SEATTLE WATERFRONT CLEAN ENERGY STRATEGY

A roadmap for power infrastructure to support electrification of buildings, vehicles, vessels and equipment on Port-owned properties in the Seattle Harbor

Port of Seattle

The Northwest Seaport Alliance
Seattle + Tacoma

Seattle City Light

DETAIL FROM THE SALISH WELCOME FIGURES AT SMITH COVE CRUISE TERMINAL, COMMISSIONED AND CREATED BY NORTHWEST CARVER AND ARTIST ANDREA WILBUR-SIGO (SQUAXIN ISLAND AND SKOKOMISH)

The Port of Seattle exists on Indigenous land. We acknowledge the ancestral homelands of those who walked here before us and those who still walk here, keeping in mind the integrity of this territory where Native peoples identify as the Duwamish, Suquamish, Snoqualmie, and Puyallup, as well as the tribes of the Muckleshoot, Tulalip, other Coast Salish peoples, and their descendants. We are grateful to respectfully live and work as guests on these lands with the Coast Salish and Native people who call this home. This land acknowledgment is one small act in the ongoing process of working to be in good relationship with the land and the people of the land.

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GLOSSARY

Decarbonization: The process of reducing or eliminating carbon dioxide (CO_2) and other greenhouse gas emissions associated with energy production, consumption, and industrial activities.

Distribution system: The utility infrastructure designed to deliver power from the high-voltage utility transmission system to Port facilities. Includes utility substations, feeders, switchgear, and transformers.

End use: Vehicles, vessels, buildings, and equipment that are expected to ultimately consume electricity within the Port's ecosystem and rely on Port and utility electrical infrastructure. These include, but are not limited to electric vehicles, electric cargo handling equipment, charging and shore power for vessels, building heating and ventilation systems, and other electrified uses.

Feeder: A high-capacity power line or cable (conductor) that transmits electricity from a substation or distribution point to a specific area, network, or set of loads. In the context of this study, feeders are Seattle City Light-owned assets that serve one or more Port facilities and may also serve non-Port loads.

Ground transport: Refers to transportation to, from and between Port properties. This category primarily includes buses (shuttle buses and motor coaches) used to transport cruise passengers to and from cruise terminals.

Non-wires technology: Innovative solutions that reduce the need for traditional infrastructure such as new power lines or substations by leveraging distributed energy resources. These include energy storage systems, distributed generation (e.g. solar panels), demand response, energy efficiency, and microgrids.

Ocean-going vessels (OGVs): Large vessels that transit long distances, often engaging in intercontinental or international trade or transport. Includes cargo vessels (container ships, bulk carriers, and tankers), cruise ships, roll-on roll-off (RoRo) vessels, and other vessel types.

OpEx: Refers to operating expenditures, the ongoing expenses associated with the maintenance and operation of assets that are in place.

Peak demand: The highest level of electrical power consumption recorded over a specific period, typically during times of maximum usage, such as certain seasons or hours of the day. Managing peak demand is critical for ensuring grid reliability, minimizing costs, and optimizing infrastructure.

Peak shaving: The practice of reducing power consumption during periods of peak demand on the electrical distribution system. May be achieved using strategies such as energy storage systems, shifting energy-intensive activities to off-peak times, curtailing uses, or on-site generation. Peak shaving helps to reduce energy costs, minimize strain on electrical infrastructure, and improve grid reliability.

Port substation: Specialized port-owned electrical equipment located at a Port facility that manages the distribution of electricity to support port operations including cranes, cargo handling equipment, refrigeration units, shore power, buildings, lighting, equipment and other electrical needs.

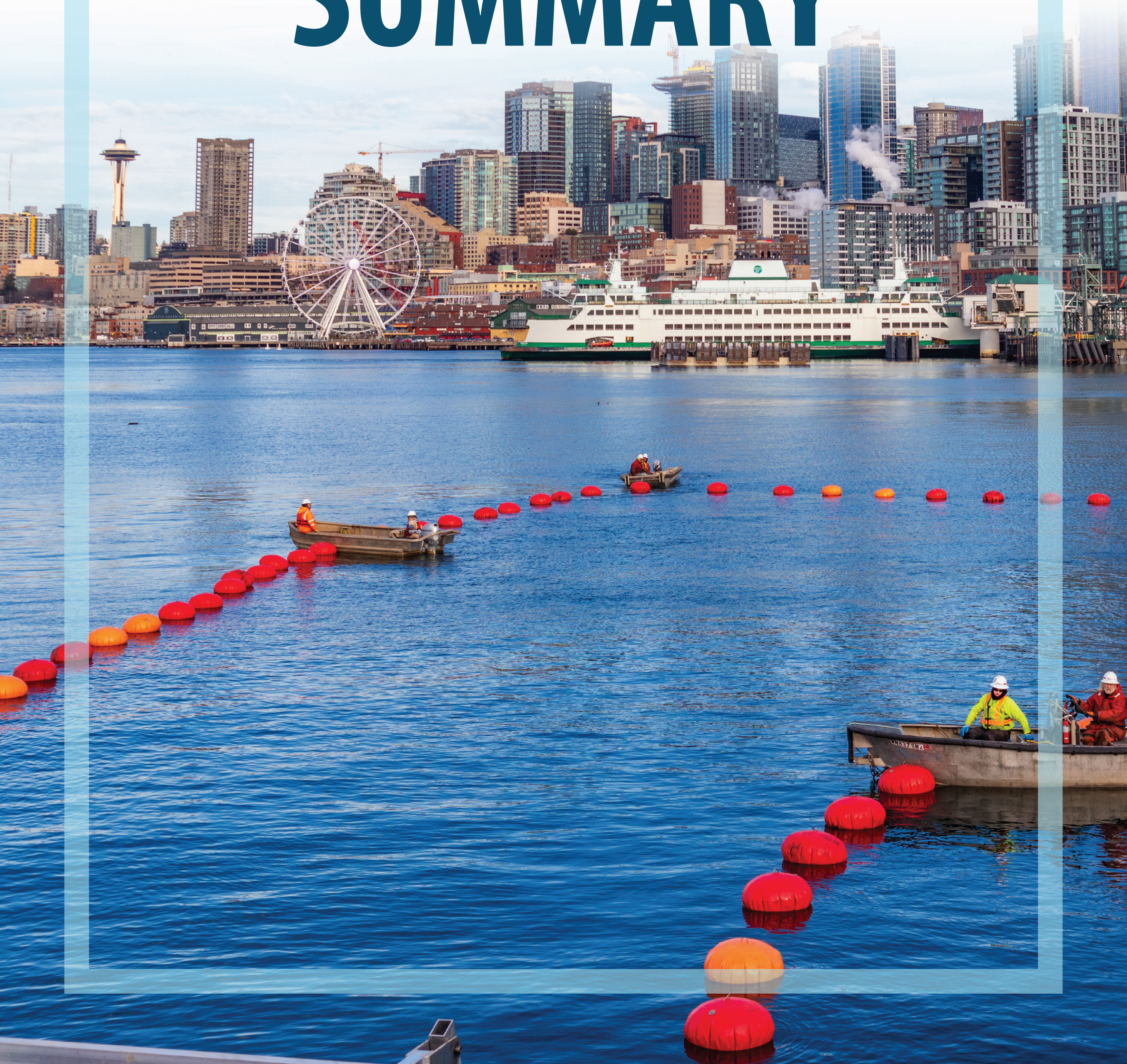
Utility substation: A utility-owned facility within the electrical power distribution system that steps down and distributes high-voltage electricity from the high-voltage transmission system to local distribution networks and end users.

ACRONYMS

BESS	Battery Electric Storage System
CHE	Cargo-handling Equipment
CIP	Capital Improvement Program
CO_2e	Carbon Dioxide Equivalent
EV	Electric Vehicle
GHG	Greenhouse Gas
kW	Kilowatt
MW	Megawatt
NWSA	Northwest Seaport Alliance
OGVs	Ocean-going Vessels
SCL	Seattle City Light
SWCES	Seattle Waterfront Clean Energy Strategy
TRU	Transport Refrigeration Unit
USCG	United States Coast Guard

NCL Bliss departs Seattle | October 2024

EXECUTIVE SUMMARY



EXECUTIVE SUMMARY

In the Pacific Northwest, access to clean (low carbon), reliable electricity is a key advantage that enables electrification of transportation and buildings and supports reductions in both greenhouse gas and air pollutant emissions. Electrification is a keystone strategy to address climate change and alleviate environmental burdens for neighborhoods and sensitive populations that live near industrial areas and concentrations of transportation activity.

For the Port of Seattle and The Northwest Seaport Alliance (NWSA), electrification is also a core strategy to achieve the shared vision of phasing out seaport-related emissions by 2050. However, the electrification of maritime industry operations will require significant, concerted, and proactive investment in the energy infrastructure serving port-owned facilities.

The Port of Seattle (the Port) and its partners are well-positioned to simultaneously advance key carbon- and air pollution-reduction technologies while enhancing services to customers. The Port owns and operates maritime properties in the Seattle harbor including two home port cruise terminals with three cruise vessel berths. The NWSA is a vital operating partner managing the Port's largest properties and the seventh largest cargo gateway in the United States. Seattle City Light (SCL) is the public electric utility serving the greater Seattle area and is a recognized leader in clean energy and the nation's first carbon neutral electric utility.

The Port, NWSA, and SCL came together to initiate a first-of-its-kind joint infrastructure planning process: the Seattle Waterfront Clean Energy Strategy (SWCES). Given the significant challenges presented by decarbonization of port operations — including long lead times for construction, high costs of electrical infrastructure projects, and rapidly evolving maritime and clean energy technologies — the SWCES recognizes the need to work collaboratively with government and industry partners to address infrastructure constraints to achieve shared decarbonization goals.

The purpose of the Seattle Waterfront Clean Energy Strategy is to proactively develop the enabling clean energy infrastructure required to electrify vehicles, vessels, rail, equipment, buildings and other end uses at Port and NWSA facilities. The SWCES takes a holistic approach to forecast future electrification demand from major maritime uses along the Seattle waterfront, assess power infrastructure constraints, identify capital investments, recommend strategic actions, and establish a framework for ongoing implementation between the Port and SCL.

The SWCES is a roadmap for the decarbonization of a significant segment of port-related maritime operations and identifies 33 capital projects and eight strategic actions for implementation. It is important to note, however, that there remains significant uncertainty in key aspects underlying this strategy and the broader energy transition in which this work is situated, including:

- The timing and sequencing of electrification loads
- The pace of technology development, cost-competitiveness, and commercial availability of both electrified end-use applications and non-wires solutions, such as battery storage
- The pace and magnitude of adjacent non-port electrification load growth and

- Realities of financing capacity, availability of grants and incentives, regulatory requirements, and overall risk tolerance of maritime business partners

Accordingly, the SWCES uses a blended approach that combines specific plans for capital investment with a set of strategic implementation actions intended to increase implementation effectiveness and reduce uncertainty.

Development of the SWCES included creation of an electrical load forecast across key port and adjacent properties and an analysis of the ability of existing infrastructure to accommodate those future loads. Key findings of the analysis include:

- **Port power needs (peak electricity demand) is expected to increase four-fold by 2050.** As of 2019, 74% of total port-wide energy use was in the form of fossil-based liquid fuels. As fossil-fueled operations transition to electrification, power demand will increase substantially. Estimates of peak power use at key maritime facilities in the Seattle harbor are modeled to more than quadruple from 53 megawatts in 2019 to over 225 megawatts by 2050.
- **Shore power continues to be the key driver of near-term power demand.** Of the expected electrified end uses, shore power use by oceangoing vessels (OGVs) is by far the most significant driver of near-term demand. Charging of vehicles, vessels and equipment are expected to be drivers from 2035 and beyond while also introducing more short duration peak loads.
- **Port-adjacent sites are significant contributors to SCL's load growth.** Redevelopment at "near-port" sites (facilities sharing power distribution feeders with port locations), notably the United States Coast Guard (USCG) facility at Pier 36 and Washington State Ferry (WSF) terminal at Pier 52, are expected to contribute significantly to SCL distribution system constraints, particularly in the southern portion of the harbor.
- **Both SCL and Port electrical infrastructure will face constraints in the future.** Of the 16 SCL distribution system feeders serving key maritime facilities, 10 are expected to exceed their electrical capacity planning limits by 2040. In addition, multiple on-terminal Port substations will face capacity constraints, with eight sites expected to exceed total site capacity through the forecasted timeframe.
- **Traditional infrastructure solutions are currently most cost-effective.** Traditional solutions such as improvements to substations, feeders and distribution lines are currently more cost-effective than distributed, "non-wires" technologies such as battery energy storage systems in addressing the most significant power distribution bottlenecks. The high costs of non-wires technologies to address significant, longer duration loads are presently prohibitive. Technologies should continue to be reviewed over time and considered for smaller scale deployment at cargo handling equipment, truck charging, and other similar projects to mitigate intermittent loads and demand charges.
- **Long-term planning and resiliency gaps exist.** Long-term plans and resiliency requirements for port operations and tenants are not currently well defined, which may limit more holistic investment strategies for individual sites.

