Given that there are currently no secondary market programs around the country, simply having an incentive program for used zero-emission trucks will provide a strong market pull from OEMs nationally, regional dealers, and large leasing/rental companies eager to sell used ZEVs.

How a Secondary Market Could Emerge in Washington

Focusing on purchase incentives for used trucks is a relatively simple way to accelerate the market. For example, a $10 million pilot project could fund 100 trucks at $100,000 each, bringing the purchase price down to rough parity with a $60,000 diesel truck. Hundreds of vehicles are likely to become available from large fleets in California in the next couple of years from trucks deployed in early ZEV projects. Program success could be leveraged to attract additional state and federal funding and scale the program.

A program would require that eligible trucks:

- Meet a specification appropriate for drayage
- Be inspected and verified as in good working order (e.g., via dealer or OEM qualification and QA/QC process)

It would require that eligible grant recipients:

- Use vehicles in drayage operations
- Run the vehicle in the Puget Sound gateway for a minimum of three to five years
- Meet requirements for income, business size, or other factors as appropriate to target opportunities equitably

To be most successful, a program would also need to:

- Ensure adequate charging and fueling infrastructure for vehicles in the program
- Ensure adequate maintenance through certified OEM and dealer truck services

[30] When considering financial incentives for secondary markets, the Collaborative considered the pros and cons of incentives for purchasers of these used vehicles as well as incentives for purchasers of new vehicles who commit to sell them into secondary markets after a set time. Overall, the Collaborative concluded that providing incentives to purchasers of used vehicles was far more feasible to implement, easier to target to the Puget Sound drayage market, and sufficient to send the right signals to the market about resale value. As the secondary market develops and lessons are learned about effective incentive programs, it may be valuable to revisit whether additional strategies are needed to incentivize primary purchasers to sell into secondary markets and to support accurate accounting of resale value in financing of new trucks.

Recommendation 6.13: Keep incentive programs and market transactions as simple as possible. Minimize the need for granting agency involvement in transactions.

Recommendation 6.14: Encourage enabling programs for secondary markets, including QA/QC and certified reconditioning of used vehicles.

Recommendation 6.15: Encourage access to used ZEVs from California for drayage drivers and companies in the Puget Sound gateway. This may require waiting until California grant contract terms end and vehicles are allowed to move out of California. It may also require incentive program conditions that help ensure used trucks from California are appropriate for the Puget Sound gateway (e.g., weight, wheelbase, etc.).

Recommendation 6.16: Consider conversions of diesel vehicles to ZEVs, as technologies improve and costs decline. Several companies currently promote their services for converting diesel vehicles to an electric power train. This typically involves removing and replacing the diesel engine and transmission with an electric motor, battery pack, power electronics, cooling systems, and software (along with new wiring and instrumentation). Retrofitted vehicles must comply with safety standards and be certified.

Conversion has the potential advantage of lower costs and reuse of existing assets. However, currently available technologies have performance issues and may impact vehicle warranties.

Provide Alternatives to Vehicle Ownership

New models for accessing ZEVs are emerging in the market and creating alternatives to fleets and drivers purchasing and owning their own vehicles. Trucking-as-a-service, leasing, and related business models may be appealing alternatives for certain segments of the drayage market. These options can help customers take advantage of financial incentives, mitigate technology risk, and ensure maintenance is taken care of. They can create a relatively accessible entry point for drivers and fleets interested in ZEVs.

Overview of Alternative Business Models

Trucking-as-a-service: A model where companies provide trucks, charging/fueling, and services like maintenance and management on a subscription or pay-per-use basis. This allows businesses to use ZEVs without the need for ownership.

Charging-as-a-service: Offers EV charging infrastructure and services on a subscription or fee basis, providing installation, maintenance, and operational management, so fleets can access charging without the upfront investment.

Leasing: Involves renting vehicles or equipment for a specified period, offering flexibility and lower upfront costs compared to purchasing.

Sponsorship: Involves financial or resource support from external organizations or companies to offset costs of ZEV adoption, often in exchange for branding or promotional opportunities.

Co-op: A member-owned business model where stakeholders share ownership, decision-making, and profits, pooling resources to access ZEV infrastructure or services collectively.

Companies employing innovative ZEV business models are interested in investing in the region and may be among the first wave of opportunities to bring vehicles and infrastructure to the Puget Sound gateway. They can create awareness and exposure and facilitate testing of ZEVs in practice, helping kick-start the overall ZEV market. For battery electric ZEVs, combining vehicle availability with charging access can provide utilities with an additional increment of certainty that facilities will be sufficiently utilized.

Infrastructure requirements and challenges for trucking-as-a-service facilities are similar to those for large public charging sites, including real estate availability, distribution grid infrastructure, and appropriate location. Incentives and other policies that make markets attractive for trucking-as-a-service and leasing providers are those that help advance the market generally: point-of-sale incentives for vehicles, incentives for infrastructure, grants for demonstration projects, and regulations that require sale or purchase of ZEVs.

While there are many favorable aspects of these emerging business models, there are also some potential concerns:

- Some IOOs value vehicle ownership and may be resistant to non-ownership models.
- The perceived cost may be too high for some drivers. In the North Harbor driver listening session, for example, nearly all participants had the impression that trucking-as-a-service and leasing would be too expensive for IOOs (although the specific costs of these services were not discussed). In the South Harbor driver listening session, drivers were more open to the idea of trucking-as-a-service and leasing if these approaches were cost-competitive with their current arrangements.
- The dependence of drivers and companies on one or a few trucking-as-a service or leasing companies may reduce competition, locking these drivers and companies into financial arrangements.
- Several companies using these business models are new, and their long-term viability is uncertain.
- Drivers and companies with low credit may not be eligible. However, trucking-as-a-service and leasing companies may have underwriting flexibility to tailor for lower credit customers. (Presenters on a Collaborative panel indicated they had been able to underwrite most drivers and companies interested in their services.)
- Licensed motor carriers cannot contract with trucking-as-a-service companies and provide the trucks to IOOs as this would result in the IOO being classified as an employee; IOOs would therefore have to contract directly with the trucking-as-a-service company.
- Trucking-as-a-service companies may choose to locate charging facilities in areas with affordable land and utility access, but these may not be locations that near-port communities find favorable.

Recommendations

Recommendation 6.17: Support demonstration projects of trucking-as-a-service, leasing, sponsorship, co-ops, and other models that make ZEVs available in the Puget Sound Region.

Recommendation 6.18: Advocate for financial incentive policies and programs that encourage deployment of a variety of business models, including:

- Ensuring that state, local, and federal stackable financial incentives for infrastructure are available to trucking-as-a-service, leasing, sponsorship, and related companies.
- Providing Clean Fuel Standard capacity credits for private facilities that serve multiple fleets (See more detail in Recommendation 7.4.)

Mitigate Impacts of Additional Vehicle Weight on Drayage Operations

Trucks in Washington are subject to weight restrictions, which vary by road type and trailer configuration. Standard federal interstate weight limits are 80,000 pounds (inclusive of the tractor, trailer, and cargo), but some state roads may allow weights up to 105,500 pounds. These higher weight limits are often critical for the efficient movement of heavy cargo such as steel, liquids, and paper. While federal rules adopted by Washington provide an additional weight allowance of up to 2,000 pounds on interstates, the added weight of a battery electric truck compared to a diesel truck can substantially exceed this allowance. Over time, technological innovations may reduce the weight of batteries.

For now, weight restrictions limit the maximum weight of loads that zero-emission trucks can legally carry,[31] potentially limiting the opportunity to haul heavy loads such as agricultural products and increasing the number of drayage vehicles needed to carry a given amount of freight. Weight and payload capacity loss for ZEVs is a major concern for the trucking industry. Because accurate information on cargo weight is often not available prior to picking up a container, this may mean a lost turn cycle for a drayage truck if the container is determined to cause the vehicle to be overweight. Drivers are also concerned about the cost associated with the potential additional wear-and-tear from higher vehicle weight, especially on tires.

Federal action would be needed to adjust weight limits for ZEVs.[32] A key consideration is how allowing higher weights would impact roads and freight infrastructure.

Recommendations:

Recommendation 6.19: Collaborate with other organizations and states to explore strategies for adjusting federal regulatory weight limits that can bring payload capacities for ZEVs into parity with diesel.

Ensure Adequate Vehicle Maintenance and Services

Maintenance and avoiding unexpected down time while vehicles are being repaired is a key concern of drivers. While perhaps less frequent, ZEV repairs may take longer because they are more likely to be addressing an issue with major systems (e.g., battery, drive motors, etc.). Equipment is specialized and expensive – it is not currently stocked by dealers, and there is less experience maintaining it.

With more advanced and unknown technologies and potential safety issues, ZEVs need to be maintained and repaired by certified dealers and/or companies (e.g., for high voltage, hydrogen, etc.). Drivers that currently maintain their own diesel vehicles would need to pay for maintenance elsewhere. Local service stations in near-port communities—a source of jobs and revenue—may be displaced.

Emergency services may also not be as available for ZEVs given their specialized technology, weight, and insurance policies. First responders need to be trained to respond to ZEV emergencies, including how to handle high voltage equipment and battery fires. In listening sessions, drivers noted concerns about breakdowns or dead batteries on port property that could disrupt operations without adequate emergency services to respond.

[31] In the simplest calculation, a ZEV that weighs 8,000 pounds more than a diesel would be able to carry 8,000 pounds less maximum cargo (e.g., 48,000-pound containers for diesel compared to 40,000 pounds for ZEVs or 42,000 pounds on interstates). More complete analysis of weight impacts needs to take into account individual axle loads, distances between axle groups, and overall safe balancing of the load and can result in further cargo capacity reductions.

[32] Federal action would also be needed to allow triple trailering.

Recommendations:

Recommendation 6.20: Incentivize dealers to become certified for ZEV maintenance. Certification can cost $50,000–$100,000. These costs may be passed on to customers, further raising the price of ZEVs. Publicly funded incentives or loans can help ensure dealer capacity for maintaining the initial wave of ZEV drayage vehicles.

Recommendation 6.21: Educate and train drivers and fleets on the maintenance needs of ZEVs, including through programs at truck driving schools, trade schools, and community colleges.

Recommendation 6.22: Provide emergency services for ZEVs at terminals and along drayage routes.

Recommendation 6.23. Train fire, police, and other first responders to address ZEV truck emergencies, including how to handle high voltage equipment, battery fires, and hydrogen fuel.