Based on these findings, the following implementation actions are recommended:

- **Incorporate high priority capacity improvements into port and SCL capital improvement plans (CIPs)**. Approximately $208 to $457 million (2024 dollars) in port and utility investments have been identified through 2050, including $139 to $288 million in port investments and $69 to $168 million in utility investments. Related support for planning and pre-design activities including infrastructure evaluation, site planning, tenant and contractor engagement, market assessment, securing tenant zero-emissions deployment commitments, and feasibility analyses will be important to prepare for initiation of future projects, particularly those involving higher levels of complexity and long lead-times. Final investment decisions will need to be made after these deeper analyses are complete. Financing options and sequencing should be developed and evaluated with key partners and considered alongside other port funding priorities.

- **Increase emphasis on prospective, "planned-capacity" improvements** as a part of a shift from an incremental, project-by-project approach. Such a shift requires weighing potential risks of stranded assets and may not be practical in all cases. Monitoring and regular assessment of distribution system and on-terminal conditions, intentional engagement with end-use stakeholders, modular design, technology assessment, and complementary strategies to incent or require phased-in adoption of electrification technologies can help to mitigate risks.

- **Establish a Joint Port-Utility Implementation Framework to drive ongoing implementation**. In accordance with the 2021 Partnering Agreement between the Port, SCL, and NWSA, the parties agreed to develop an implementation framework to guide ongoing implementation of the SWCES. This framework lays out implementation workstreams and a schedule for ongoing planning, coordination and adjustment. It will allow the parties to plan for timely delivery of capital projects, assess the pace of technology deployment, support deployment of electrified equipment, and make necessary adjustments. Included should be long-lead project planning items such as new utility substations or major transmission line extensions.

- **Develop funding-ready projects.** The Port, NWSA, SCL, and industry partners should use the SWCES results to assess and develop a suite of funding-ready capacity improvements and decarbonization projects. This may include utility distribution system assets (e.g. feeders, substations, transformers, switchgear, smart meters, utility-side storage, etc.), port on-terminal assets (e.g. port substations, solar panels, communications, duct banks, etc.), and electrification deployment projects (e.g. shore power, vessel charging, fleets and equipment, building electrification, etc.). Establishing funding-readiness will allow project partners to more effectively consider external funding opportunities to help offset the significant costs of upgrades. Careful attention should be made to grant requirements to avoid additional costs, time delays and overall risk.

- **Use the SWCES findings to inform port master site development plans** or specific site decarbonization plans that move study recommendations forward to pre-design and advanced project planning. Master site plans are needed to ensure compatibility between the overlapping planning priorities at Port sites, including decarbonization, economic development, line of business needs, resiliency, and others. Such plans should use SWCES data to align strategic goals with site conditions to guide short and long-term development. Ideally, infrastructure, including power infrastructure, should provide for the achievement of overall site objectives and follow an integrated planning effort.

- **Assess port facility power resiliency requirements**, including clear identification of critical facilities, utility hazard exposure and risk, minimum functional operational standards, and tenant requirements. A clear understanding of facility power resiliency requirements will help to refine site power distribution options, add value to distributed production and storage options, and assist with further prioritization of electrification infrastructure investments.
- **Apply an innovation-focused maritime decarbonization lens** that encourages assessment and trial of new concepts and technologies to improve services and help spur electrification technology deployment. The Port can leverage its concentration of heavy-duty transportation end-uses, diverse array of properties, high visibility, non-governmental organization (NGO) partnerships, ambitious emissions reduction targets, and economic development mission to support pilot projects, new business models, and industry partnerships.
- **Assess port electrical asset conditions (e.g. age, equipment functionality) and vulnerabilities (e.g. flooding and sea level rise, groundwater intrusion, seismic hazards)** to further inform capital improvement recommendations and prevent system failures. When combined with an evaluation of critical facilities for power resiliency, a more holistic view of electrical infrastructure needs and opportunities will be available to inform capital investments and project schedules, while enhancing project outcomes.
- **Consider options for enhancing management and development of shared infrastructure on port properties.** Providing for ownership responsibility for shared infrastructure can help to enhance delivery of infrastructure improvements, manage asset conditions, and help ensure integrated designs which meet overall site-wide plans and business goals.

With the completion of the Seattle Waterfront Clean Energy Strategy, the Port, NWSA, and SCL are poised for action to advance a triple-bottom line mission and drive decarbonization of the region's maritime industry while prioritizing environmental justice and increasing economic opportunity in the region. Successful implementation will require significant levels of effort and valuable capital resources. Effective, dedicated leadership, ongoing coordination, innovation, and implementation of strategic actions will be vital to reduce risks, increase competitiveness for external funding, prioritize capital investments, and provide a holistic view of infrastructure investment benefits.

NCL Bliss Plugging into Shore Power at Bell Harbor Cruise Terminal | October 2024

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INTRODUCTION AND CONTEXT

Through the Northwest Ports Clean Air Strategy[1] the Ports of Seattle and Tacoma and The Northwest Seaport Alliance (NWSA) adopted a shared vision to phase out seaport-related emissions by 2050. In 2021 and 2023, the ports accelerated goals for their own port-controlled operations, aiming to reach net zero greenhouse gas emissions by 2040. The City of Seattle similarly established targets essential to meeting global climate commitments, aiming to achieve carbon neutrality city-wide by 2050.

The Port of Seattle and Northwest Seaport Alliance

The Port of Seattle (referred to herein as “the Port”) is a highly diversified seaport, encompassing several maritime lines of business with varying operational and energy use profiles. The Port is a key gateway to the Alaskan market, with the largest cruise port on the U.S. West Coast and home to the North Pacific fishing fleet. The Port’s maritime lines of business also include a grain terminal, recreational marinas, and commercial and industrial real estate properties. The NWSA provides a vital joint cargo operating partnership between the Ports of Seattle and Tacoma, comprising the seventh largest container gateway in North America. As the licensed operator of Port cargo terminals in the Seattle Harbor, the NWSA is a key partner in the Port’s electrification efforts.

Importantly, more than 94% of the ports’ maritime emissions are outside of their direct operational control. These emissions sources include oceangoing and harbor vessels, locomotives, trucks, ground transportation, and cargo handling equipment that are privately owned, but operate on and around Port properties. The remaining emissions that fall under the ports’ direct control stem largely from the Port’s maritime and economic development operations, which includes Port-owned buildings, fleet vehicles and equipment, and activities such as employee commuting, waste management, and staff business travel.

The Port and NWSA (collectively referred to as “ports”) work closely with their tenants and customers in joint planning, coordination of operations, and deploying capital improvement projects on their properties. Moving forward, the SWCES will be a key tool to provide the Port, NWSA, and SCL with information that can be used to plan and deploy clean energy improvements to support tenant and customer needs.

Seattle City Light

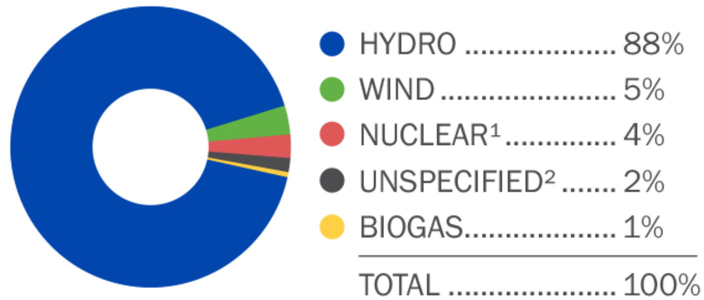
Seattle City Light (SCL) is a municipal power utility serving nearly 700,000 residents including the City of Seattle and several adjoining jurisdictions. To serve these customers, SCL owns, maintains, and operates a multi-billion-dollar generation, transmission, and distribution system. This includes:

- 14 major substations and more than 2,500 miles of overhead and underground utility wiring
- Seven hydroelectric plants on the Skagit, Cedar, Tolt, and Pend Oreille Rivers with a combined capacity of almost 2,000 megawatts

[1] The Northwest Ports Clean Air Strategy is a collaboration between the Ports of Seattle and Tacoma, Vancouver-Fraser Port Authority in British Columbia, and Northwest Seaport Alliance to voluntarily reduce seaport-related emissions that contribute to air pollution in the shared Puget Sound-Georgia Basin and global climate change.

- 650 miles of high-voltage transmission lines
- A state-of-the-art System Control Center
- Billing and metering equipment for more than 375,000 accounts.

Figure 1: SCL 2022 Power Generation Sources



SCL's power generation mix is shown in Figure 1.[2] Over 80% of the power that SCL delivers is generated from carbon-free hydroelectricity. The remaining power is generated from a mix of power sources purchased from the Bonneville Power Administration (BPA) and other renewable sources. In total, approximately 95% of SCL's overall energy mix comes from non-emitting sources as of 2022. The balance of emissions is offset, creating a carbon-neutral utility — the first of its kind in the United States.

In the Pacific Northwest, electricity from established hydropower facilities is inexpensive relative to other regions and supports SCL's ability to provide lower cost energy to end users

Joint Planning for Clean Energy

Port operations currently run primarily on liquid fossil fuels (primarily gasoline, diesel, and bunker fuel). To achieve their collective decarbonization goals, the ports must transition operations to non-fossil forms of energy. This will require electrification of vessels, vehicles, and equipment where feasible, as well as maximizing the use of shore power for oceangoing vessels. Transitioning these operations will create unprecedented demands for power, creating the need for a joint planning framework to support electrification.

The SWCES charts a long-term course of action to establish the enabling clean energy infrastructure necessary for the decarbonization and phase-out of emissions from the maritime industry operating at Port-owned properties. The Port and collaborating partners SCL and NWSA, have developed the SWCES as a strategic initiative to further advance the region's interrelated climate, equity, and economic development goals.

This groundbreaking collaboration recognizes the unique roles of the ports and the City and seeks to leverage expertise, establish a new joint implementation strategy, and together prepare for the significant load growth expected with electrification. This once-in-a-generation transition from fossil liquid fuels to

Seattle Waterfront Clean Energy Strategy Partners Vision:

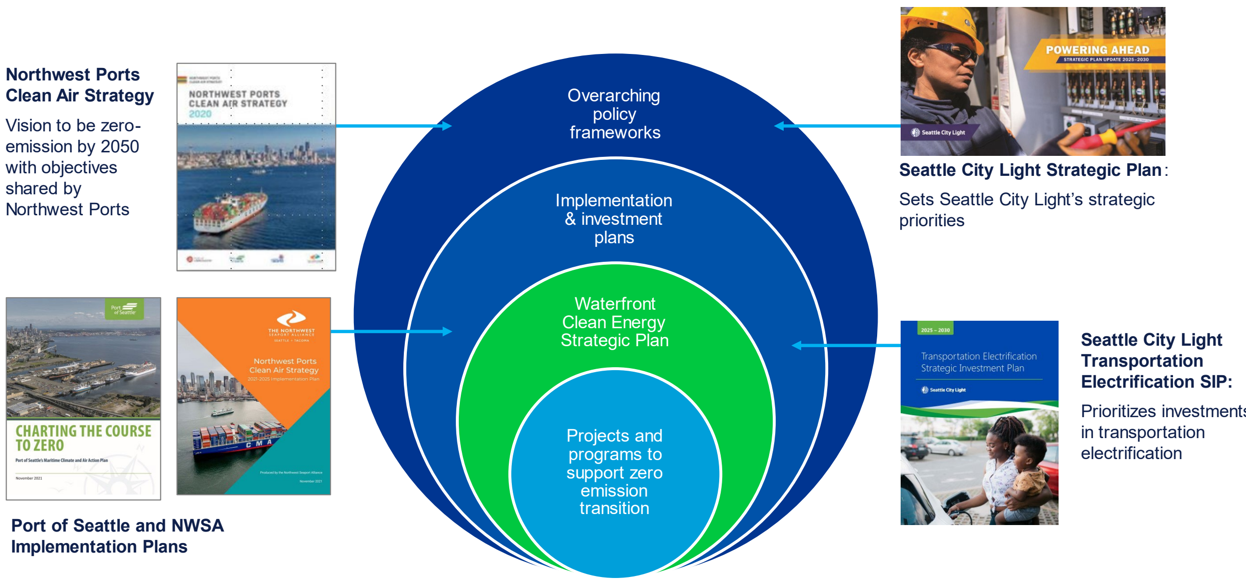
A lasting partnership deploying clean energy infrastructure and driving equitable economic development for a zero-emissions working waterfront by 2050.