Advance Programs for Residual Battery and Tire Recycling and Disposal

ZEVs create new issues for component disposal and reuse. In several community meetings, participants encouraged the Collaborative to be mindful of the battery lifecycle–from mining of lithium to disposal. Batteries at the end of their useful life for heavy-duty vehicles may still have considerable residual value for energy storage or material recovery. For example, the National Renewable Energy Laboratory is working with Argonne National Laboratory and the Oak Ridge National Laboratory as part of the ReCell Center on improving direct recycling of lithium-ion batteries.[33] There are several startup companies that are developing high volume battery recycling programs based on the concept of developing a circular supply chain where recycled materials from existing vehicle batteries are used to make new batteries.[34]

Community members also encouraged drivers and companies to use environmentally safe truck tire disposal methods, recognizing that ZEVs may go through tires more quickly because of weight. Washington state developed a tire waste disposal program beginning in 2005 that charges a $1 fee per new tire purchased and established a program at the Department of Ecology to address tire waste.

Recommendations

Recommendation 6.24: Advance markets for battery and tire reuse or recycling and ensure batteries and tires are disposed of properly; consider extended producer responsibility.

Provide Non-financial Benefits for ZEV Drivers at Ports

During listening sessions, drivers noted that operational changes at port terminals providing preferential access for ZEVs would be valuable non-financial incentives for ZEV adoption. These might include dedicated lanes for ZEVs, appointment system preferences, or exclusive gate times.

Terminal operators convened by the Collaborative noted several challenges with operational changes. Terminals are space-constrained and already have issues with congestion and idling, which could be exacerbated by dedicated ZEV lanes or on-terminal charging facilities. Charging drayage vehicles may compete with infrastructure and time for other equipment that terminal operators are working to electrify (e.g., cargo-

[33] See: https://recellcenter.org/.
[34] See, for example, Redwood Materials: https://www.redwoodmaterials.com/

handling equipment). Expanded gate times may add to neighborhood parking and traffic challenges as vehicles queue up for gates to open. Appointment system preferences for ZEVs may delay access for other drivers.

Until there are enough ZEV drayage vehicles in operation to guarantee that operational changes will be fully utilized, terminal operators preferred solutions that could link near-port charging and fueling facilities to gate efficiency improvements, such as better queuing space to help trucks flow faster into terminals.

Recommendations

Recommendation 6.25: In the near-term, explore operational changes that would link near-terminal charging/fueling and waiting areas with terminal gate operations. For example, ZEVs using a charging and fueling facility could complete transactions and data transfer while using the facility and then be dispatched directly to the terminal rather than going through the standard terminal gate infrastructure.

Recommendation 6.26: Stand up emergency services for ZEVs accessing port terminals for issues like towing or a dead battery, similar to how terminals would address emergency needs of diesel vehicles.

Recommendation 6.27: In the longer term, when ZEVs make up a significant percentage of the drayage fleet, consider strategies that would dedicate terminal space to ZEVs, such as ZEV priority lanes.

7. Infrastructure: Recommendations

This section outlines recommendations related to charging and fueling infrastructure, describing actions to:

- Develop initial publicly available charging and fueling infrastructure, and ensure a mix of options over time
- Ensure adequate power supply and infrastructure from utilities
- Enable an appropriate role for hydrogen vehicles and fueling as zero-emission solutions

Develop Initial Publicly Available Charging and Fueling Infrastructure, and Ensure a Mix of Options Over Time

Given the diversity of the drayage sector, there is no "one size fits all" charging and fueling solution. Rather, the region will need an ecosystem of public and private charging and hydrogen fueling facilities at dwell locations, along drayage routes, and along regional corridors (e.g., to Eastern Washington for the transport of agricultural products). Some needs—such as charging while parking along streets—will require new solutions.

In the near term, the region should focus on developing initial public and private charging. This initial infrastructure is a necessary step for enabling early deployment of ZEVs. Gaining experience with a diversity of infrastructure will support learning and adapting strategies over time. It will be important to recognize that early deployments may only be "approximately right."

Recommendations

Recommendation 7.1: Develop initial publicly available charging and fueling stations in a set of "no regrets" locations where they are most likely to serve high-volume local drayage routes and dwell locations. These locations are most likely in Sumner and Fife (near Tacoma), Tukwila and the Kent Valley (near Seattle), and/or near-port terminals. Port-owned real estate should be considered for charging and fueling infrastructure. Locations should be consistent with the drayage patterns for likely early adopters and demonstration projects.

It is important that some early deployments of charging and fueling infrastructure are publicly available (versus behind the fence) to make sure that independent owner operators and small businesses have access to these facilities if they choose to transition to zero-emission trucks. Not having to invest in their own charging or fueling would help lower their overhead and make the transition more affordable. Various types of fee or subscription arrangements can be regarded as "publicly available," as long as they make these charging and fueling services accessible to a broad range of the drayage market, including IOOs and small businesses. Subscriptions should not lock IOOs and small businesses into arrangements harmful to their businesses or livelihoods.

As part of this effort, regional stakeholders will need to refine understanding of potential early public charging and fueling locations by:

- Applying local knowledge from trucking companies and drivers about what distribution centers, warehouses, and other facilities are influencing routes and dwell times (and the likelihood that sites would be used by early adopters).
- Engaging communities about benefits, concerns, and optimal locations for facilities.
- Assessing utility infrastructure capacity and needs for charging infrastructure.
- Understanding real estate opportunities and land uses that can guide identification of sites/parcels.

Recommended Criteria for Evaluating Potential Charging and Fueling Sites

- **Locations make sense for existing supply chain routes.** They are along the most frequently traveled routes and where drayage vehicles are most likely to dwell (e.g., warehouses, logistics centers)
- **Locations make sense for drivers.** They should be accessible to drivers coming to and from work and include amenities for drivers, such as places to park their light-duty vehicles, bathrooms, and other services.
- **Locations make sense for communities.** They are located to maximize air quality benefits and minimize negative impacts (e.g., traffic, idling, parking, etc.)
- **Timely availability of electric service from utilities.** Infrastructure can bring the power needed to reliably charge vehicles.
- **Appropriate real estate is available.** Sites for charging and fueling stations are easily accessible from drayage routes and have ample area for vehicles and trailers to maneuver and park and to provide amenities for drivers.
- **Sites can be secured to prevent vandalism and theft.** Drivers are confident their vehicles will be safe, and charging equipment won't be inoperable due to damage.

Recommendation 7.2: Work aggressively to obtain funding at the magnitude needed for early development of a range of types of charging and fueling. Sufficient funding should be available to create publicly available charging infrastructure that is priced to provide lower, or at least comparable, operating costs compared to diesel.

Recommendation 7.3: Support technical assistance programs and incentive funding for companies to develop private behind-the-fence charging facilities. These facilities can provide safe and secure parking for the many drayage vehicles parked in company lots overnight.

Seattle City Light and the Breaking Barriers Collaborative currently provide technical assistance on fleet charging in the region.[35] WSDOT will begin offering technical assistance to help fleets plan for medium- and heavy-duty ZEV adoption in early 2025.

Recommendation 7.4: Provide Clean Fuel Standard infrastructure capacity credits for newly established publicly available charging and hydrogen fueling infrastructure owned by private entities. These credits would help generate momentum for private companies to invest in charging or refueling capacity by allowing them to receive credits based on the full capacity of the infrastructure, while utilization increases over time as vehicles are deployed.

The Washington Department of Ecology is currently considering amendments to the advanced credits program under the Clean Fuel Standard that would allow privately owned charging facilities available to multiple fleets to earn infrastructure capacity credits (see call-out below for more information on the CFS credits). The amount of such credits would be capped at a maximum not-to-exceed percentage of total CFS deficits of 2.5%.

Washington Clean Fuel Standard Credits for Electric Vehicle (EV) Charging

Washington's Clean Fuel Standard allows revenue to be generated through credits created by installing EV chargers and tracking and reporting the electricity used to displace fossil fuels for fleets. Owners of EV charging stations that receive credits can use revenue from credits sold in the Clean Fuel Standard market to pay for various projects, including installing more EV chargers and buying EV fleets. They are required to install meters to measure kilowatt hour usage and report regularly to Ecology. Once Ecology verifies reports and issues credits, owners can bank them or sell them.

In addition, current Ecology rules allow public entities to receive and sell advance credits for charging *capacity* at publicly owned and publicly available chargers. These credits are based on the capacity of the EV fast-charging site or hydrogen station minus the amount of fuel dispensed. Advance credits are currently only available to public entities, which may apply to borrow against future credit generation to purchase electric vehicles or vessels.

Recommendation 7.5: Provide trucking-as-a-service and other electric vehicle supply equipment (EVSE) companies with infrastructure planning resources, such as:

- Utility power capacity mapping to identify charging sites.
- City, county, port and other analysis of their properties suitable for charging (and/or private property in their jurisdictions).

Recommendation 7.6: Design infrastructure facilities to serve the needs of drivers with amenities, security, and reliability, specifically:

- Maximize co-location opportunities with amenities that are helpful for drivers, such as restrooms and food facilities. Longer charging times offer a new challenge, but also opportunities to help drivers meet their needs as they charge or take breaks required to meet hours of service rules.
- Ensure that charging facilities are safe, secure, and conveniently located along drayage routes.

[35] For Seattle City Light, see: https://www.seattle.gov/city-light/business-solutions/renewable-energy-services/fleet-electrification-program. For the Breaking Barriers Collaborative, see: https://www.breakingbarrierscollaborative.org/about.

- Ensure high levels of infrastructure reliability through uptime requirements and secure facilities. Reliability is critical to boost driver confidence and to meet the needs of drayage drivers that are constrained by hours-of-service rules and terminal schedules

Recommendation 7.7: Maximize co-location opportunities for public charging with other types of charging. Co-locating charging and fueling facilities with dedicated infrastructure for zero-emission transit buses, medium-duty ZEVs, or other large electricity loads can leverage existing infrastructure capacity. Publicly available "fence line" facilities could be co-located with private behind-the-fence charging.

Recommendation 7.8: Forecast scenarios of fully building out charging and fueling infrastructure to meet the needs of a future fleet of zero-emission drayage. Building on the high-level forecasts in Section 5, scenarios can examine alternate mixes of battery electric and hydrogen ZEVs, types and locations of charging facilities, technology advances, and timelines. Full buildout scenarios can be used to understand the funding needs for infrastructure, utility requirements, land use options, and traffic patterns, among others. Forecasted scenarios provide a foundation to work back to what will be needed in earlier phases of development.

Recommendation 7.9: Monitor the development of emerging and innovative charging and fueling alternatives that may be especially appropriate for drayage. These include inductive charging (e.g., while drivers wait for loads at ports or distribution centers), battery swapping, and street right-of-way charging.