[2] Footnotes to Figure 1: [1] This fuel represents a portion of the power purchased from BPA. [2] SCL does not have coal or natural gas resources in its power supply portfolio. It does make market purchases to balance or match its loads and resources. These purchases, along with market purchases made by BPA, may incidentally include coal or natural gas resources, which are assigned to the utility. Any emissions associated with unspecified market purchases are offset through our GHG neutrality policy.

electrification and other low carbon technologies involves significant uncertainty in the timing, magnitude and characteristics of new loads and represents an important opportunity to strategically guide investments.

The SWCES considers elements of existing plans deployed by the ports and SCL, and serves as an important holistic, cross-sector strategy to ensure sufficient power is available to enable the transition to zero emissions operations along Seattle's waterfront.

Figure 2: Plans Supported by the SWCES



To facilitate the successful development and implementation of the SWCES, the project partners entered into a Partnering Agreement in October 2021 to memorialize the shared ambition for a clean energy future. In a joint Vision Statement, the partners established specific guiding principles for joint planning, innovation, cooperation, and implementation:

- Achieve carbon neutrality and zero emissions by 2050
- Lead with equity
- Foster economic growth
- Support and drive workforce development

Collectively, these ambitions serve as high-level goals to drive the execution of projects, initiatives, and follow-on studies.

Environmental Justice

In addition to identifying the infrastructure pathways to support maritime decarbonization, the SWCES also addresses persistent environmental justice concerns for those living adjacent to industrial areas. Communities located in the vicinity of the ports are disproportionately exposed to air pollution and other environmental factors, with criteria air pollutant emissions — such as those resulting from diesel combustion — a particular concern. The region meets federal air quality standards, but even as vehicle engines become cleaner and more efficient, diesel exhaust from transportation activity (including ships, trains, and trucks) remains a source of air pollution in the Puget Sound.

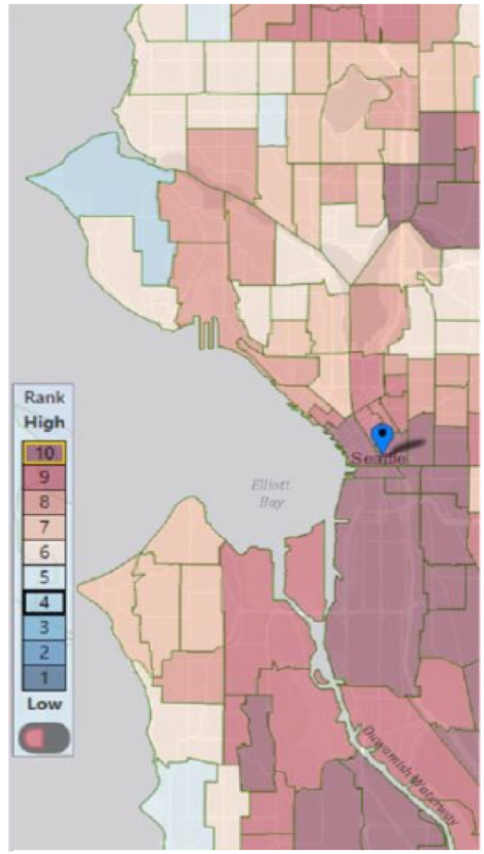


Figure 3: Ranking of diesel pollution impact on census tracts surrounding port facilities. *Source: Washington Tracking Network Health Disparities - Diesel Pollution & Disproportionate Impact Index*

People living in several of the communities surrounding industrial South Seattle experience economic and health disparities. In communities in the Duwamish Valley for instance (specifically South Park and Georgetown) residents have been shown to have a 13-year difference in life expectancy and a more than two-fold higher incidence of heart disease as compared to other, wealthier areas of Seattle.[3] More effective and deliberate actions and investments are needed to address both the health and economic inequities and to counteract environmental injustices impacting these residents.

In 2019, the Port established a Duwamish Valley Port Community Action Team (PCAT) and adopted a Duwamish Valley Community Benefits Commitment to build capacity for ongoing collaboration, advancement of environmental and community health, and fostering economic prosperity in-place. Similarly, the City of Seattle adopted a Green New Deal Resolution in 2019, and the Port established a Workforce Development policy in 2020, both designed to advance equitable workforce development with an emphasis on expanding opportunities to disproportionately impacted communities.

The SWCES builds upon these policies and other efforts to increase investment and reduce environmental health disparities. The SWCES will facilitate the deployment of low and zero emissions equipment and contribute to the reduction of pollution exposure in neighboring communities.

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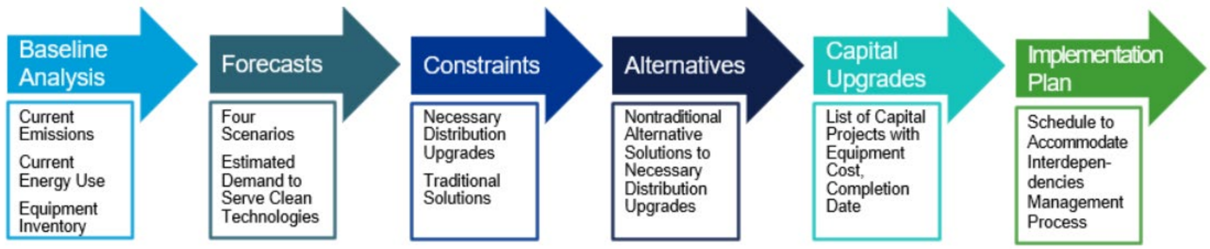
[3] See*: Gould L, Cummings BJ. Duwamish Valley Cumulative Health Impacts Analysis. Seattle, WA: Just Health Action and Duwamish River Cleanup Coalition/Technical Advisory Group. March 2013.* https://www.drcc.org/s/CHIA_low_res-report.pdf

Strategy Development

The Port owns 24 properties along Seattle's Elliott Bay, the Duwamish River, the Lake Washington Ship Canal, and Shilshole Bay (see map in Figure 3). These sites are managed by a combination of the Port's Maritime Division and the NWSA, and are operated by the Port as well as a variety of private sector entities through lease arrangements. The uses and operational profiles of these properties varies widely and includes maritime, industrial, commercial and recreational uses.

The SWCES took a site-by-site approach to evaluate the different operations at each location. The overall strategy development process included six steps: Baseline Analysis, Forecast, Constraints Analysis, Alternatives Analysis, Capital Upgrades, and Implementation Plan. Each of these steps in summarized in the following sections.

Figure 4: SWCES Development Process



Baseline Analysis

A detailed inventory of end uses was evaluated on a site-by-site basis. This inventory considered aspects such as equipment quantities, end-use equipment types and age, building and site information, fuel use, operational characteristics, and gas and power data. This approach was intended to capture the site-specific energy uses across the ports' varied facilities and was used as a foundation for analysis.

The baseline analysis focused on 2019 energy usage[4] and emissions and quantified current energy end-uses and emissions production. Sites were then prioritized for further analysis based on total emissions contributions, known electrical infrastructure capacity (or in limited cases, condition) issues, expected development plans, and load growth potential.

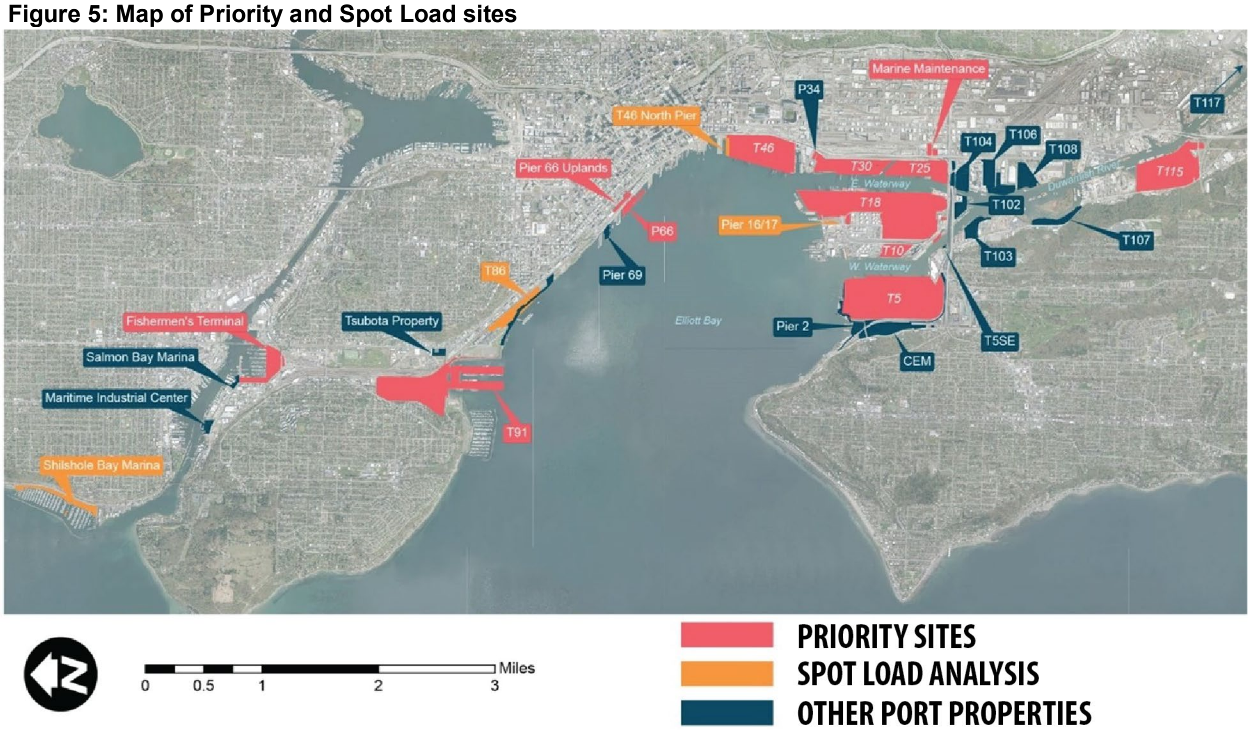
Of the initial 24 sites considered under the SWCES, a subset was identified for further levels of analysis, organized in four categories:

- **11 Priority sites:** Eleven sites were prioritized for detailed analysis
- **4 Spot-load sites:** Four locations were identified where underlying site conditions were expected to remain relatively stable but where significant increases from specific, intermittent electrified end use "spot loads" were expected. These spot load end uses included switcher locomotives, tugboats, and passenger ferries

[4] The 2019 baseline year was selected to minimize data irregularities associated with non-typical port operations during Covid, the timing of the technical analysis, and the availability of data from multiple sources including power, natural gas, fueling, and fleet equipment inventories. Known projects in planning stages, such as Pier 66 shore power, were taken into consideration in the forecast analysis.

- **3 Truck charging sites**: Three sites were considered for heavy-duty truck charging loads under a truck charging depot scenario
- **4 Near-port sites**: Four industrial and transportation sites close to port properties were identified based on potential impact on load forecasts and constraints analyses in subsequent steps. These sites included Vigor Shipyards, the United States Coast Guard Base (USCG), Pier 50, and Colman Dock

Figure 5: Map of Priority and Spot Load sites



Forecast Analysis

Forecasts of power demand were developed using a bottom-up approach based on electrification of end uses, planned development, fleet turnover, business operational activity projections, regulations, and policy targets. Modeling was developed for tug, passenger ferry, and rail spot load deployments as well as three heavy duty drayage truck charging locations.

Policy targets included state and local mandates such as laws for electric vehicle sales and building performance, as well as port targets in strategy documents such as shore power development and fleet electrification (for a list of regulations and policy targets considered, see Appendix A).