Recommendation 7.10: Align local charging planning and infrastructure with state and federal planning for corridor charging along key I-5 and I-90 long-distance corridors, recognizing frequent longer distance travel patterns originating at the Ports of Tacoma and Seattle. Key initiatives focused on charging and hydrogen fueling along long-distance corridors include:

- The *National Zero-Emission Freight Corridor Strategy*, which identifies several charging hubs in the Seattle/Tacoma area and designates I-5 and I-90 as key corridors.
- The Federal Highway Administration's *Alternative Fuel Corridors Program*, which designates major national highways for installation of EV charging, hydrogen, and other fueling infrastructure at strategic locations. These corridors are eligible for Bipartisan Infrastructure Act funding. I-5 and parts of I-90 and I-82 in Eastern Washington are designated as Alternative Fuel Corridors for electric vehicles.[36]
- The *West Coast Clean Transit Corridor* project, an ongoing collaboration of West Coast utilities, to support the development of electric vehicle charging facilities along I-5 for heavy- and medium-duty freight haulers and delivery trucks.[37]

Recommendation 7.11: Utilities should provide rate structures that encourage optimal charging times for EVs, such as time of use (TOU) rates. TOUs offer lower cost electricity at certain times, typically during the night when the cost of generating electricity and demand for electricity are both low. These types of rate structures can provide lower-cost electricity consistent with overnight charging patterns and help utilities balance loads by avoiding charging during peak periods.

[36] See: https://www.fhwa.dot.gov/environment/alternative_fuel_corridors/.
[37] See: https://westcoastcleantransit.com/.

Seattle City Light is currently developing TOU rates, targeted for full customer launch in early 2025.[38] Puget Sound Energy launched a TOU pilot program in October 2023 to work with a limited number of residential homes for two years to study the impacts of different TOU designs.[39]

Ensure Adequate Power Supply and Infrastructure from Utilities

Charging facilities will require significant utility infrastructure to power them. Until recently, Puget Sound area utilities have not experienced large increases in load. They are now looking at rapid load growth projections—not just from transportation but also from electrification of buildings and an influx of new large data centers. To manage load growth, utilities are looking for demand-side solutions like managed charging and demand-response. Traditional approaches of meeting growth with increased energy efficiency are no longer sufficient. This is a transformative time for utilities.

A key challenge is that traditional utility planning and investment practices, which are governed by rules and regulatory oversight, are unlikely to allow utilities to proactively make infrastructure investments at the scale needed to fully transition drayage vehicles to ZEVs in the Puget Sound region. This is true for both regulated utilities and publicly owned utilities, although the specific governance and regulatory issues and barriers vary for different utility types. Specific barriers include:

- **Regulations:** Rules and approaches influencing utility investments in charging infrastructure differ between customer-owned utilities and investor-owned utilities regulated by the state's Utilities and Transportation Commission (UTC). To show that investments are prudent, some utilities need a customer application, which can hinder long-range infrastructure investments. These utilities need early engagement with customers to support project planning.
- **Cost and equity:** If not using state or federal funds or payments by large individual customers, utility investment costs are covered by ratepayers, raising equity issues for low-income customers (which can be one-third of customers in some Puget Sound-area service areas).
- **Lack of state and federal funding:** State and federal funding for infrastructure to support charging is valuable because it is not rate-based and can avoid increases in customer rates. However, there is a gap in federal and state funding for heavy-duty charging and fueling.
- **Competition for electricity with other sectors and needs:** This includes shore power and electrification of non-road equipment at ports as well as demands from other electric vehicles and other sectors, such as building electrification and data centers.

It is important for utilities to accurately map loads and forecast future system needs. Because they hear directly from potential customers, utilities often have the most comprehensive view of where there is interest in charging. However, it can be challenging for utilities to forecast where power will be available in the future for specific charging sites and/or customers because of dynamic conditions on the grid, project-specific needs, and lack of information about future demand from customers. Utilities need better data on customers' medium- and long-term charging plans (loads and locations) to inform system planning.

Planning and investment timelines also vary greatly based on project characteristics such as size, location, and current infrastructure. It is difficult to put any consistent timeline to projects.

[38] The Seattle City Council approved Seattle City Light's plans to introduce TOUs in September 2022. See: https://powerlines.seattle.gov/2024/01/30/an-update-on-city-lights-time-of-use-rate/.
[39] See: https://www.pse.com/en/account-and-billing/time-of-use

Recommendations

Recommendation 7.12: Advocate for state policies that give utilities greater ability to proactively build out charging infrastructure, drawing on policies being considered or implemented in other states. A potential model to draw on for Washington is California's "Rule 29," which allows utilities to rate-base charging infrastructure investments.[40]

Recommendation 7.13: Customers interested in charging facilities should proactively engage utilities, communities, and supply chains about proposed projects. They should consult with utilities before choosing a site to understand areas that may have the most suitable infrastructure and work with utilities to consider technology and design alternatives whose load profile is easier to meet (e.g., battery-supported charging). Utilities can help customers "right-size" charging infrastructure to match power needs, vehicle duty cycles, and fleet operations—and potentially avoid demand charges. They can co-develop phased plans that work with the capacity available today while additional capacity is built out. Together, customers and utilities can explore charging strategies that help utilities manage loads (e.g., battery storage and advanced controls such as vehicle to grid, or V2G). Utilities can also help these customers understand and utilize applicable incentive programs.

Customers should also proactively engage communities to understand their needs (e.g., parking, security) and reduce the likelihood of project-related conflicts during permitting, construction, and operation.

Customers should comprehensively plan project components and schedules to help avoid project delays. For example, customer-side purchases and installation of electrical switch gears are a frequent source of charging infrastructure project delays.

Prologis Heavy-Duty EV Charging Hub Powered by Microgrid

Prologis Mobility and Performance Team, a Maersk company, launched the Denker charging depot in April 2024 near the Ports of Los Angeles and Long Beach. Powered by a 2.75 MW microgrid with battery storage, the facility can charge nearly 100 heavy-duty electric trucks simultaneously. The microgrid allows the facility to operate independently or connect to the grid, increasingly reliability and resilience. The project was developed through partnerships with local authorities and utility companies, which helped expedite the process and overcome typical delays associated with grid upgrades.

Recommendation 7.14: Project proponents, like ports and state agencies, should add a requirement to charging infrastructure RFPs that applicants communicate early with utilities and engage in community-based planning for charging sites and local benefits.

Recommendation 7.15: Utilities should encourage customers to plan, communicate, and collaborate with them proactively by:

- Offering a pre-application process for charging infrastructure projects.
- Offering customer-facing programs, such as comprehensive fleet assessments, which allow the collection of data on potential charging infrastructure projects. This information can help inform longer-range system planning.

[40] See, for example: https://www.sce.com/sites/default/files/2022-07/EV%20Rule%2029%20Fact%20Sheet%200622_WCAG%20(V2).pdf

- Helping direct customers to utility, local, state, and federal vehicle and infrastructure incentive programs and assisting with stacking of incentives.

Recommendation 7.16: Utilities should collaborate with charging partners on demonstration projects.

Recommendation 7.17: Utilities should conduct iterative planning to assess how much capacity will be needed in 1-2 years, 3-5 years, and at scale. To inform this planning, they should:

- Work with large customers to gather information about medium- and longer-term plans to inform system planning.
- Partner with research and other organizations like the Electric Power Research Institute, Lawrence Berkeley National Laboratory, Pacific Northwest National Lab, and Puget Sound Clean Air Agency to research planning and infrastructure needs.
- Collaborate with each other and with regional stakeholders to help inform a Puget Sound regional picture of charging facility plans and infrastructure needs.

Recommendation 7.18: Utilities should explore strategies that can create grid capacity and management benefits from electrification, such as vehicle to grid, use of residual capacity of batteries for grid services, and the use of solar or other distributed energy resources at charging facilities or substations. For example, a vehicle-to-grid export rate would help boost vehicle-to-grid opportunities where drayage vehicles are idle for predictable periods of time. Infrastructure investments should be consistent with industry standards that allow for bi-directional and grid-interactive charging.[41]

Recommendation 7.19: Utility ZEV leads and regional stakeholders should educate utility leadership, regulators, and state policymakers about the needs and value of heavy-duty electrification. Frontline utility managers and staff working on heavy-duty electrification should be working with their boards, leadership, and regulators to raise awareness and build support. Utilities should proactively engage with state policymakers on infrastructure funding and program design—especially to leverage sources of funds that aren't rate based and don't raise utility rates—helping utilities maintain long-term rate affordability.

Recommendation 7.20: Utilities should consider their potential role in owning and operating charging infrastructure or utilizing utility property for charging. This may be most applicable where there is a barrier to privately funded charging or a clear public benefit, such as serving drivers that don't have access to private charging.

[41] These standards include OCPP and ISO 15118-20. See also, EPRI, Open Vehicle-Grid Integration Platform: https://www.epri.com/research/products/000000003002016236/

Utility Incentives for Zero-Emission Vehicles

Utilities in the Puget Sound region have several financial incentive programs to advance vehicle electrification.

Puget Sound Energy's Up and Go Fleet Incentives offer incentives up to $250,000 per charging location to help public and private fleets transition to electric vehicles. This includes support for electric service upgrades, EV charging equipment, and installation. PSE also provides load management incentives for off-peak charging, with credits ranging from $10 to $165 per charger monthly.

Seattle City Light's Fleet Incentives offer comprehensive support for fleet electrification, including advisory services, fleet assessments, and EV charging assessments. The program provides up to 100% of the cost for eligible charging infrastructure, with tiered rebates for different types of equipment. Rebates are available for both large entities and smaller businesses, including higher incentives in overburdened communities, to help reduce emissions and operational costs.

Tacoma Power's Community EV Charging Rebate provides incentives for publicly accessible chargers. The program focuses on expanding charging access and supporting the transition to electric vehicles by offering financial assistance for infrastructure upgrades, especially targeting public and community-based installations.

Enable an Appropriate Role for Hydrogen Vehicles and Fueling as Zero-Emission Solutions

Hydrogen-fueled ZEVs have some similar and some different characteristics from battery electric ZEVs. While ZEVs using these different fuels will likely compete for drayage market share, they can also be complementary, with each being used in duty cycles that favor their relative strengths.

Hydrogen-fueled ZEVs have several potential advantages compared to battery electric vehicles, including faster fueling times, lighter weight, extended range, and cold weather performance. They are also resilient to power loss and do not require as rapid a scaling of utility infrastructure (although hydrogen production facilities and supply chains are needed). There is substantial funding coming into the Pacific Northwest for supply, distribution and fueling (e.g., through the Pacific Northwest Hydrogen Hub, of which the NWSA is a part).

Hydrogen also has some disadvantages compared to battery electric vehicles and charging. Vehicles and fuel are currently more expensive, and anticipated state incentive programs don't recognize the cost difference. The production and supply system for hydrogen is less well-developed than for electricity. Limited fuel supplies—especially for green hydrogen produced via clean energy—means there is more competition for hydrogen fuels between sectors, potentially causing shortages for transportation.

Hydrogen fueling and battery electric charging also share some characteristics. Both are nascent, so there is lack of familiarity and experience with both. Adoption is currently driven by financial incentives and requirements. Both lack secondary vehicle markets. Each fuel type's GHG impact depends on its energy source: Washington's clean electricity grid supports substantial emissions reductions for battery electric vehicles, while green hydrogen is essential to achieving similar benefits in hydrogen fueling.