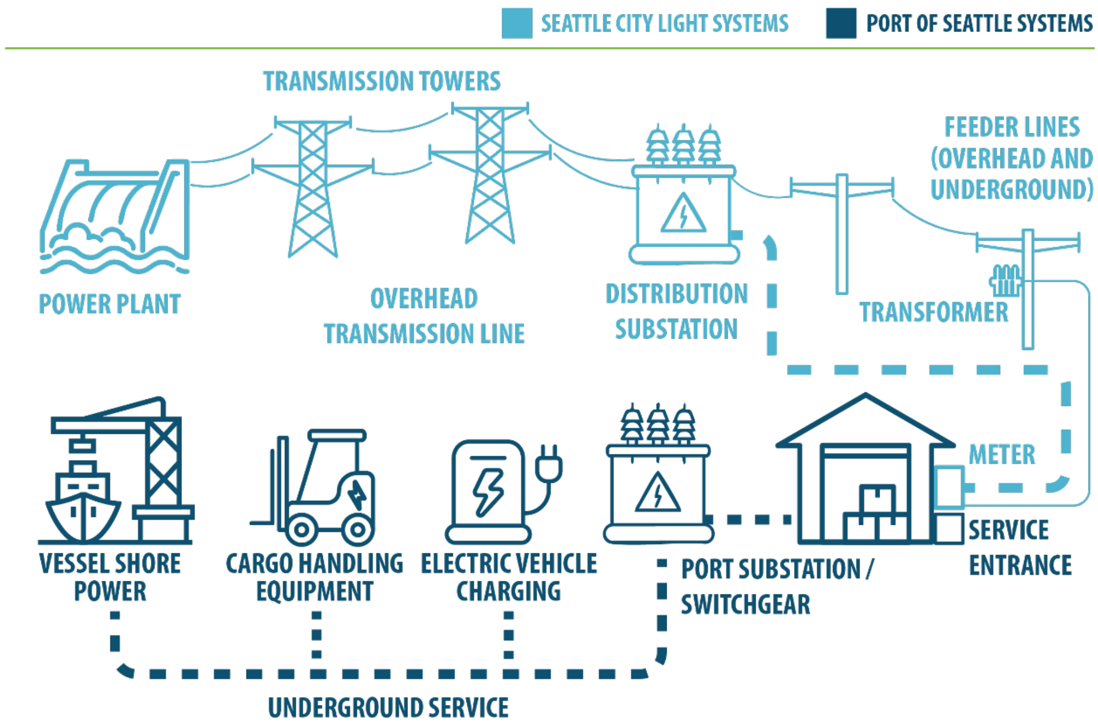
Interviews were conducted with operators at port and near-port sites to help identify aspects such as operational patterns, anticipated load increases and timing, potential charging schedules, and additional equipment information.

Four future load scenarios were developed to show a range of potential future outcomes: business-as-usual (BAU), low, medium, and high. The BAU scenario forecasted power demand assuming current operational conditions and plans, and adherence to existing energy use and emissions-related regulations. The low, medium and high scenarios included assumptions within a variety of categories including operational activity levels, electric equipment adoption, energy demand, cargo throughput, and shore power availability.

Constraints Analysis

The forecasts were then compared against SCL's distribution system and load planning models, transformer capacity at the specific sites, and the Port's on-terminal substation infrastructure. This analysis identified constraints at the distribution system level, for each site as a whole, and for specific on-terminal equipment.

Figure 6: Power Distribution System



Alternatives Analysis

Four of the sites with the most significant distribution system constraints were selected for further exploration of "non-wires" alternative solutions—including energy storage, distributed generation, and hydrogen technologies—to address constraints instead of traditional upgrades to the capacity of existing infrastructure. For each of the four sites, the analysis made recommendations related to the feasibility and cost-effectiveness of alternative solutions and strategies for future study.

Capital Projects

The results of the analysis allowed the partners to identify the capital upgrades necessary on both port facilities and within the utility's power distribution system. These include initial recommendations for the timing of infrastructure upgrades.[5]

Implementation Strategy

The final step in the process was the development of implementation recommendations including infrastructure improvements, supporting actions, areas for further evaluation, and an implementation framework.

KEY FINDINGS AND INSIGHTS

Baseline Analysis

The Baseline Analysis determined that 74% of port-wide onsite[6] energy use was in the form of liquid fuels including diesel, gasoline, and fuel oil in 2019 (the baseline year). Combined, these fuels produce over 93% of port GHG emissions. Electricity represents just 22% of onsite energy use and 3% of GHG emissions[7], with natural gas representing approximately 4% of energy use and 4% of GHG emissions.

Figure 7: 2019 Port-wide Onsite Energy Use by Fuel Type (MMBtu)

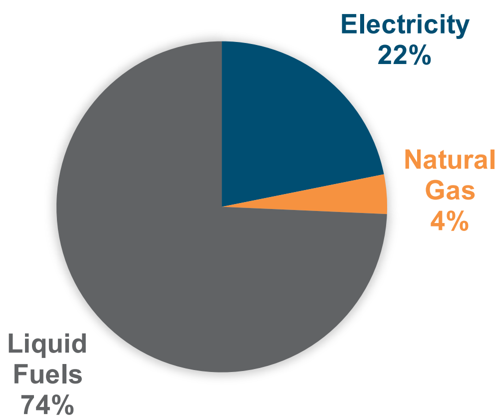
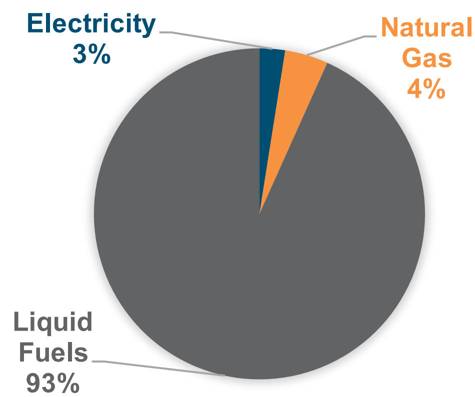


Figure 8: 2019 Port-wide Onsite CO_{2e} Emissions by Fuel Type (tonnes)



From an energy end-use perspective, vessels at berth and cargo handling equipment account for more than 86% of liquid fuel energy use and 85% of CO_2 emissions, followed by on-terminal

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[5] The SWCES is intended to provide for the implementation of two overarching plans, the NW Ports Clean Air Strategy and Maritime Climate and Air Action Plan, both of which underwent environmental review with the Port of Seattle (2021-02 and 2021-07, respectively). Similarly, any capital projects identified herein are expected to go through appropriate environmental review and permitting as projects are further vetted and approved.

[6] The SWCES focuses on site-based energy use. Accordingly, the baseline and forecast do not include transportation activity off terminal (such as cruise passenger travel, truck travel to warehouse or other facilities, tenant commuting, and offsite ground transportation) or fuel use by vessels when not at berth.

[7] SCL uses carbon offsets to address the carbon emitting portions of its electricity generation fuel mix. However, the ports' carbon accounting protocols for purchases of electricity do not consider carbon offsets, which results in a small portion of electricity-associated emissions.

trucking, fleet vehicles, and other end-uses. Key electricity uses include building heating and cooling, lighting, ship-to-shore cranes, shore power, refrigeration plugs, and cold storage. The predominant use of natural gas is for space and water heating.

At a site level, electrical energy use varies dramatically, both in magnitude and pattern of energy usage. Sites such as Fishermen's Terminal show electrical energy consumption within a relatively narrow range on a year-round basis, reflecting stable operations dominated by building energy use, with additional seasonal loads from fishing vessels at berth, while sites such as Terminal 91 show a consistent baseload marked by large, intermittent peaks, reflecting cruise shore power energy use (see Figure 10).

Figure 9: Liquid Fuel CO_{2e} Emissions by End-Use Type

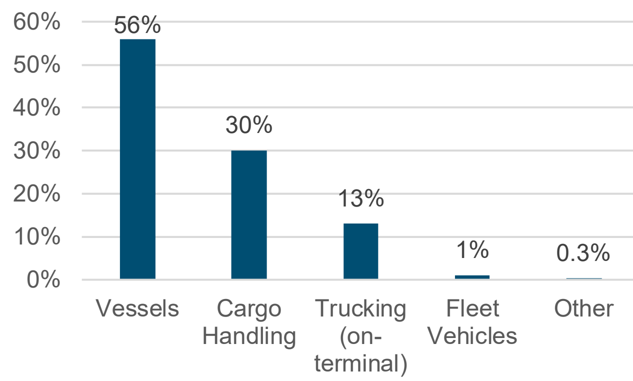
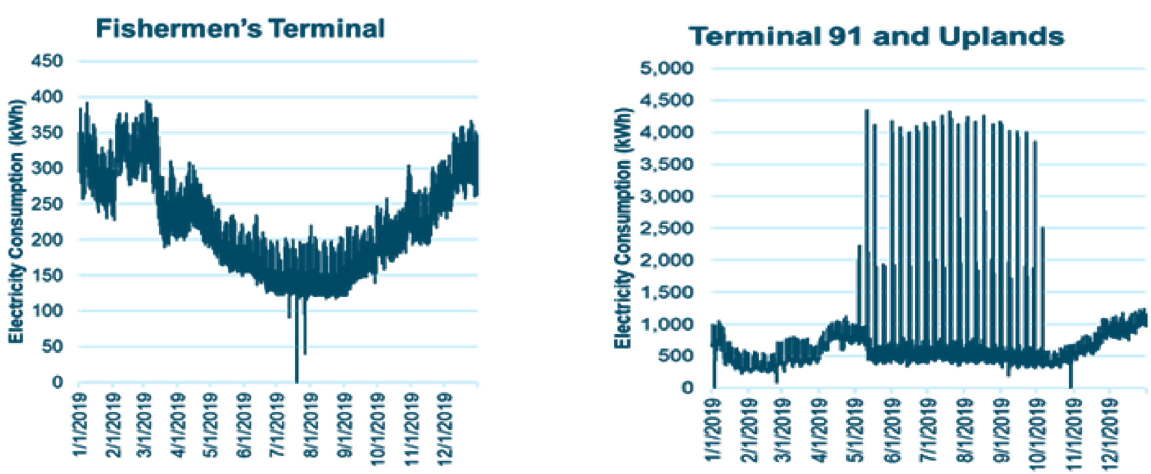


Figure 10: Annual Energy Use Profile at Fishermen's Terminal and Terminal 91

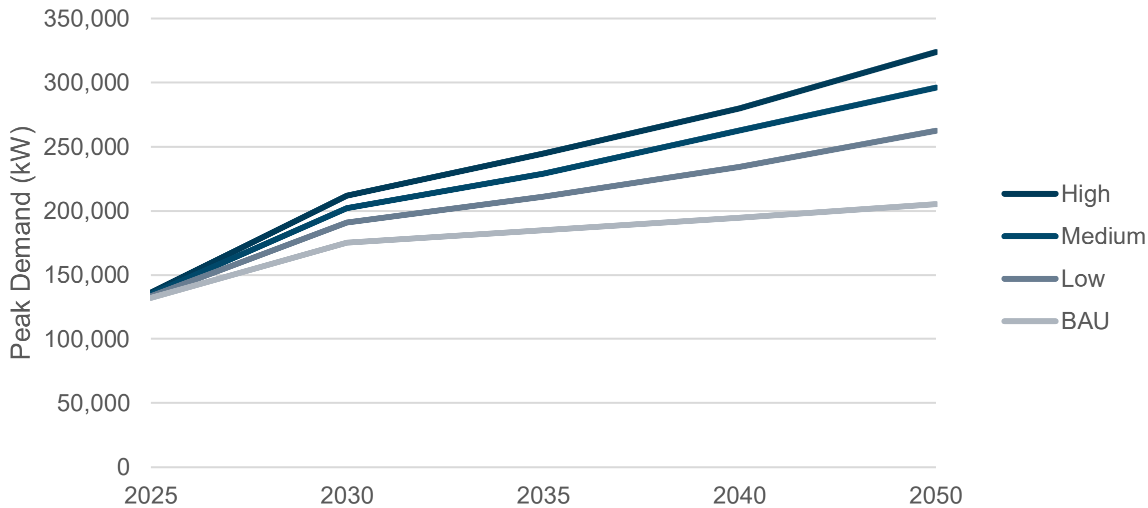


Load Forecast

The SWCES load forecast provides valuable insight into future power demand conditions for the ports and SCL. The forecast estimates an increase in peak demand at port sites from a base of 53 megawatts (MW) in 2019 to more than 224 MW in 2050, representing more than 4x increase in load growth. When including the near-port sites considered in the forecast, this figure rises to 296 MW in 2050. A range of 262 to 324 MW is seen across the low to high scenarios, respectively (Figure 11).

Overall, the forecasted load scenarios show little variation in the near term because planned shore power additions and building redevelopment and upgrades are anticipated across the board in all scenarios. Only limited electrification of cargo handling equipment, trucks, or other equipment is expected in the initial years of the forecast. However, from 2035 onward, the gap between low and high load scenarios begins to grow, driven by increased cargo handling equipment and fleet vehicle electrification over time, as well as modeled differences in public charging infrastructure, cargo activity growth, and treatment of spot loads at specific sites. Notably, underlying Business as Usual (BAU) load growth is significant, reflecting the expected impacts of state mandates driving electrification of fleet vehicles, heavy duty trucks, and buildings.