Recommendations

Recommendation 7.21: Advance hydrogen fueling and vehicles in parallel with battery electric trucks and charging. The same infrastructure and vehicle incentive recommendations should be applied to both.

Demonstration projects and early investments should be designed to learn about the relative strengths and optimal deployment of each.

Recommendation 7.22: Lean into the specific strengths of hydrogen over battery electric trucks in certain applications, especially for drivers and companies mixing drayage and long-haul routes who would benefit from greater range and faster fueling. Conversely, avoid focusing on hydrogen for applications where battery electric trucks make more sense.

Recommendation 7.23: Advocate for use of hydrogen with the lowest carbon intensity, such as electrolytic hydrogen, to maximize emissions reduction opportunities.

Recommendation 7.24: Continue collaboration with the Pacific Northwest Hydrogen Hub to develop regional hydrogen supply chains. Encourage the Hub to follow through on drayage-related projects and explore new drayage opportunities. Emphasize development of the fueling infrastructure needed to support hydrogen-fueled ZEVs working in and around the ports.

8. Equity and Opportunity: Recommendations

A key goal of the transition to zero-emission vehicles serving Puget Sound Gateways, and this Roadmap, is improving air quality in near-port neighborhoods that are disproportionally impacted by air pollutants from diesel vehicles. Another key focus of the Roadmap is how to make the transition work for the IOOs and small businesses that depend on drayage for livelihoods.

Considerations of how to transition to zero-emission drayage in a way that provides equitable opportunity to drivers and respects the opportunities and concerns of near-port communities are reflected in many of the recommendations on vehicles and infrastructure, described in previous sections. This section addresses other key areas important for an equitable transition, outlining actions to:

- Ensure drivers and small companies have opportunities to adopt ZEVs but don't bear the risk of the transition
- Provide opportunities for drivers to test and understand ZEVs
- Provide driver education, outreach, assistance, and ongoing engagement
- Engage communities regarding new facility siting and maximize community benefits
- Leverage the opportunity for the ZEV transition to create jobs and economic opportunity

Ensure Drivers and Small Companies Have Opportunities to Adopt ZEVs but Don't Bear the Risk of the Transition

Drivers identified many barriers to their adoption of ZEVs, led by the cost of vehicles and uncertainty about how ZEVs might disrupt their businesses. They said they wanted to know more about the trucks and how they operate in the real world. They want to see solid examples and hear from people who have driven ZEVs on a daily basis to build comfort and trust in the new technologies. Drivers have specific questions, such as how well ZEVs go up and down hills and how charging works in practice.

Drivers noted that most IOOs and small fleets can’t afford to be the first adopters of ZEVs. Rather, the transition should start with large trucking companies that can bear the financial and operational risks of ZEVs and demonstrate how they work in practice (as well as providing used ZEVs for secondary markets). If the zero-

emission trucks work for the large- and medium-size companies, and the infrastructure is in place, drivers said IOOs will consider it. When drivers start seeing ZEVs on the road, they can begin to feel more comfortable.

Recommendations

Recommendation 8.1: Help ensure that ZEVs are accessible for smaller companies and owner-operators if they choose to purchase them. As outlined through recommendations in Section 6, this includes accelerating the secondary market for used vehicles. It also includes ensuring new and used vehicle purchase incentives have voucher amount plus-ups, or modifiers, for vehicles operating in disadvantaged communities and those owned by small, minority-owned businesses. These programs should also offer technical assistance, accessible application processes, and tailored education and outreach.

Recommendation 8.2: Encourage preferential financing for purchases of new and used ZEVs by IOOs and small businesses if they choose to do so. For example:

- Offer financing wrap-around services for IOOs and small businesses to help them access loans.
- Reduce default risk through state run loan-loss reserves to help smaller operators qualify for loans and protect banks from default.
- Co-sign leases with smaller operators.

Examples of Financial Support for Purchasing New and Used Zero-emission Trucks

The **California Capital Access Program** (CalCAP) offers loan-loss reserve support to encourage lenders to provide financing for the purchase or retrofit of cleaner trucks and buses. This program specifically targets small businesses, helping them replace older, higher-emission vehicles with newer, zero-emission or low-emission alternatives. CalCAP covers a portion of the lender's potential losses on loans, making it less risky for lenders to finance zero-emission vehicles.

The **NWSA** has established a loan-loss reserve program implemented through Community Development Financial Institutions (CDFIs), specifically designed to support the replacement of diesel trucks with cleaner alternatives.

Forum Mobility and **Climate United** (a national coalition providing loans for clean energy projects) have launched a leasing program for Class 8 trucks aimed to provide low-cost access to ZEVs for fleets. The program is intended to primarily serve drayage drivers and fleets. It is starting with the Ports of Long Beach and Los Angeles in California. Climate United has committed up to $250 million to acquire 500 electric trucks, leveraging nearly $7 billion in federal funding. Forum Mobility is providing charging solutions paired with each truck lease.

Recommendation 8.3. Don't require scrappage as a condition of receiving financial incentives for the purchase of new or used ZEVs. Scrappage requirements create an additional barrier to adoption on top of the uncertainty that drivers already have about making a substantial upfront investment in a new technology. Some drivers and small companies may opt to retain diesel vehicles as backup or to use for longer-distance trips until charging and fueling infrastructure is more extensively deployed. Rather than *requiring* scrappage, ZEV incentive programs could consider encouraging it by offering an additional financial incentive.

Recommendation 8.4: Help ensure that start-up companies based on new business models demonstrate financial strength to provide confidence to drayage operators that services will remain available. This may be especially valuable for smaller operations that are more vulnerable and have less capacity to research and validate these companies.

Provide Opportunities for Drivers to Test and Understand ZEVs

During listening sessions, drivers suggested offering a demonstration program to expose truck drivers to zero-emission trucks and let them test the vehicles on their drayage routes and use charging and fueling infrastructure. Such programs would increase awareness and decrease uncertainty about unfamiliar technologies. They would help demystify new technologies and increase confidence that ZEVs can perform in drayage duty cycles.

Recommendations

Recommendation 8.5: Offer accessible opportunities for current NWSA drayage owners and operators to drive ZEVs and use related charging and fueling systems through a demonstration center and ride-and-drives. Offering a variety of ways to learn about and test zero-emission trucks will help meet the needs and constraints of a diverse set of drivers. Facilities offering these services can also offer wrap-around services to help drivers access and bundle incentive programs and financing. They can help connect drayage drivers in the Puget Sound region with drivers and small businesses in California and elsewhere who have had direct experience using zero-emission trucks for port drayage.

Recommendation 8.6: Seek funding for and implement a temporary replacement vehicle or "truck loaner" program that allows drivers to test out ZEVs in drayage duty cycles for several days or weeks and access related charging and fueling infrastructure. These programs would be especially helpful when drivers' own vehicles experience down time for maintenance. Potential models include:

- Programs funded by the state or ports offering loaner ZEVs for short periods at rates comparable to diesel (see example in call-out box).
- Loaner programs offered by dealers or OEMs, including for when trucks are being serviced.
- Loaner programs offered by larger freight companies that have purchased or leased ZEVs and make them available to contracted IOOs.

Los Angeles Area Clean Technology Truck Loaner Program

In mid-2024, the South Coast Air Quality Management District in Southern California solicited proposals to develop a program to provide short-term truck rental services for zero-emission medium- and heavy-duty on-road trucks. Based on a plan published in 2023, the program would provide fleet owners and operators in Los Angeles the opportunity to experience zero-emission trucks for a short period in their regular transport and cargo businesses at little to no cost. The primary objective is to enable these fleet owners and operators to assess the suitability of zero-emission medium- and heavy-duty trucks for their operations. The effort was spurred by a recognition that many fleet owners and operators have been slow to embrace zero-emission technology due to concerns about costs, range, and insufficient charging infrastructure.

Provide Driver and Small Business Education, Outreach, Assistance, and Ongoing Engagement

Drayage drivers will need targeted outreach and hands-on assistance to help make the transition to ZEV technology successfully.

Driver Engagement Lessons from Seattle

The Somali Independent Business Alliance, a Seattle program partner, evaluated the city's incentive program for zero-emission vehicles and provided feedback on driver engagement. The evaluation highlighted the need for culturally relevant outreach and support to better connect with drivers from diverse communities. The Alliance recommended expanding outreach efforts statewide, using targeted messaging and accessible resources to enhance driver participation in ZEV programs. They emphasized the importance of engaging community leaders and using trusted channels to build awareness and trust among drivers.

Recommendations

Recommendation 8.7: Conduct surveys to understand drivers' needs, and preferences, thus fostering better engagement.

Recommendation 8.8: Engage drivers directly through accessible meetings and trainings that offer:

- Flexible scheduling at times that are convenient for drivers to accommodate their busy schedules.
- Compelling experiences to learn about and test zero-emission technologies, such as offering ZEVs for ride-and-drives.
- A mix of online and in-person workshops, training, and informational sessions.
- Stipends, recognition, awards, refreshments, and other incentives that recognize the value of drivers' time, especially during in-person meetings.
- Culturally and linguistically appropriate support, ensuring materials and interactions are culturally sensitive and in a variety of languages.

Recommendation 8.9: Distribute information through trusted sources, including community-based organizations with established relationships within the community. Provide information, education, and training to community-based organization staff to help ensure they can effectively answer questions about these complex technologies.

Recommendation 8.10: Offer technical assistance to drivers and small businesses, including one-on-one assistance in several languages. This assistance can help drivers and small businesses navigate decision making about ZEV adoption and help them access available incentives for vehicles and infrastructure.

Recommendation 8.11: Establish an advisory committee for ZEV transition projects comprised of drivers and owners to enhance communication and trust. Compensate participants for their time.

Recommendation 8.12: Provide drivers and affected communities with regular updates through newsletters and other channels to keep them apprised of opportunities and lessons.

Recommendation 8.13: Create lines of communication for feedback from drivers about their experiences with ZEVs, both positive and negative.

Engage Communities Regarding New Facility Siting and Maximize Community Benefits

Community members and organizations see the benefits of ZEVs improving air quality but also potential disruptions from new infrastructure, traffic patterns, and shifts in the market for drayage driving and servicing.

Recommendations

Recommendation 8.14: Proactively engage with communities on charging/fueling infrastructure location and design. Locations with ZEV infrastructure will be the places where air quality benefits are realized soonest. Community needs should inform where to target early adoption.

Community Engagement for ZEV Infrastructure

The City of Long Beach Blueprint for Medium- and Heavy-Duty Zero Emission Vehicle Infrastructure outlines a comprehensive approach to developing medium- and heavy-duty zero-emission vehicle infrastructure in Long Beach, California. It includes strategies for engaging local stakeholders, identifying suitable locations, and integrating community needs into planning. The goal is to ensure that infrastructure development aligns with environmental justice targets, supports local workforce development, and addresses community-specific concerns. This model emphasizes collaboration and community involvement to create accessible and equitable ZEV infrastructure.

Recommendation 8.15: Design overnight charging and fueling infrastructure to provide a safe and secure place for vehicles as an alternative to illegal neighborhood parking. Site and design infrastructure in ways that help resolve neighborhood issues with traffic, congestion, and noise.

Recommendation 8.16: Conduct community engagement efforts on the clean air benefits of ZEVs and address specific concerns and misconceptions. Partner with community-based organizations on outreach and engagement to community members and drivers. Train and compensate these organizations to ensure they are equipped with the knowledge and resources needed.

Leverage the Opportunity for the ZEV Transition to Create Jobs and Economic Opportunity

A transition to ZEVs in the drayage market (and across the entire transportation sector) represents a monumental change in technology and massive financial investments. These changes will undoubtedly require significant workforce growth and training in the Puget Sound Gateway to support sales, maintenance, operations, and construction of vehicles and infrastructure. Many of these workforce impacts and opportunities will be local. In particular, infrastructure construction and maintenance will require boots on the ground in the region. So too will trained technicians to maintain and repair the vehicles.

Early examples of large-scale ZEV truck deployments have shown that fleets quickly need to identify and train technicians to safely handle and service vehicles as soon as those vehicles enter the fleet. Fleets typically rely on dealerships to service ZEVs in the first few years, as both fleets and manufacturers develop the right training materials to eventually allow fleets to perform more complex service activities that may involve high voltage systems. The best technicians for these new vehicle platforms may not be the most experienced diesel

technicians. Identifying and training eager, engaged employees who want to learn these new technologies appears to provide the best results for early adopter fleets and dealerships.

Trained technicians will also be needed to install, operate, and maintain infrastructure. Fortunately, many of the skills required to support light-duty fast charging infrastructure are equally applicable to heavy-duty charging infrastructure. However, evolving standards and increasing power and voltage levels in both the light-duty and heavy-duty markets will certainly require ongoing training for the existing workforce, and increased deployments of infrastructure will require greater numbers of technicians.

Recommendations

Recommendation 8.17: Foster collaboration among government, manufacturers, dealerships, fleets, labor organizations, technical colleges, and trade schools to develop and offer technician training programs for skilled ZEV mechanics. Ensure that the timing, cost, and content of training is accessible for people currently working in the drayage sector, including opportunities to pursue training during periods of slow business due to dips in cargo volumes.

Recommendation 8.18: Assist the development of new small businesses and expansion of services for existing small businesses in near-port communities. Examples include providing technical assistance for service businesses to become certified to provide maintenance for ZEVs or support to create new businesses that improve access to vehicles and infrastructure.

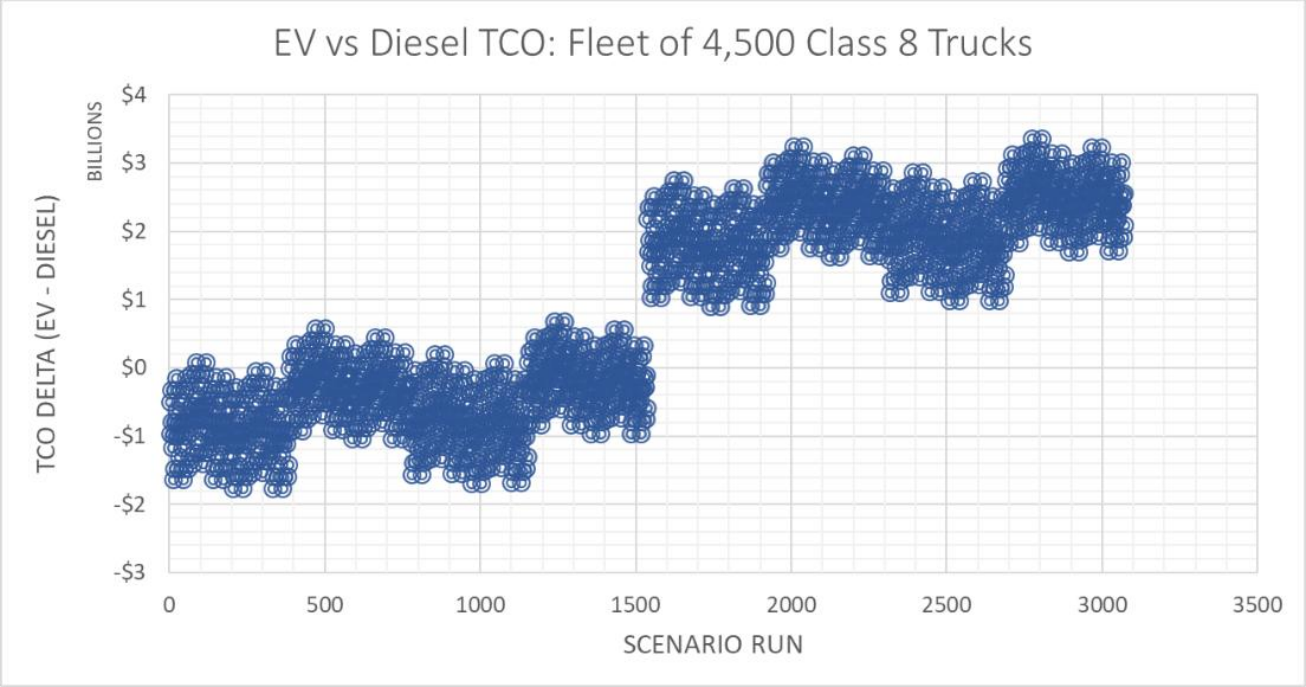
9. Funding the ZEV Transition

Cost of the Transition

The total cost of the ZEV transition for a fleet of 4,500-5,000 drayage vehicles in the Seattle/Tacoma Gateway is highly uncertain. Based on data for battery electric trucks, estimated incremental costs compared to a diesel baseline range from $1.8 billion less than diesel to $3.4 billion more than diesel, with a mid-range estimate of around $1 billion more than diesel (see Figure 10, which plots the simulated cost differential between battery electric and diesel trucks across thousands of scenarios with varying estimates of key costs across a range of values).[42] As the transition shifts from public investment to increasing private investment, most of these costs will eventually be passed through to consumers in the form of higher shipping costs.

[42] This estimate is just based on data for battery electric trucks. Currently, hydrogen fuel cell trucks are more expensive than battery electric trucks and their fuel costs are greater, so overall transition costs would be higher. In the future, hydrogen may have more opportunity to benefit from increased scale of production and technology maturation. Generally, the long-term costs for a full transition are uncertain, as is the ultimate mix of technologies the market will adopt.

Figure 10. Cost Estimates of ZEV Transition (Battery Electric Only)



Source: GNA for Zero-emission Truck Collaborative

The wide range in the cost estimate is mostly driven by uncertainty about the future purchase price of ZEVs—estimated to be $223,000 per battery electric vehicle for the lower cost scenarios (lower left quadrant of Figure 10) and $640,000 for the higher cost scenarios (upper right quadrant of Figure 10).[43] Over the long term, vehicle price is expected to decline relative to range and performance. This decline will help reduce, but not eliminate, the gap between the price of a new ZEV and a new diesel truck.

Long-term cost estimates for the ZEV transition also include the cost of infrastructure equipment and installation along with grid-side costs to supply electricity. These infrastructure costs range from around $1,300 to $3,700 per kilowatt depending on the type of charger. Grid-side costs are difficult to estimate but may be significant, estimated at $90 million to $550 million. If fully rate-based, these grid-side costs would be passed on to utility rate payers.

Public Funding for the ZEV Transition

There is a clear need for substantial public funding to incentivize the transition to zero-emission drayage vehicles, helping bridge the price gap between ZEVs and diesel vehicles and funding charging and fueling infrastructure. While there is promise in creating a secondary market for ZEVs over time, that will also require substantial public incentives as used ZEV prices will continue to be greater than used diesel vehicles.

One of the key goals of this Roadmap is to make the transition to zero-emission drayage equitable, retaining the ability of current IOOs and small drayage trucking businesses to be successful. Meeting that goal will require

[43] The $223,000 to $640,000 price range is based on low and high estimates from a range of studies. The $430,000 price used for the TCO analysis in Section 4 is the midpoint between these high and low values.

careful design of incentive programs that adapt over time to rapidly changing market dynamics. Current incentives remain fragmented and somewhat uncertain.

Fleet owners and even alternative operators such as trucking-as-a-service providers will also require substantial upfront capital for charging infrastructure, and that will also require incentive funding. Development of publicly available charging infrastructure will be needed for IOOs and small businesses to successfully make the zero-emission transition. They simply do not have the available capital to make a large upfront investment in charging and fueling. IOOs have also been clear that they will need to have maintenance and other support, such as replacement vehicle availability, as this transition occurs.

In Washington state, there is a real opportunity to overcome some of these challenges with careful implementation of subsidy programs and stackability of a variety of newly available state and federal incentives and grant programs. At the time of publication, the status of many federal incentives has become uncertain, and it will take some months to clarify which may remain available to be stacked with state and other incentives. Currently, federal and state incentives are fragmented, have different eligibility requirements, and some contain barriers such as Buy America provisions. (A listing of current federal and state incentive programs is included as Appendix D.) State agencies and organizations like NWSA and the Puget Sound Clean Air Agency can play an important role in bringing funding to the region and helping make it accessible to public and private organizations working on zero-emission drayage.

The Washington State Legislature has initially made $110 million available for a state-wide medium- and heavy-duty vehicle incentive program.[44] The recommended program has been designed to be stackable with federal grant and incentive programs and for eventual development of secondary market incentives. WSDOT has publicly indicated the program will be up and running with a third-party administrator in the second quarter of 2025.

The NWSA has also been pursuing federal and regional grant funding opportunities and has issued a number of Requests for Proposals intended to provide the necessary funding support to get the first ZEVs into the NWSA gateway. The NWSA has successfully obtained $6 million from Washington's Climate Commitment Act (CCA), $2.8 million in a Congestion Mitigation and Air Quality Grant (CMAQ). An additional $28 million from two U.S. FHWA grant programs have been preliminarily awarded, but at the time of publication there is uncertainty regarding whether these funds will be subject to funding freezes at the federal level under the new administration. NWSA continues to pursue additional grant funding. Creating NWSA funding programs through grants obtained directly by NWSA creates an opportunity to fill some of the gaps in other funding programs, and NWSA is expected to announce the recipients of the first of those funding programs in the first or second quarter of 2025.

The grants the NWSA has received are intended to help get a start-up number of ZEVs into the Tacoma and Seattle gateways. This will allow drayage operators to see how the vehicles perform here in typical Pacific Northwest weather and drayage operating conditions. It will create the opportunity to learn what infrastructure and support is necessary to make the transition. Complementary efforts to provide experience with ZEVs through ride-and-drives and loaner vehicle programs are recommendations of this Roadmap (see Section 8).