Figure 11: Forecasted Peak Demand to 2050, All Scenarios



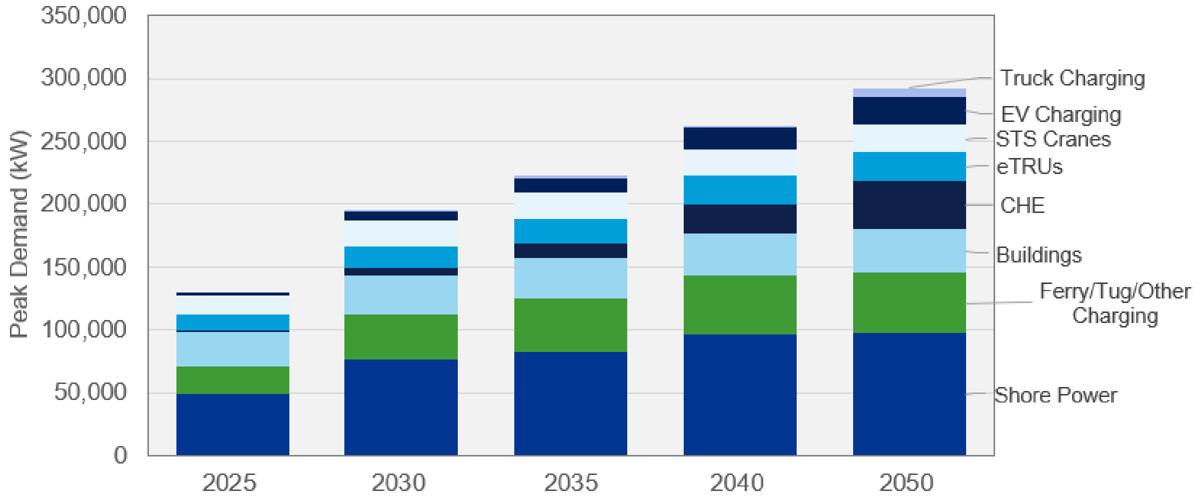
The medium load scenario is used for planning purposes, reflecting implementation of state-level policies, port strategy targets, stable but growing operational activity, and rapid deployment of electrification technologies. The scenario assumes deployment of shore power across all cruise, international container, and commercial fishing terminals as well as electrification of vehicles at a rate higher than state mandates for zero-emissions vehicle sales. Key differences in the medium and high forecast include: the number, size, and type of truck charging locations deployed; the pace of electrified CHE deployment; quantities of public EV charging; the forecasted rate of growth of cargo throughput; numbers of electrified vessels and locomotives at spot load sites; and the level of assumed alternative fuel technology deployment (such as renewable fuels and hydrogen fuel cell technologies).

Forecast Results by End Use

The load forecast analysis shows how end-use load contributions may change over time in response to variables like increased business and operational activity, electrification of multiple end-uses, and the addition of large prospective spot loads such as passenger ferry, tug, or heavy-duty truck charging (Figure 12). The load forecast also considered daytime and nighttime operations and potential timing of peak loads.

Shore power provides the largest overall contribution to peak demand, with cruise terminals driving most near-term peak loads. Shore power additions at cargo sites (Terminals 5, 18, 25/30, and 46) and, importantly, redevelopment at near-port sites such as the USCG facility at Pier 36, are expected to significantly increase loads on SCL feeders serving port locations in the medium- and long-term.

Figure 12: Forecasted Loads by End-use



Electrification of cargo handling equipment[8] (CHE) and the deployment of electric vehicle (EV) charging for fleet vehicles, public vehicles, and ground transportation increase significantly through the forecast period.

Ferry and tug charging, modeled at spot load sites (Shilshole Bay Marina, Pier 16-17, and Terminal 46 North), and Near-port sites (Pier 50 and Colman Dock) are expected to contribute significantly to peak loads over time, with Washington State Ferry charging at Colman Dock starting as soon as 2028.

While building loads are not expected to increase significantly over time — results show an estimated increase of 6-9 MW by 2050 — building electrification and site redevelopment remain a significant component of overall loads. The pace by which the Port electrifies its buildings and facilities also impacts when and where these loads occur.

Similarly, loads from ship-to-shore (STS) cranes and electric transport refrigeration units (eTRU) are expected to increase moderately over time with increased cargo activity, but the magnitude of the overall load contribution from these uses is substantial.

Forecast Results by Site

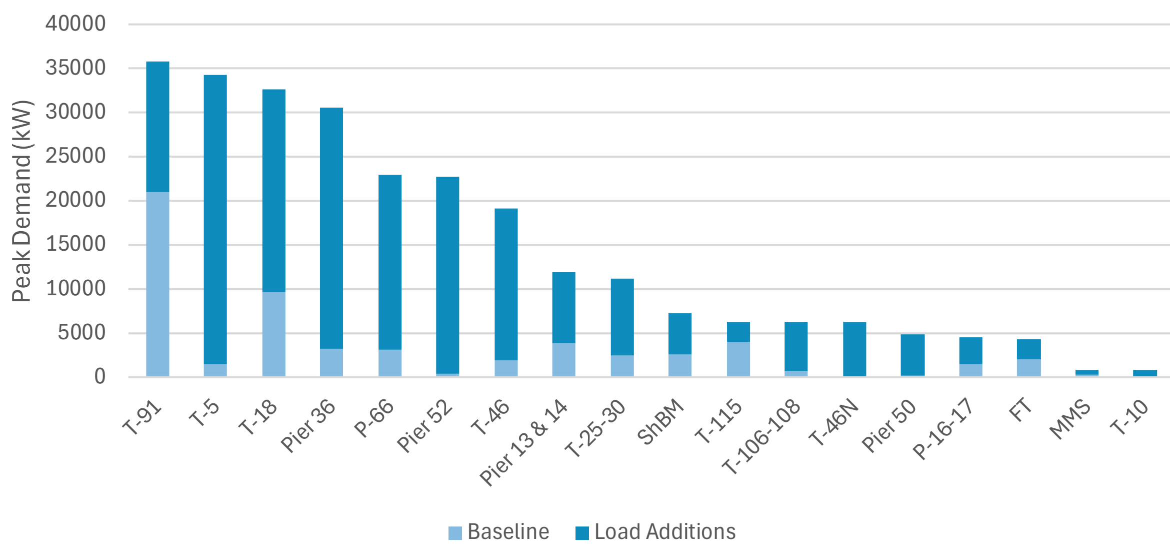
Forecasted load among individual sites varies widely due to the type and quantity of specific electrified end-uses at each site. Table 1, below, shows the primary types of electrification load drivers expected at priority sites and Figure 13 shows forecasted peak demand in 2040. Peak load increases at each site above the 2019 baseline are important considerations because those increases help to determine if power distribution overload conditions may occur.

[8] Cargo handling equipment includes forklifts, yard trucks, top-picks, side-handlers, and rubber-tired gantry cranes (RTGs)

Table 1: Expected Electrification Loads at Priority Sites

SITE	EXPECTED ELECTRIFICATION END-USE LOADS
Shilshole Bay Marina	Passenger ferry spot load, public EV charging
Fishermen's Terminal	Building electrification, building redevelopment, CHE, fleet vehicles, public EV charging, commercial fishing shore power
Terminal 91	Building electrification, building additions/demolitions, shore power, commercial fishing shore power, TRUs, CHE, fleet vehicles, public EV charging, ground transport (motorcoaches)
Terminal 86	Switcher locomotive spot load
Pier 66 (including uplands)	Shore power, building electrification, transport refrigeration units (TRUs), fleet vehicles, public EV charging[9]
Terminal 46 North	Tug and passenger ferry charging spot load
Terminal 46	Cranes, buildings, shore power, CHE, fleet vehicles, TRUs, commercial fishing shore power (Terminal 46 North)
Terminal 25 and 30	Cranes, buildings, shore power, CHE, fleet vehicles, TRUs, truck charging (Terminal 25 South)
Marine Maintenance Shop	Building electrification, fleet vehicles
Terminal 18	Cranes, buildings, shore power, CHE, fleet vehicles, TRUs, truck charging
Pier 16 and 17	Tug charging
Terminal 10	Redevelopment to transload facility (railcar pullers, locomotives, CHE)
Terminal 5	Cranes, buildings, shore power, CHE, fleet vehicles, TRUs
Terminal 115	Buildings, CHE, fleet vehicles, TRUs, truck charging
Terminal 106 and 108	Warehouse redevelopment, CHE

Figure 13: Forecasted Peak Demand at Individual Sites in 2040



[9] Options for EV charging for taxis and transportation network company (TNC) vehicles at the Pier 66 Uplands Garage are additionally being explored. At the time of the analysis, options for taxi/TNC charging on port sites were not in consideration and are not included in forecasts.

Overall, cargo (T-5, T-18, T-46, T-25-30) and cruise (T-91, P-66) sites show the most peak power demand due to significant shore power loads. Completion of site redevelopment and shore power additions at Terminal 5 are expected to increase peak demand above Terminal 18 over time. The significant load addition at T-5 is due to the incomplete state of redevelopment at the time of the baseline in 2019. At Terminal 91, development of the uplands and EV charging are key contributors to peak demand increases through 2040, while uplands public EV charging at Pier 66 (which includes both cruise operations as well as the uplands areas) adds a more modest two MW of additional peak demand. Other priority sites do not contribute significantly to port-wide peak demand.

Load growth at near-port sites is also important for the ports and SCL to consider, with significant new loads anticipated at the USCG (Pier 36) and Washington State Ferries (Pier 52) sites, contributing upwards of 49 MW to the SCL distribution system through 2040.

INFRASTRUCTURE CONSTRAINTS ANALYSIS

The infrastructure constraints analysis used results of the demand forecast to identify where and when constraints would arise for both the SCL distribution system and on-terminal Port electrical infrastructure.

Constraints on Seattle City Light's Infrastructure

Constraints on SCL's power distribution system were identified by comparing forecasted loads with the existing capacity of power distribution feeders and equipment serving Port facilities. Based on available data, most SCL feeders are currently within their system design and thermal capacity limits. Two SCL feeders recently exceeded design parameters because of load growth, but mitigating solutions were already being actively explored.

The forecast constraints analysis merged the ports' forecasted loads into the SCL's distribution system forecast model, LoadSEER. This allowed for consideration of the impacts of both port and non-port loads on feeders serving port sites. The results of the analysis showed that of the 16 feeders serving port facilities, 10 feeders are anticipated to exceed design or thermal conductor limits by 2040, with seven of those feeders exceeding limits as early as 2035. Out of the 10 feeders forecasted to exceed their design limits, eight are directly the result of forecasted port demand.

SCL then conducted an analysis of solutions to mitigate identified feeder overload conditions and generated rough order of magnitude (ROM) cost estimates for those improvements. The analysis focused on traditional solutions such as substation improvements, switching, and feeders and distribution lines. SCL identified mitigating solutions at a total estimated cost of $69 to $168 million (2024 dollars).

Table 2: Distribution System Mitigating Solutions

Feeder	Sites Served	Identified Upgrades
FA01	T-91	Upgrade switches, feeder, load reconfiguration
FA02	T-91, T-86	Upgrade switches
FA03	T-106-108	Upgrade switches, feeder improvements
FA04	T-5	Upgrade switches, feeder improvements
FA05	T-10, Harbor Island Truck Charging	Upgrade switches

Feeder	Sites Served	Identified Upgrades
FA06	T-18, T-25-30, MMS, P-16-17, T-25S	Load transfer, upgrade conductors, new feeder
FA07	POS loads transferred	Upgrade conductor and switches
FA08	T-46, T-46N	Upgrade switches, new feeders
FB01	T-115	Upgrade switches, feeder improvements
FB02	T-5	Upgrade switches
FB03	West Marginal Way - T-115	Feeder improvements
FB04	Pier 2, CEM Property	Feeder improvements

Constraints on Port of Seattle and NWSA Infrastructure

Onsite infrastructure was assessed similarly to the utility distribution system analysis by disaggregating and mapping onsite loads to equipment and comparing forecasted loads to equipment ratings over the forecast timeframe. Constraints were evaluated for SCL transformers, at port site service entrances, and at on-terminal port substations. The analysis identified eight locations with constraints for the site as a whole and multiple port substation limitations. Table 3 summarizes individual site results and identifies recommendations to address the constraints.