The stability and adaptability of funding sources over time must also be a consideration. Because this is a very dynamic time in the transition to zero-emission trucking, it is likely that much will be learned as vehicle pricing changes, alternative financing methods become more available and charging infrastructure matures.

[44] See: https://leg.wa.gov/JTC/Meetings/Documents/Agendas/2023%20Agendas/Oct%209/CALSTART_MHDZEV.pdf

Development of a secondary market will provide more certainty for initial purchasers that there is a stable resale value for zero-emission trucks. Incentives for secondary market purchases should help address equity concerns for IOOs and small businesses.

The initial funding released by NWSA will create a learning opportunity and should be adapted based on lessons about what is needed to successfully support charging infrastructure development and equitable vehicle acquisition programs. Long-term stability of funding sources will be needed to increase the momentum of the transition. At the same time, elimination of disincentives to the transition should also be pursued. This would include items such as repeal of federal excise taxes for zero-emission truck purchases and consideration of ways to keep public charging costs lower than diesel fuel costs.

Private Funding for the ZEV Transition

Public sector funding is critical to jump-starting the ZEV transition and accelerating its early development. However, there is and will continue be, large amounts of private capital going to zero-emission vehicles, infrastructure, technology innovation, and other aspects of the ZEV transition. Most public funding programs require significant private cost share or investment from the recipient to qualify for incentives.

It is difficult to estimate the overall magnitude of private sector investment in the heavy-duty ZEV sector and to parse out investments in the drayage sector specifically. However, some examples give a sense of the scale of private investment.

In a 2024 analysis, the Environmental Defense Fund found that over the past 9 years (2015-2024), EV manufacturers in the U.S. announced investments of over $188 billion in the manufacture of EVs, batteries, and other supporting technologies.[45] About 7.5% of that investment went specifically to medium- and heavy-duty vehicles, and another 70% went to work on batteries, EV components, and other elements of the EV supply chain that can serve both passenger and commercial vehicles.

New business models and private sector collaborations are emerging to invest in charging. Last year, for example, companies announced a $67.5 million joint venture for a 280-mile commercial charging corridor between Los Angeles and Las Vegas and more than $1 billion raised from investors for heavy-duty charging stations between California's Port of Long Beach and El Paso, Texas.[46]

Additionally, utility programs are directing funds toward EV deployments by providing revenue streams for EV users, charging station owners, and project developers. Utilities are also investing in grid upgrades to support transportation electrification.

10. Roles and Responsibilities

The transition to ZEV drayage at scale will take the aligned effort of many types or organizations. The table below indicates key organizations and their opportunities to advance the ZEV transition. Relevant recommendations are referenced in parentheses next to each bullet point.

[45] Environmental Defense Fund, *U.S. Electric Vehicle Manufacturing Investments and Jobs*: https://www.edf.org/sites/default/files/2024-03/EDF_US_EV_Manufacturing_Investments_Spring2024.pdf
[46] "Big-Truck Charging Has Private Money's Attention," Transport Topics: https://www.ttnews.com/articles/greenlane-truck-hub

Table 7. Roles in the ZEV Transition (with reference to key Roadmap recommendations)

Type of Organization	Opportunities to Advance ZEV Transition
OEMs	• Ensure availability of ZEV options in Northwest markets (6.2, 6.18) • Partner with carriers to adopt ZEVs (6.10, 6.17) • Support and participate in secondary market opportunities for used ZEVs (6.12, 6.14, 6.15) • Provide used vehicle reconditioning and QA/QC programs (6.14) • Offer ZEV leasing options (6.10, 6.18)
Dealers	• Raise awareness and educate customers about the benefits, features, and operational considerations of ZEVs (6.7, 6.9, 8.8, 8.9, 8.10) • Leverage established networks, customer relationships, and marketing capabilities to promote ZEVs (6.6, 6.9, 8.8 8.9) • Administer point- of- sale vouchers for ZEV incentive programs (6.2, 6.8) • Provide certified after-sales support and maintenance services for ZEVs (6.20, 8.17) • Provide ZEV service training programs (6.21, 8.17, 8.18) • Bundle financial incentives for ZEVs (6.4, 6.6, 6.18) • Inform future product development through feedback from users (6.11) • Advocate for ZEV infrastructure investments (7.1, 7.2)
Trucking Companies and Drivers	• Utilize incentive programs for vehicles and infrastructure (6.7, 6.8, 8.1) • Participate in training and education programs (6.9, 8.8, 8.10) • Inform siting of charging and fueling infrastructure in locations most appropriate drayage users (7.1, 7.8, 8.14)
Charging and Fueling Providers/Trucking-as-a-service	• Proactively engage communities, drivers, and trucking companies about infrastructure location and land use; seek to maximize co-location opportunities with amenities helpful to drivers and communities (7.6, 7.7, 8.14) • Proactively engage with utilities regarding existing infrastructure and power supply needs (7.13, 7.15) • Comprehensively plan infrastructure projects to help avoid project delays (7.5, 7.14, 7.17)
Utilities	• Provide information on electricity capacity for target charging locations (7.5, 7.13) • Offer a pre-application process for charging infrastructure projects (7.15) • Offer customer-facing programs, such as comprehensive fleet assessments, which allow the collection of data on potential charging infrastructure projects. This information can help inform longer-range system planning (7.15, 7.17) • Help direct customers to utility, local, state, and federal vehicle and infrastructure incentive programs and assisting with stacking of incentives (7.15) • Collaborate with EVSE partners and others on demonstration projects (7.16) • Partner with research and planning organizations like the Electric Power Research Institute, Lawrence Berkeley National Laboratory, Pacific Northwest National Lab, and the Puget Sound Clean Air Agency to research planning and infrastructure needs. (7.17) • Conduct iterative planning to assess how much capacity will be needed in 1-2 years, 3-5 years, and at scale. (7.17) • Explore strategies that can create grid capacity and management benefits from electrification, such as vehicle-to-grid, use of residual capacity of batteries for grid-services, and the use of solar or other distributed energy resources at charging facilities or substations. (7.18)
Carriers/Site owners	• Adopt new and/or use vehicles into fleets (6.12, 8.1) • Develop behind-the-fence charging at facilities (7.3) • Proactively engage utilities about charging projects and anticipated future needs (7.13, 7.15)

Type of Organization	Opportunities to Advance ZEV Transition
	• Comprehensively plan infrastructure projects to help avoid project delays (7.5, 7.14, 7.17)
State Government	• Sponsor sustainable vehicle and infrastructure incentive programs that meet goals of the Roadmap (6.1, 6.2, 6.3) • Fund demonstration projects (6.10) • Design heavy duty ZEV regulations to meet goals of Roadmap (6.4, 7.4, 7.23)
Local Government	• Sponsor sustainable vehicle and infrastructure incentive programs that meet goals of the Roadmap (6.1, 6.2) • Fund, implement, and partner on demonstration projects (6.10) • Facilitate development of publicly available charging and fueling infrastructure along drayage routes and at dwell locations (7.1, 7.5)
Regional Government (e.g., Puget Sound Clean Air Agency)	• Administer or support sustainable vehicle and infrastructure incentive programs that meet goals of the Roadmap (6.1, 6.2) • Fund, implement, and partner on demonstration projects (6.10) • Convene and collaborative with companies transitioning fleets and/or supporting the transition (6.7, 8.17) • Inform regulations and program development (e.g., with air quality data from the Puget Sound Clean Air Agency) (6.4, 7.4)
Federal Government	• Design vehicle/fuel regulatory programs to meet goals of Roadmap (6.3) • Provide funding for state, local, and ports ZEV programs (6.3, 7.2)
Ports/NWSA	• Raise funds for ZEV programs (6.1, 6.3, 7.2) • Sponsor demonstration programs (6.10) • Sponsor vehicle incentive programs (6.1, 6.2, 6.12) • Accelerate vehicle replacement programs (6.12, 8.3) • Add requirement to charging infrastructure RFPs requiring early engagement with utilities and community-based planning for charging sites (7.14)
Terminal Operators	• Stand-up emergency services for ZEV's accessing port terminals for issues like towing or a dead battery, similar to how terminals would address emergency needs of diesel vehicles (6.25) • Coordinate with near-port charging facility providers to explore opportunities for linking charging facilities with terminal gate operations (6.25)
Community-based organizations	• Participate in opportunities to inform communities and drivers about ZEVs and help link them to financial incentives and programs (6.9, 8.9, 8.16) • Participate in community-level processes related to infrastructure siting, traffic, parking, and other issues related to zero-emission drayage (8.14, 8.15)
Shippers and logistics companies	• Set decarbonization/ESG goals, assess fully lifecycle emissions, and include drayage transportation emissions in action plans • Convert own fleets to ZEVs, as applicable • Contract/partner with companies committed to transitioning to ZEVs • Educate carriers about ZEVs and charging/fueling • Support or encourage charging/fueling infrastructure investments • Provide non-financial incentives for ZEVs, such as priority loading (6.25) • Sponsor alternative business models that make ZEVs available to drivers or otherwise provide financial incentives for drivers/companies that use ZEVs for drayage (6.17, 6.18)

Type of Organization	Opportunities to Advance ZEV Transition
	• Explore opportunities for pre-competitive business collaboration committing to ZEV drayage, drawing on models like Cargo Owners for Zero Emission Vessels (COZEV) and the Zero Emission Maritime Buyers Alliance (ZEMBA)
Advocates	• Advocate for state and federal funding and programs to meet goals of Roadmap (6.2, 6.3, 6.4, 6.12, 6.18)

11. Ongoing Collaboration and Coordination

Ongoing collaboration and coordination will be needed to advance the recommendations in this Roadmap and to monitor and learn from implementation activities going forward.

Collaborative 2.0

Current members of the Collaborative support the continuation of the effort as "Collaborative 2.0" with the following purpose:

1. Continue to be a collaborative forum for:

- Cross-sector dialogue and collaboration
- Community, environmental justice, and driver engagement
- Private sector engagement (OEMs, dealers, infrastructure, trucking-as-a service, unions)

2. Track and learn from ongoing implementation, especially:

- Regional demonstration projects for vehicles and infrastructure
- Market development for used and new ZEVs
- Implementation and impact of vehicle incentive and financing programs (e.g., Washington state, NWSA)
- Regional public, utility, and private sector investment in EV charging and fueling infrastructure
- Siting and design of the charging infrastructure and hydrogen fueling network

3. Continue to inform the ZEV transition in priority areas where opportunities and needs are evolving, specifically:

- Secondary market development
- Charging and fueling infrastructure forecasts, including refined estimates of number, location, and type
- NWSA incentive and other program design
- Workforce development and economic opportunity

4. Advise on optimal use of grant and other resources coming into the region to implement the Roadmap

5. Advise on and advocate for state and federal funding and policy for the ZEV transition

6. Monitor emerging issues and identify areas for research and solutions development

7. Update Roadmap recommended actions based on sector development and learning

8. Act as a "clearinghouse" of information on zero-emission drayage implementation in the region, including:

- Public charging and fueling infrastructure development
- Demonstration projects
- ZEV market data (e.g., vehicle purchases)

Collaborative 2.0 Membership and Engagement

As the Collaborative continues its work, it should continue to center the needs of BIPOC and low-income truck drivers and impacted communities in Collaborative discussions. To do this, the Collaborative should hold community engagement-focused events or outreach to give environmental justice communities impacted by this transition the ability to learn and contribute. It should continue to hear directly from drivers and consider creating a drayage driver forum that can provide direct insights on process and help drivers effectively acquire ZEVs.