Table 3: Port and NWSA Infrastructure Capacity Constraints by Site

Site	**Capacity Constraints** On-terminal port Substations	**Capacity Constraints** SCL Transformers	Entire Site Capacity Exceeded	Mitigation Recommendations
Shilshole Bay Marina (spot load)	No	None	Site loading limited by onsite SCL substation	• Monitor peak demand for vessel shore power and EV charging loads • Infrastructure planning to address needs by 2035-2040 to accommodate charging loads
Fishermen's Terminal	Yes One substation constraint (2040)	None	No	• Port substation upgrades by 2040 • Assess asset conditions for equipment overdue for replacement
Terminal 91	Yes Multiple substation exceedances with current configuration	Yes Two main substation exceedances with current configuration	Forecasted peak demand exceeds site capacity in 2035 with current infrastructure	• Review site resiliency requirements and load configuration • Removal of some electrification loads may alleviate constraints • Uplands redevelopment plans & designs could alleviate constraints • Upgrade transformers (Port and SCL) aligned with redevelopment plans

Site	Capacity Constraints On-terminal port Substations	Capacity Constraints SCL Transformers	Entire Site Capacity Exceeded	Mitigation Recommendations
Terminal 86 (spot load)	None	SCL upgrades at Terminal 91 will alleviate constraints at Terminal 86	None	• Managed charging for switcher locomotive to alleviate potential peak demand coincidence
Pier 66	Yes Main campus exceedance by 2040 due to building electrification. Uplands area exceedance by 2030 due to EV charging demand	Yes Main campus and uplands	No	• Upgrade main campus supply to accommodate building electrification from 2040-2050 • Upgrade uplands building service transformers to accommodate EV charging dependent on garage deployment timeline (public/TNC)
Terminal 46 and Terminal 46N	Yes Tug charging will require a new substation. Future cargo operations will require South Substation upgrade	Yes Three service entrances could exceed limits	Total site exceedance in 2050. Shifts to 2040 with near-port load growth	• Expected substation upgrade for vessel charging at T-46N • Expected substation upgrade to accommodate CHE electrification • Assess tug charging market conditions and timeframes
Terminals 25 and 30 (Includes T-25S truck charging)	Yes One substation exceedance in 2040	None Truck charging may exceed limits depending on configuration	Total site capacity may be exceeded depending upon truck charging configuration	• Central substation replaced with planned capacity for future shore power • The configuration of truck charging equipment type may trigger additional improvements.
Marine Maintenance Shop	Yes North and South service entrances (2035-2045)	None	Total site capacity exceeded by 2040	• Upgrade North service entrance to accommodate building electrification from 2040-2050 • Upgrade South service entrance to accommodate EV charger growth from 2035-2050

Site	Capacity Constraints On-terminal port Substations	Capacity Constraints SCL Transformers	Entire Site Capacity Exceeded	Mitigation Recommendations
Terminal 18	Yes One exceedance in 2040-2050. Insufficient capacity to meet CHE electrification (2040)	Sufficient capacity in near term with two planned substations CHE charging may exceed limits if peak loads align with other end-uses (2035-2040)	Sufficient capacity in near term with two planned substations CHE charging may exceed limits if peak loads align with other end-uses (2035-2040)	• Shore power is currently in design • Further site upgrades (in addition to Table 5) expected to be required for CHE charging, including consideration of overall on-site power distribution and asset conditions. Includes SCL transformers and additional on-site substations • Shift CHE charging windows where possible to limit peak contributions on coincident days • Assess condition of site substations and address potential constraints in mid-term with any improvements
Pier 16-17 (spot load)	Yes	None	Site exceedance in 2035 with tug charging	• Upgrade service entrance by 2035 • Continue to assess site upgrades and reconfiguration requirements according to tug charging market conditions and timeframes
Terminal 5	No	None	Site exceedance with CHE and eTRU load growth (2030-2035)	• Feeder upgrades (2030-2035)
Terminal 10, Harbor Island Truck Charging	No	None	Upgrades already required due to recent overload conditions	• Upgrade switches to address current infrastructure constraints
Pier 2 and CEM Property	No	None	Site exceedance with truck charging (2025-2030)	• Expected feeder upgrade to accommodate truck charging • Continue to assess timing of truck charging deployment
Terminal 115 (Includes W. Marginal Way truck charging)	Yes	None	Site capacity exceeded in 2035 with truck charging	• Upgrade onsite service transformers to accommodate load growth and truck charging
Terminal 106-108	No	None	Site exceedance with building, CHE and eTRU loads (2030-2050)	• Feeder upgrade to accommodate expected warehouse redevelopment (Terminal 106) and CHE and eTRU loads (Terminal 108)

Alternatives Analysis ("Non-Wires" Solutions)

An analysis was conducted to explore the feasibility of non-wires technologies to mitigate capacity constraints at the four most power-constrained port sites (Terminal 91, Terminal 18, Terminals 25-30, and Terminal 46 / 46 North) as an alternative to traditional upgrades at the site level. Non-wires solutions can be used to deliver clean energy, address forecasted energy needs, and provide for power resiliency.

Combinations of non-wires solutions were identified for evaluation at each of the sites. The technologies that were chosen for further consideration included solar photovoltaic (PV), battery energy storage systems (BESS), thermal energy storage, load controls, hydrogen-powered CHE, onsite fuel cell power generation, and energy efficiency.

The results of this analysis showed that traditional infrastructure improvements are currently the most cost-effective means of meeting projected load additions through 2040 for each of the sites analyzed. Alternative technologies had capital expenditure (CapEx) costs that were considerably higher than traditional infrastructure, ranging from 3x to over 10x higher at certain sites. One alternative was estimated to have high enough annual operating expenditures (OpEx) over the life of the project that those costs alone would negate the up-front cost savings from avoiding the traditional upgrade.

While not found to be cost-effective at addressing overall site capacity constraints, deployment of alternatives can occur over time or along with end-use (e.g. CHE, truck, vessel, etc.) charging installations to help offset peak loads and associated peak electrical demand charges. Solar PV, load controls, and efficiency measures may be cost-effective and practical on a stand-alone basis.

Table 4 summarizes site-specific findings and recommendations for the four sites analyzed.

Table 4: Alternatives Analysis Recommendations by Site

Site	Recommendation
Terminal 91	▪ SCL feeder upgrade is the least costly option relative to the technology alternatives ▪ Splitting the site load configuration among existing substations is the most cost-effective means of meeting anticipated load growth and could defer needed SCL upgrades through the 2040 time horizon. Recommended for further study ▪ Install PV on new buildings and evaluate, rank, and implement PV on existing buildings ▪ Evaluate opportunities for implementation of operational controls improvements for industrial refrigeration and other heavy loads ▪ Monitor costs for battery energy storage (peak load mitigation and increased resiliency)
Terminals 46 and 46 North	▪ The CapEx for the alternatives proposed is lower than the 2050 SCL upgrade, but the annual OpEx is high ▪ Pursue technology solutions as they mature, including hydrogen-powered CHE, BESS, and on-site fuel-cell power generation ▪ is Continue to monitor development of waterfront battery energy storage plans associated with adjacent sites (Pier 50, 52)
Terminals 25-30	▪ SCL upgrades are significantly lower in cost than the estimated CapEx and OpEx for alternatives that can be deployed on site
Terminal 18	▪ Near-term SCL feeder load transfer will increase feeder capacity ▪ Monitor and reassess hydrogen-powered CHE, battery energy storage systems, and onsite fuel-cell power generation as they mature between now and 2040

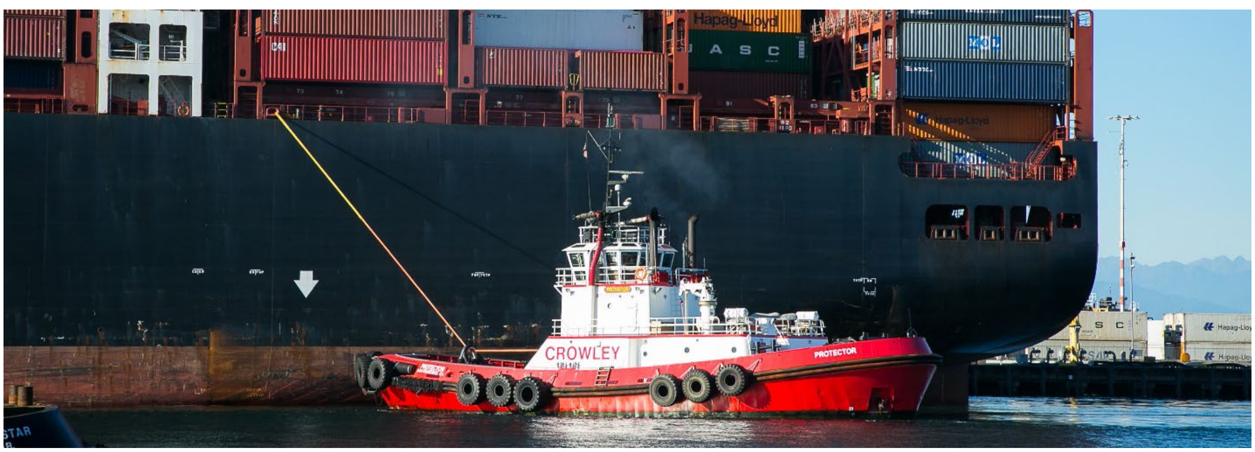
“Non-Wires” Technology Alternatives: Areas for Ongoing Study

Although alternative solutions were determined to not be cost-competitive at present, the ports and SCL should continue to monitor their feasibility as technology advance and costs fall[10]. In particular, battery storage provides a promising means of deferring or avoiding infrastructure capacity upgrades, mitigating demand charges (utility fees for peak loading), and enhancing power resiliency.

Hydrogen-powered equipment and battery energy storage systems (BESS) should continually be assessed in the near-term as opportunities to mitigate load additions, especially as part of scoping and exploring new end-use electrification projects. At sites where necessary SCL feeder upgrades are several years away, there is time for technologies to mature and potentially become cost-effective prior to making investment decisions. The cost of utility-side upgrades may also evolve.

A current SCL-sponsored study for a waterfront BESS supporting loads at Pier 50 and 52 could present energy storage options in the vicinity of Terminal 46 and T46 North. The Ports should continue to monitor plans for those sites and the adjacent USCG facility.

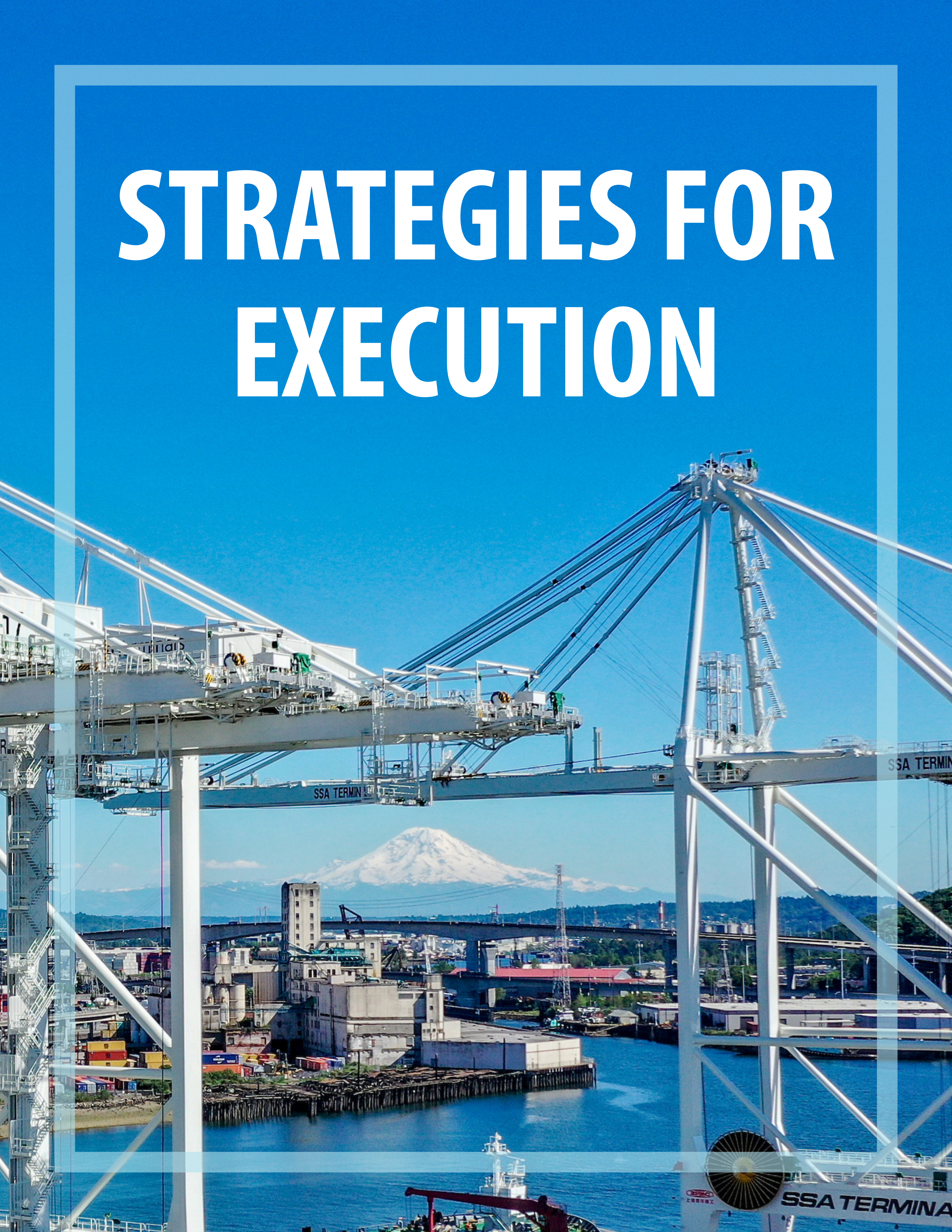
Energy efficiency may be deployed effectively to reduce overall energy requirements while maintaining or improving performance as with buildings and lighting. PVs are expected to be cost-effective on new buildings, and sites with available roof areas should be assessed and ranked for selective implementation.