Collaborative 2.0 should also expand the voices contributing to this work, either through membership in the Collaborative or other means. Priorities include:

- Drayage drivers
- OEMs, dealers, and leasing companies
- Charging providers, trucking-as-a-service firms, and other private investors and developers (e.g., truck stops)
- Policy experts (including air quality) and agency staff (including Washington Department of Commerce)
- Local government representatives (e.g., from the Kent Valley)
- Workforce development

12. Conclusion

The transition to zero-emission drayage trucks at Puget Sound Gateway ports is a critical step to reduce air pollution, greenhouse gas emissions, and environmental health disparities associated with diesel vehicles. While the challenges are significant, particularly for IOOs and small businesses, the benefits are compelling.

The Puget Sound Zero-Emission Truck Collaborative has developed this Roadmap to guide the ZEV transition at ports with recommendations related to drayage vehicles, infrastructure, and equity and opportunity. We have also outlined near-term priority actions to fully implement ZEV incentive programs, stand up demonstration projects, invest in initial public charging and fueling, plan for the massive electricity loads that may be required, and engaging drivers and communities on how to make these efforts effective and equitable. This work will require substantial investment, supportive policy, and the work of the many organizations and sectors involved in ports drayage. This is not an easy journey, but it is one very much worth taking.

Appendix A: Collaborative Members

This Roadmap was developed by the collective efforts of the members of the Collaborative. Individually, members brought their expertise, insights, and viewpoints to the process of understanding the challenges for equitably and effectively transitioning to zero-emission drayage and identifying a set of solutions to put this transition into motion. While members' individual contributions provided the raw materials for the Roadmap, the structure of its findings and recommendations were developed through the collaborative work of joint learning and discussion.

Members are committed to the path outlined in this document as the right one for the region to follow even as individual recommendations may not reflect their work or organizational focus. The Roadmap does not commit participating organizations to every recommendation—we expect to continue discussing, debating, and adapting as this transition proceeds. However, the Roadmap does reflect a commitment for each of our organizations to use it as a guide as we contribute to achieving the vision of zero-emission drayage.

Like all maps, this Roadmap will be refined as we learn more about the landscape. We are proud of our work together as a Collaborative and look forward to working within and beyond our membership for the Roadmap's effective implementation.

- Aaron August, Puget Sound Energy
- Mia Ayala-Marshall, Duwamish River Community Coalition
- Jed Boba, Puyallup Tribe of Indians
- Sheri Call, Washington Trucking Associations
- Christine Cooley, Puget Sound Clean Air Agency (Alternate: Mary Cho)
- Peter Gishuru, African Chamber of Commerce of the Pacific Northwest
- Josh Grandbouche, Washington Department of Ecology
- Jeff Grant, HTEC (Alternate: Laura Quinlan)
- Jim Jensen, WSU Green Transportation Program (Alternate: Philip Saunders)
- Rick Kolpa, Prologis
- Colin Lay, PACCAR/Kenworth (Alternate: Alec Cervenka)
- David Logsdon, Seattle City Light (Alternate: Angela Song)
- Melissa Malott, Communities for a Healthy Bay (Alternate: Logan Danzek)
- Michael Mann, Clean and Prosperous Washington
- Dan Marshall, Tacoma Public Utilities
- Betz Mayer, PNWER
- George Mitchell, Mercer Logistics
- Leah Missik, Climate Solutions
- Steve Nicholas, Northwest Seaport Alliance (Alternate: Nicola Graham)
- Clarisse Reiter, IKEA Purchasing Services (US), Inc.
- Margaret Sonnen, Tri Pak, Inc., a TTSI company
- Marcos Wanless, Latino Metropolitan Chamber of Commerce
- Meghan Weinman, SSA Marine
- Keith Weir, IBEW 46
- Tracey Whitten, City of Seattle (Alternate: Elsa Brown)
- Paul Williams, Suquamish Tribal Staff

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Appendix B: Collaborative Meeting Schedule and Topics

To develop the Roadmap, the Collaborative met approximately every two months between June 2023 and December 2024. The table below summarizes the topics discussed at these meetings. Full agendas and meeting notes can be found at the project website: Puget Sound Zero-Emission Truck Collaborative.

Table 8: Collaborative Meeting Dates and Topics

Meeting Date	Meeting Topics
June 2023	• Member introductions • Understanding of project context, background, objectives, and process • Affirmation of Collaborative charter and operating guidelines
August 2023	• Drayage driver panel and discussion • Brainstorming key issues for ZEV transition related to vehicles, infrastructure, equity, and funding • Review of draft driver and community engagement strategy
October 2023	• Community group panel and discussion • Updates on outreach and engagement • Updates on Washington state policy development • Report-outs from small group discussions on key issues (vehicles, infrastructure, equity, funding)
December 2023	• Panel on emerging business models for ZEVs, including trucking-as-a service, leasing, and sponsorship models • Presentation and discussion of secondary markets for used ZEVs
January 2024	• Presentation and discussion of ZEV transition funding needs • Panel on utility infrastructure planning and investments
February 2024: Driver Listening Sessions	• In-person sessions in Tacoma and Seattle with drayage truck drivers to discuss opportunities and challenges for transitioning to zero-emission trucks
March 2024	• Legislative session recap • Discussion of insights from driver listening sessions, driver survey, and community meetings • Presentation and discussion of drayage characterization study
April 2024	• Presentation and discussion of best practices for vehicle incentive program design and implementation • Presentations and discussion on the role of hydrogen in the ZEV transition
June 2024	• Panel perspectives from OEMs and dealers on opportunities and constraints for selling used and new ZEV trucks • Presentation and initial discussion of the potential role of shippers in the ZEV transition • Initial scoping of membership and purpose of “Collaborative 2.0” to continue work on Roadmap implementation
August 2024	• Panel and discussion of operational incentives for ZEV drayage at and around port terminals • Presentation and discussion of the role of shippers in the ZEV transition • Plan for review and refinement of draft Roadmap

Meeting Date	Meeting Topics
October 2024	• Updates on recent events related to ZEV transition • Overview and discussion of feedback on draft Roadmap • Discussion of priorities for near-term action
December 2024	• Final Roadmap review discussion • Roadmap launch and communications • Collaborative 2.0
January 2025: Driver Listening Sessions	• In-person sessions in Tacoma and Seattle with drayage truck drivers to discuss the draft Roadmap's recommendations and implementation

Appendix C: Estimates of ZEV Deployment and Infrastructure

While the pace of future ZEV deployments is unknown, the Roadmap analysis considered two scenarios to estimate ZEV deployments and associated infrastructure needs:

Scenario 1: Natural Turnover with Regulatory Requirements – In this scenario, ZEV deployments occur as the result of natural turnover of the fleet. Trucks entering the drayage market may be new or used. New trucks are assumed to be subject to ACT regulations; a fraction of these trucks equal to the ACT sales requirement for Class 7 and 8 tractors are assumed to be ZEVs (starting at 7 percent in 2025 and increasing to 40 percent by 2031). Beginning in 2036, 100 percent of new trucks entering the drayage market are assumed to be ZEVs to reach a fully zero-emission drayage fleet between 2040 and 2050.

Scenario 2: Incentivized Deployments – This scenario estimates the number of ZEV drayage trucks that could be deployed based on the funds available in Washington state and NWSA incentive programs for battery electric and hydrogen fueled ZEVs.

The following coarse assumptions are made to estimate the order of magnitude of ZEV deployments that might occur in these two scenarios.

Table 9. Assumptions for Scenario 1: Natural Turnover with Regulatory Requirements

Annual Truck Replacement	10%
Fraction of Trucks Entering Drayage That Are Bought as New	20%
Avg Age of Used Truck Entering Drayage	7

Table 10. Assumptions for Scenario 2: Incentivized Deployments

Implementing Agency	Funding Source	Timeframe	Total Funding	Fraction to Drayage Trucks	$/year to Drayage Trucks	Assumed # of Trucks per year
NWSA	CMAQ	2025 – 2026	$2.8M	100%	$1.4M	6 (BEV)
NWSA	Climate Commitment Act	2025 – 2026	$6M	100%	$3M	12 (BEV)
NWSA	FHWA	2026 -2028	$16M	100%	$5.3M	21 (BEV)
NWSA	DOE Hydrogen Hubs	2028	$12M	100%	$12M	30 (FCEV)
WSDOT	MHDV Incentive Program	2025 - 2026	$110M	25%	$13.75M	55 (BEV)

It is assumed that to incentivize a new ZEV drayage truck deployment requires $250,000 in combined incentives for battery electric ZEVs and $400,000 in combined incentives for hydrogen-fueled ZEVs.[47] While some of the identified programs do not offer this level of incentive individually, it is anticipated that fleets will need to "stack" funding from more than one incentive program in these early years of deployments. Consequently, the

[47] Funding under the Hydrogen Hubs program assumes $400,000 per FCEV.

number of trucks deployed by all incentive programs is calculated as the available funding in a given calendar year divided by $250,000 per battery electric ZEV and by $400,000 per hydrogen-fueled ZEVs. Several assumptions are also made regarding the timing of funding and the fraction of funding disbursed to drayage trucks. These are not firm requirements of the funding programs, and the actual awards will differ from the assumptions shown above. Additionally, only near-term incentive programs are considered. Incentive programs may exist in various forms in all phases of the transition, likely offering different incentive amounts and priorities.

Based on these assumptions, the number of ZEV drayage trucks anticipated to be deployed in Phase 1 (2025-2027) ranges from 29 to 217 trucks. Incentives from the FHWA and WSDOT programs are the primary drivers of the upper end estimate. By the end of Phase 2 (2028-2035) the number of deployed ZEVs ranges between 473 and 712 trucks. Beginning in 2036, the Mature Market phase, the number of annual ZEV deployments increases significantly as all new trucks are assumed to be ZEVs and many ZEVs are assumed to exist in the used truck market.

Table 11. Projected Zero-Emission Drayage Deployments through Mature Market Phase

Phase	Scenario 1 Natural Turnover – ZEVs Deployed	Scenario 2 Incentivized Trucks – ZEVs Deployed	Combined Scenarios 1 + 2
Emerging Market (2025-2027)	29	188	217
High-Growth Market (2028-2035)[48]	473	239	712
Mature Market (2036+)	Full fleet (~4,500)		

The table below translates the ZEV deployment estimates into infrastructure requirements. Consistent with the discussion in Section 3, the table describes the "edge" cases where either all new ZEVs are battery-electric (see "Charging Infrastructure" columns) or all new ZEVs are hydrogen fueled (see "Hydrogen Fueling Infrastructure" columns). In reality, infrastructure will likely be a mix of charging and hydrogen fueling in various configurations and sizes.

Table 12. Infrastructure Requirements for Zero-Emission Drayage Truck Deployment

	Charging Infrastructure (Assuming all ZEVs are battery-electric)			Hydrogen Fueling Infrastructure (Assuming all ZEVs are hydrogen fueled)	
Phase	High Power (350 kW) Charging Points	Mixed Low (50 kW) + High-Power (350 kW) Charging Points	Simplified Average Power (180 kW) Charging Points	Small Stations (2,000 kg/day)	Large Stations (6,000 kg/day)
Emerging Market (2025-2027)	4 to 32	22 to 164 low power + 3 to 19 high power	6 to 48	1 to 5	1 to 2

[48] Assumes vehicles from previous period still in use.

	Charging Infrastructure (Assuming all ZEVs are battery-electric)			Hydrogen Fueling Infrastructure (Assuming all ZEVs are hydrogen fueled)	
High-Growth Market (2028-2035)	70 to 106	357 to 538 low power + 42 to 63 high power	105 to 158	12 to 17	4 to 6
Mature Market (2036+)	670	3,400 low power + 400 high power	1,000	110	40

Appendix D: Current Federal and State Tax Incentives, Grant Funding, and Incentive Programs

Washington State Incentive Programs

Washington State Medium and Heavy-Duty Vehicle Incentive Program. The Washington State Legislature has made a $100 million appropriation to create this program. It is currently under final design at the Washington State Department of Transportation. Details on the recommended program design can be found here: https://leg.wa.gov/JTC/Meetings/Documents/Agendas/2023%20Agendas/Oct%209/CALSTART_MHDZEV.pdf

Washington State Department of Commerce Electrification of Transportation Systems Program. Provides grant funding for transportation electrification infrastructure to Washington local governments, Tribal Governments, and retail electric utilities. The first round made $1 million available. Details can be found at: Electrification of Transportation - Washington State Department of Commerce.

Alternative Fueling Infrastructure Grant Program. WSDOT offers competitive grants to strengthen and expand the West Coast Electric Highway network by deploying Level 2 and direct current fast charging electric vehicle chargers and hydrogen fueling infrastructure along highway corridors in Washington. Eligible project costs include siting, equipment purchases, electrical upgrades, installation, operations, and maintenance. For more information, including funding availability and application periods, see the WSDOT Zero-Emission Vehicle Grants website. Also, see: RCW 47.04.350: Alternative fuel vehicle charging and refueling infrastructure program—Bid proposal requirements, evaluation, financing—Workshops—Rules. (wa.gov)

Washington State Clean Fuel Standard. Washington state has adopted a low carbon fuel standard that requires a reduction in carbon intensity of transportation fuels and provides for saleable credits to be generated for installation of vehicle electrification or hydrogen refueling infrastructure. Credits may be purchased by fuel producers that do not meet the carbon intensity reduction requirements. See more about the program at: Chapter 70A.535 RCW: TRANSPORTATION FUEL—CLEAN FUELS PROGRAM (wa.gov) and information from the Department of Ecology at: Clean Fuel Standard - Washington State Department of Ecology.

Washington State Business and Occupation Tax Credit for Clean Alternative Fuel Vehicles. Commercial entities paying state Business and Occupation taxes (B&O Tax) are allowed a credit against the tax according to the gross vehicle weight rating of the vehicle and the incremental cost of the vehicle purchased above the purchase price of a comparable conventionally fueled vehicle. The credit is limited, as set forth in the table below, to the lesser of the incremental cost amount or the maximum credit amount per vehicle purchased, and subject to a maximum annual credit amount per vehicle class.

Table 13. Washington State B&O Tax Credit for Clean Alternative Fuel Vehicles

Gross Vehicle Weight	Incremental Cost Amount	Maximum Credit Amount Per Vehicle	Maximum Annual Credit Per Vehicle Class
Up to 14,000 pounds	75% of incremental cost	$25,000	$2,000,000
14,001 to 26,500 pounds	75% of incremental cost	$50,000	$2,000,000
Above 26,500 pounds	75% of incremental cost	$100,000	$2,000,000

Commercial entities subject to the B&O Tax are allowed a credit against the tax imposed for up to 50% of the cost to purchase alternative fuel vehicle infrastructure, tangible personal property that will become a component of alternative fuel vehicle infrastructure, and installation and construction of alternative fuel vehicle infrastructure, but excluding the cost of property acquisition and site improvement related to the installation of alternative fuel vehicle infrastructure. The credit is subject to a maximum annual credit amount of $2,000,000.

Limits on the annual amount of credit and the number of vehicles per taxable entity or person are detailed at: RCW 82.04.4496: Credit—Clean alternative fuel commercial vehicles. (wa.gov).

Federal Programs

The federal programs below were available at the time of Roadmap development. There is currently uncertainty about their availability going forward. If federal tax credits and grants are removed, there will be a need for either greater state and local incentives or the ZEV transition may happen more slowly.

Federal Tax Credits

Commercial Clean Vehicle Credit. Can be used by businesses and tax-exempt organizations to purchase a qualified commercial clean vehicle for a tax credit up to $40,000. The credit equals the lesser of 15% of the basis in the vehicle or 30% if not powered by gas or diesel or the incremental cost of the vehicle. (Internal Revenue Code 45W Commercial Clean Vehicle Credit | Internal Revenue Service (irs.gov)).

Alternative Fuel Infrastructure Credit. Makes alternative fueling equipment, including electric charging equipment, in certain census tracts eligible for a tax credit of 30% of the cost, not to exceed $100,000. (Internal Revenue Code 30C Credit Refueling Infrastructure Tax Credit | Argonne National Laboratory (anl.gov)).

Federal Grant and Incentive Programs

Congestion Mitigation and Air Quality (CMAQ) Improvement Program. The CMAQ Program provides funding to state departments of transportation (DOTs), local governments, and transit agencies for projects and programs that help meet the requirements of the Clean Air Act by reducing mobile source emissions and regional congestion on transportation networks. Eligible activities include transit improvements, travel demand management strategies, congestion relief efforts (such as high occupancy vehicle lanes), diesel retrofit projects, alternative fuel vehicles and infrastructure, and medium- or heavy-duty ZEVs and related charging equipment.

United States Environmental Protection Agency Opportunities

U.S. EPA Port Initiative. Works in collaboration with the port industry, communities, and all levels of government to improve environmental performance and increase economic prosperity. It has many technical resources and sources news about new technology and funding opportunities. See: https://www.epa.gov/ports-initiative

U.S. EPA Clean Ports Program. Received $3 billion from the Inflation Reduction Act of 2022 to fund zero-emission port equipment and technology and to help ports develop climate action plans to reduce air pollutants at U.S. ports. See: https://www.epa.gov/inflation-reduction-act/clean-ports-program#technicalRFI

U.S. EPA Diesel Emissions Reduction Act (DERA) National Grants program. Will open in early 2023 and will likely continue to focus on achieving significant reductions in diesel emissions. Eligible diesel vehicles include school buses, Class 5-Class 8 heavy-duty highway vehicles, locomotive engines, marine engines and nonroad

engines, equipment or vehicles used in construction, handling of cargo, agriculture, mining, or energy production. See: https://www.epa.gov/dera/national

U.S. EPA Clean-Heavy Duty Vehicle Program. Received $1 billion in funding from the Inflation Reduction Act to replace dirty heavy-duty vehicles with clean, ZEVs, support ZEV infrastructure, and to train and develop workers. The program offers grants and/or rebates to eligible recipients to replace existing heavy-duty vehicles with clean, ZEVs. Funding is also available for ZEV infrastructure, workforce development and training, and planning and technical activities. See: https://www.epa.gov/inflation-reduction-act/clean-heavy-duty-vehicle-program

U.S. EPA SmartWay Program. Helps carriers demonstrate their fuel efficiency achievements, show continuous improvement and commitment, learn best practices, and receive industry recognition. See: https://www.epa.gov/smartway/become-smartway-carrier-partner

U.S. EPA Greenhouse Gas Reduction Fund Zero-emission Technologies Grant Program. Was established by the Inflation Reduction Act. It funds projects that reduce or avoid GHG emissions and other forms of air pollution, with a particular emphasis on projects in low-income and disadvantaged communities. See: https://sam.gov/fal/cffd228dd8a34254b68d497672a5235e/view

U.S. EPA Climate Pollution Reduction Grants Program. Received a $5 billion investment from the Inflation Reduction Act to develop and implement strong, local GHG reduction strategies. The program is broken into Phase I Planning Grants and Phase II Implementation Grants. See: https://www.epa.gov/inflation-reduction-act/climate-pollution-reduction-grants

United States Department of Transportation Opportunities

U.S. DOT Maritime Administration Port Infrastructure Development Grants. Expects to award 50 projects designed to improve the safety, efficiency, or reliability of the movement of goods through ports and intermodal connections to ports. See: https://www.maritime.dot.gov/office-port-infrastructure-development/port-and-terminal-infrastructure-development/2019-port-1

U.S. DOT Federal Transit Administration Low or No Emission Vehicle Program. Received $1.2 billion in funding to support state and local efforts to buy or modernize buses, improve bus facilities, and support workforce development. See: https://www.transit.dot.gov/lowno

U.S. DOT Charging and Fueling Infrastructure (CFI) Discretionary Grant Program. Will award $2.5 billion over five years to fund EV charging and alternative-fueling infrastructure in communities across the country and along designated highways, interstates, and major roadways. See: https://highways.dot.gov/newsroom/biden-harris-administration-opens-applications-first-round-25-billion-program-build-ev

U.S. DOT Rebuilding American Infrastructure with Sustainability and Equity (RAISE) Discretionary Grant Program. Received $1.5 billion in grant funding for 2023. This funding will focus on completing critical freight and passenger transportation infrastructure projects. See: https://www.transportation.gov/RAISEgrants

United States Department of Energy Opportunities

U.S. DOE Regional Clean Hydrogen Hubs Program. Part of an $8 billion effort to catalyze investment in a national clean hydrogen network to decarbonize multiple sectors of the economy. See: https://oced-exchange.energy.gov/Default.aspx#FoaId4dbbd966-7524-4830-b883-450933661811