Crowley tug assisting container ship to Terminal 18 | November 2018

[10] Studies in 2023 by NREL on utility scale battery costs projections identified a reduction in 4-hour lithium-ion battery system costs of 16-47% by 2030 as compared to 2022, and 21-67% by 2050. See: Cost Projections for Utility-Scale Battery Storage: 2023 Update, National Renewable Energy Laboratory, https://www.nrel.gov/docs/fy23osti/85332.pdf

STRATEGIES FOR EXECUTION



STRATEGIES FOR EXECUTION

Successful implementation of the SWCES requires ongoing and coordinated implementation by the ports, SCL, industry, and other interested parties. The SWCES includes two categories of recommendations: Capital Investments and Strategic Implementation Actions. It is expected that the implementation strategy will be discussed and reviewed by and among partners' operations and leadership to review viability and confirm best approaches.

Capital Investments at the Port, NWSA, and SCL

The SWCES analysis identified a series of distribution system and site-level upgrades needed to support electrification of port facilities and equipment. These include an estimated $69 to $168 million in distribution system infrastructure costs and an estimated $106 to $187 million in on-site transformer, switchgear, and substation equipment costs over the planning horizon (through 2050). These figures are preliminary, rough order of magnitude estimates and do not include the costs for vehicles, vessels, and cargo handling equipment or the associated charging station equipment and related site improvements.

Port electrical equipment and utility infrastructure upgrades by site are outlined in Table 5. The table identifies project locations, the asset owner, load triggers expected to drive the need for upgrades, anticipated timing for upgrades, and costs. It should be noted that "asset owner" refers to the owner of the equipment for each project, but does not indicate fiscal responsibility, which would need to be determined on a case-by-case basis. For assets on NWSA-licensed properties, NWSA is listed as the asset owner. In-service years labeled as "current" were assumed to be under evaluation by SCL as of the time of the study.

The project cost estimates for on-site equipment are "Class 10" estimates and should be considered as preliminary estimates for early-stage, programmatic planning. Class 10 estimates have a high degree of uncertainty and a wide range of accuracy. For the on-site equipment estimates below, the range of uncertainty is -30% to +95%. This uncertainty stems from unknown future inflation rates, electrical equipment supply chain limitations and other factors. Cost estimates for SCL infrastructure projects were provided separately by SCL. For projects identified in 2030 and beyond, SCL is also using a "Class 10" estimate.

Drayage truck driver inspects connections at Terminal 5 | October 2022

Target in-service years refer to the year that the anticipated upgrade is expected to be needed, based on the forecast conducted as part of this study. This in-service year is contingent upon the identified load trigger(s) being met. As the timing for project development and approval is not known at this time, project cost estimates are expressed in present-day (2024) dollars rather than escalated for future project delivery years.

Projects are expected to undergo a detailed capital project scoping and development step before moving forward Projects may ultimately include additional electrical infrastructure repair or replacement due to age or condition of equipment. A minimum five-year lead time requirement is expected for planning, design, and construction of most projects. More extensive solutions such as feeder additions will require longer lead times in the range of 10 or more years. Although the certainty of the timing and magnitude of individual loads decreases over the planning horizon, planning should nevertheless begin early on long lead-time projects to ensure the ability to meet future load conditions. A set of initial, near-term capital investments are recommended for detailed evaluation and incorporation into Capital Investment Plans and are identified in blue in Table 5.

All of the capital projects recommended in the Strategy will go through required environmental review, permitting, and approvals prior to construction and implementation at the relevant time.

Harbor Island and surrounding area | May 2021

Table 5: Port and Utility Capacity Improvements Project Summary

Site	Project	Asset Owner	Load Trigger(s)[11]	Target In-Service Year	Rough Order of Magnitude (ROM) Cost
Fishermen's Terminal	Upgrade existing POS Substation No. 5	Port of Seattle	Public EV charging (~68% by 2040, ~66% by 2050); C-15 building electrification (~23% by 2040, ~25% by 2050)	2040	$5,700,000 - $15,800,000
Terminal 91	Upgrade switches	SCL	Shore power, building electrification	Current	$100,000
	Load balance substations	Port of Seattle	Following review of site resiliency requirements	n/a	n/a
	Upgrade feeder backbone	SCL	Shore power, building electrification, EV charging	2030	$6,600,000
	Upgrade switches	SCL	Shore power, building electrification, EV charging	2030	$220,000
	Upgrade Main Substations (MSS-1, MSS-2) SCL transformers	Port of Seattle, SCL	Overall site demand additions (shore power, uplands redevelopment, building and fleet electrification, etc.)	2030-2040	$270,000 - $800,000
	Substation 13 (SS-13) Upgrade	Port of Seattle	Uplands redevelopment	2040	*Project currently in design*
	Substation 5 (SS-5) Upgrade	Port of Seattle	Forklift Charging	2030	$14,300,000
Terminal 86	See Terminal 91 – upgrade switches with Terminal 91 in 2030.				

[11] Where expressed as percentages, load triggers represent the percentage contribution to site peak demand additions in the specified year.

Site	Project	Asset Owner	Load Trigger(s)[11]	Target In-Service Year	Rough Order of Magnitude (ROM) Cost
Pier 66	Main campus service upgrade	Port of Seattle	Building electrification at Bell Harbor International Conference Center and/or Anthony's Restaurant; project location and scope dependent on upgrade sequencing and building code determinations	2040-2050	$7,800,000 - $21,600,000
	Upgrade uplands service	Port of Seattle	Public EV charging and/or TNC charging; project is not currently forecasted to be needed, but should be re-evaluated depending on EVSE siting and timing	n/a	*Project scope will be dependent on future EVSE deployment plans*
Terminal 46 & 46N	New Harbor Vessel Charging Substation (T46N)	Port of Seattle, SCL	Harbor vessel charging spot load	2035	$16,000,000 - $44,600,000
	Substation upgrades (T46)	Port of Seattle, NWSA, SCL	CHE charging (~94% of new peak demand by 2030); Fleet vehicle electrification (~12% of new peak demand by 2035)	2035	$33,800,000 - $94,300,000
	Two new feeders to cover load (T46)	SCL	Load growth at P66, T46, T46N and non-Port sites	2050	$35,000,000 - $97,500,000
Multiple Sites – Seattle Harbor South (MMS, T25/30, T18, P16/17, T5)	Load transfer, upgrade conductors	SCL	Future load growth at multiple sites	Current	$2,000,000
	Feeder upgrades	SCL	Port loads transferred	Current	$3,300,000
	New Feeder	SCL	Future load growth at multiple sites	2050	$19,250,000 - $53,625,000
Marine Maintenance Shop (MMS)	Upgrade North Service Entrance	Port of Seattle	Building electrification (~71% by 2035, ~63% by 2040)	2035	*Project currently in planning*

Site	Project	Asset Owner	Load Trigger(s)[11]	Target In-Service Year	Rough Order of Magnitude (ROM) Cost
Marine Maintenance Shop (MMS)	South Service Entrance, Substation Transformer Upgrade	Port of Seattle, SCL	Fleet EV charging (~28% by 2030, ~35% by 2035)	2045	$4,000,000 - $11,200,000
Terminals 25 and 30	Terminal 25, South Substation	NWSA	Truck Charging (2040-2050)	2030	$7,600,000
Terminal 18	Substation Upgrade	NWSA	CHE electrification (2030-2050)	2030	$10,500,000
Pier 16 and 17	Upgrade Service Entrance	NWSA	Tug Charging spot load	2035	$7,500,000 - $21,000,000
Terminal 5	Upgrade switches A	SCL	CHE electrification	2030	$100,000
	Upgrade switches B	SCL	CHE electrification	2030	$500,000
	Feeder improvements	SCL	CHE electrification	2035	$385,000 - $1,072,500
Terminal 10, Harbor Island Truck Charging	Upgrade switches	SCL	Recent overload conditions; CHE and non-Port loads	Current	$100,000
Pier 2 & CEM Property	Feeder upgrade	SCL	Truck Charging (2025-2030)	Current	*Project currently in planning*
Terminal 115, West Marginal Way Truck Charging	Upgrade South Substation	NWSA	C-4 building electrification and forecasted load growth (2025-2030) CHE & fleet vehicle charging (2030-2050)	2030	$12,000,000
	Upgrade SCL Transformer	SCL	C-4 building electrification and forecasted load growth (2025-2030) CHE & fleet vehicle charging (2030-2050)	2030	$11,800,000
	Upgrade switches	SCL	EV fleet vehicle and CHE electrification	2030	$110,000
	Upgrade East Substation	NWSA	Forecasted reefer plug additions by 2035 (400 to 600)	2035	$8,300,000 - $23,200,000

Site	Project	Asset Owner	Load Trigger(s)[11]	Target In-Service Year	Rough Order of Magnitude (ROM) Cost
Terminal 115, West Marginal Way Truck Charging	Feeder upgrade	SCL	EV fleet vehicle and CHE electrification	2035	$231,000 - $643,500
	Feeder upgrade	SCL	Truck charging	2035	$508,200 - $1,415,700
Terminal 106-108	Feeder upgrade	SCL	Buildings, CHE and fleet vehicle charging (2030-2050)	2040	$385,000 - $1,072,500

Strategic Implementation Actions

Strategic actions will be critical to help ensure achievement of decarbonization goals, provide a holistic approach to capital planning and investment, and reduce project risk. Eight strategic actions plus a Joint Implementation Framework have been identified for implementation in concert with capital project improvements.

SA1. Design for Future Electrification Capacity

The ports and SCL should continue to emphasize “planned capacity” improvements as a part of preparations for electrification and a shift from an incremental, project-by-project investment approach. This means making proactive improvements in anticipation of load growth rather than improving capacity to the requirements of immediate projects.

The Port has begun implementing modular (expandable) substation designs in anticipation of future electrification load increases and should continue to anticipate and budget for future load increases proactively as a part of all infrastructure projects. By designing infrastructure for increased load capacity to support end use electrification demands, the ports will be preparing for the future and may avoid the need for costly and time-consuming additional upgrades as loads increase.

This shift will increase the risk of stranded assets if increased loads from end use electrification fail to materialize — as through delayed electrification equipment investment and changes in alternative technology development. However, efforts can be taken to help mitigate these risks. For example, continued and enhanced power monitoring can help to refine estimates of future power need which can be factored into planning and design work, and ongoing engagement with tenants and customers will enhance understanding of electrification plans, timing and need for support.

Support for a planned capacity approach to infrastructure planning may be implemented through the Port’s Sustainable Evaluation Framework (SEF) and regularly evaluated as a part of engineering design alternatives. Implementation of the planned capacity approach and SEF would also be reinforced by site master planning (also recommended below), which would refine a site’s long-term capacity target and conceptual space utilization parameters based on planned uses.

SA2. Asset Condition Assessment

To inform implementation of the SWCES, the ports should continue to work with tenants to assess and document the current condition of on-terminal infrastructure, expand assessments to all sites, and use the resulting data to make necessary adjustments to the infrastructure investment and project schedule recommendations. Some condition assessments and power safety assessments have been pursued at the ports. However, detailed information on the condition of port-owned on-terminal electrical infrastructure was not available for most assets during the baseline assessment portion of this project. Therefore, recommendations for capital projects are based on forecasted electrical load capacity constraints and did not consider equipment age or condition.

SA3. Identification of Critical Facilities for Resiliency

Energy resiliency is the ability of the electrical grid, and the buildings, communities, and other critical services that are served by that grid, to withstand and rapidly recover from power outages or other disruptions. In the case of seaports, resilience is largely defined by the ability to remain operational and continue to offer services to ships, cargo carriers, and other customers during disruptions. Resilient ports, as characterized by the United Nations, are those that "can cope with shocks, absorb disruptions, quickly recover and restore operations to a level similar to — or even above — a baseline, as well as adapt to changing conditions, as it continues to develop and transform."[12]

In development of the SWCES, resiliency was considered a co-benefit. To leverage investments in port infrastructure and increase operational reliability, the Port should work with tenants to assess power resiliency requirements, identify critical facilities, identify utility hazard exposure, risk, and vulnerabilities (e.g. flooding and sea level rise, groundwater intrusion, seismic hazards), and assess the status of backup generation resources at Port facilities. This assessment should also identify facility-specific resiliency improvement opportunities.

Technological alternatives such as onsite battery energy storage systems (BESS) or more extensive microgrids could provide resiliency benefits to Port facilities, enabling continuity of critical port or tenant operations in the event of grid outages. With an increased focus on electrification of end uses and load growth in the Pacific Northwest, the availability of power is increasingly important. Furthermore, regional sea level rise studies have identified groundwater intrusion as a significant concern on waterfront facilities, potentially affecting the reliability of duct banks, vaults, and other electrical infrastructure and the potential need for relocation of equipment. Finally, strategies to optimize power distribution to port facilities will benefit greatly from a clear understanding of power redundancy and resiliency requirements for Port and tenant operations at different sites.

SA4. Integration with Site Master Planning

Port properties do not currently have site master plans to guide future development. This makes preparations for future infrastructure investment challenging given that infrastructure capacity, location, and timing are inextricably linked to the future uses at a site. In addition, port property is a highly valued commodity (estimated at over $150,000 per acre per year for cargo sites) and allocating space for switchgear, transformers, battery storage, charging equipment, and other above and below ground power infrastructure will need to be planned carefully. Master site development plans should use SWCES data to align strategic goals with site conditions, resiliency strategies, and business and other organizational priorities to guide short and long-term development. Ideally, infrastructure, including power infrastructure, should provide for the overall site objectives and follow an integrated planning effort.

Recent redevelopment plans and strategic evaluations identified the need for shared infrastructure development and reconsideration of site uses. Additionally, to meet decarbonization goals, cargo facilities are expected to require significant investment in electrified CHE and on-terminal infrastructure which may impact current terminal operations and layout.

As a next step in the implementation process, preparation of site-level electrification master plans would begin the process of detailed on-terminal design. Ideally, electrification master

[12] https://resilientmaritimelogistics.unctad.org/guidebook/21-defining-port-resilience

plans would follow and complement overall site master plans that also account for expansion, reconfiguration, changes in land use, and circulation among other aspects.

Findings from the SWCES analysis point to the near-term need to complete electrification master planning efforts for Terminal 91 and Pier 66. Additional priority locations for electrification-decarbonization master planning include Terminal 18, Terminal 25/30 and Terminal 46 (including T46 North). These sites should be prioritized because they include a combination of potentially significant load growth from cargo handling equipment, shore power, truck charging, and harbor vessel charging and have significant distribution system constraints under current feeder arrangements. The timing of these electrification master planning studies should be determined based on engagement with the tenants at these facilities, timing of any planned redevelopment projects, and scope/timing of key adjacent projects that may impact these facilities and local system capacity, such as the potential USCG base expansion project.

SA5. Infrastructure Management and Development

Port lines of business currently share responsibility for development, regulatory compliance, and management of onsite infrastructure including power as well as water, sewer, stormwater, communications, and transportation. This arrangement reflects the multiple users benefiting from these common assets but requires high levels of continuous coordination. Individual project needs for a line of business can also trigger much more significant site infrastructure improvement requirements, potentially overwhelming an individual project's feasibility.

Differentiating site-wide infrastructure responsibilities from those of individual lines of business and tenants can help to improve the Port's ability to effectively meet the myriad, interrelated demands on these assets. These include parameters such as capacity, reliability, safety, and resiliency — all of which will be critical to meeting decarbonization, sea-level rise, asset replacement, site redevelopment, long-term operations, and other objectives.

SA6. Increase Grant Project Readiness

The ports and industry partners should use the SWCES results to assess, scope, and regularly update a suite of grant-ready projects to be well positioned for funding opportunities to increase the likelihood of funding to offset port, utility and tenant investment costs. The assessments and updates should include utility distribution system assets (e.g. feeders, substations, transformers, switchgear, smart meters, utility-side storage, etc.), port on-terminal assets (e.g. port substations, distributed generation and storage, energy monitoring, duct banks, etc.), and public and private decarbonization deployment projects (e.g. shore power, vessel charging, fleet and equipment charging, building electrification, etc.). Outside funding will be essential to reduce barriers to deployment, but careful attention should be made to the complexities of grant obligations and multi-party commitments to minimize any added costs, delays and overall deployment risk.

SA7. Clean Technology Development

The Port should consider an innovation-focused maritime decarbonization lens as a useful framework for the Port to advance the deployment of electrification and clean energy technologies on Port-owned properties. This framework seeks to align and integrate clean energy and economic development objectives to advance the development, demonstration, and/or deployment of zero emissions technologies at the Port as a part of a holistic decarbonization and economic development strategy.

The commercial availability of electrification technologies is a key factor which will drive load growth timing and the ability to achieve long-term targets. However, electrified end-uses designed for the operational demands of the maritime environment present varied challenges including technological readiness, the cost gap between electric equipment and conventional fossil-fueled equipment, operational limitations of electric equipment, special requirements for maritime equipment, and space constraints on Port properties for charging infrastructure (a summary of expected barriers for different end use categories is included in Appendix B).

The ports' primary role as landlords means that electrification and decarbonization of end uses will need to largely occur through private sector investments. Accordingly, it is critical for the ports and utility to continue to monitor technologies and actively engage with maritime industry operators to understand overall site investment plans, build awareness of alternatives, and identify additional barriers and opportunities to help ensure effective planning for power infrastructure.

The Pacific Northwest is a leader in clean technology business investment and home to an emerging hydrogen ecosystem. The Port should leverage these clean technology conditions and its concentration of heavy duty transportation end uses, diverse array of properties, high visibility, NGO partnerships, ambitious emissions reduction targets, and economic development mission to encourage maritime innovation at the Port. Working together, the ports and SCL could explore opportunities to pilot new technologies, develop market transformation supportive initiatives, or leverage planned investments to support neighboring industries.

Efforts such as the U.S. Department of Transportation Maritime Administration's National Center for Maritime Innovation are intended to facilitate increased study, development, assessment, and deployment of emerging maritime technologies related to environmental challenges specifically including vessel and port emissions.

Emerging hydrogen technologies are expected to play a role in decarbonization of site operations, potentially addressing limitations of battery technologies for heavy lift or extended range applications while reducing requirements for peak power delivery. A diversified power resiliency strategy could include hydrogen fuel cell-based backup power as equipment costs decline and clean hydrogen supply develops in the region. Hydrogen technologies should continue to be evaluated as a part of planned end-use technology assessments and considered for support through technology advancement and joint innovation projects in collaboration with NGO and port business partners.

While the focus of the SWCES is on electrification, given its efficiency and emissions reduction potential, low carbon fuels are expected to play an important role in decarbonization of the maritime sector. The overall investment in electrified zero emissions equipment is likely to be in the billions of dollars for the end-uses covered by this strategy and is forecasted to occur in phases throughout the 25-year planning horizon. In the interim, renewable diesel is a drop-in fuel that can produce GHG emissions reductions of up to 50% or more in existing vehicles, vessels, and equipment. The ports can simultaneously leverage grants, phased-in requirements, zero emissions clean technology pilot project support, and other strategies to accelerate turnover. The ports should continue to advance parallel efforts as a part of its

Sustainable Maritime Fuels program and increase the availability and uptake of low and zero carbon liquid fuels.

As the ports support advancement in new technologies, there should be attention to potential impacts to the maritime workforce and ways to ensure they are ready for this transition. Re-skilling, technical education, career-connected learning, and other workforce development strategies should be considered as important complementary efforts to the transition to new technologies and fuels.

SA8. Innovative Business Models and Financial Strategies

The Port should consider leveraging alternative business models and financial strategies to facilitate the deployment of clean energy infrastructure and end uses. Such approaches could include innovative models of financing, ownership, electricity rate design, or lease and agreement terms that ultimately encourage or enable the adoption or use of zero-emissions technology. Innovative business models and financial strategies may help address today's barriers to adoption through lower up-front capital costs and cost recovery, by creating an incentive for electrification, by harnessing operational efficiencies, and creating other potential benefits.

The Port considered a range of potential business models and financial strategies and identified the four summarized in this section as the most promising to support deployment based on Port circumstances and current end-use technologies. It should be noted that this is not intended to be an exhaustive list, and the Port should continually evaluate opportunities, particularly as new partnership opportunities arise with customers, tenants or third-party providers and as state, federal or international policies change. These funding and financing strategies will need to be weighed against and in context of the ports' and utility's other financial strategies and demands. The business models and financial strategies identified are:

- Inflation Reduction Act (IRA) Elective Pay Funding
- As-a-Service Models
- Innovative Rate Design
- Special Purpose District Authorities

Inflation Reduction Act (IRA) Elective Pay Funding: Elective Pay, also called Direct Pay, is a ground-breaking tax mechanism introduced under the IRA that involves leveraging expanded tax credits to support clean energy sector manufacturing, installation, and production through 2032. The Elective Pay system enables tax-exempt and governmental entities to receive payments equivalent to the full value of tax credits for building certain clean energy projects. Tax credits can be roughly divided into production tax credits (for the production of electricity or fuels) and investment tax credits (for capital investments in clean energy technology).

Elective Pay has the potential to be used for clean electricity (production or investment), carbon dioxide sequestration, advanced energy investments (including clean energy manufacturing and industrial decarbonization projects), commercial clean vehicles, alternative fuel vehicle refuelling, clean hydrogen production, and other projects. The program is potentially beneficial to the Port in that it enables the Port to participate as a viable stand-in for private sector tax equity financing. Importantly, Elective Pay credits can be used to supplement funding from other federal or state grant programs without penalty.

As a next step, the Port should conduct a more detailed study on the applicability of Elective Pay to prospective Port projects. For example, Elective Pay includes specific requirements for project siting and technology utilization that should be considered in detail alongside current operational profiles at Port properties. This type of study would be a necessary first step towards determining Elective Pay's feasibility as a financing mechanism for deployments of new electrification technology or supporting infrastructure at the Port.

Potential applications: energy storage, clean hydrogen production, EV purchase, EV or hydrogen fuelling infrastructure, solar, clean energy demonstration projects, microgrid technology.

"As-a-Service" Models: As-a-service models are financial arrangements where a third-party provider owns, operates, and maintains an energy system or equipment and charges the customer for the service or output, rather than any one entity paying the upfront capital cost to own the system or equipment. As-a-service models can be applied to various systems, including charging as a service, storage as a service, trucking as a service, and various other applications. As-a-service models support the deployment of energy systems or assets by reducing up-front capital costs as well as operational and maintenance risks and are well-suited to deploying assets with high up-front costs where a revenue stream can be generated during operations to offset as-a-service fees. A typical arrangement would involve a private third party as the service provider, however, the Port could also act as a service provider. For Port-owned projects, As-a-service models typically wouldn't provide as clear a benefit given the Port's low cost of capital and relative access to capital funds.

As a next step, the Port should continue to consider As-a-service models to support deployments where opportunities for such deployments arise at Port properties. In particular, electric heavy-duty trucking is a current area where the Port is engaging with As-a-service providers as a potential means of deploying infrastructure.

Potential applications: Solar, energy storage, microgrid systems, EV or hydrogen fueling infrastructure deployment, electric heavy duty trucks.

Innovative Rate Design: Innovative rate design refers to methods for pricing electricity to achieve specific goals with regards to tenant or customer energy usage. Targeted electricity rates could be used to lower barriers to the adoption and use of desired technologies, particularly where high operating costs associated with energy usage contribute significantly to overall project costs. This could allow for a more rapid return on investment for technologies that are in a demonstration phase and/or have very high up-front adoption costs as compared with incumbent fossil-fueled technology, such as electric harbor vessels, CHE, or zero-emissions trucking. This model could also help to incentivize more widespread usage of shore power for a variety of commercial vessel types at various Port facilities.

At present, any new rate structures used at the Port would need to be carried out in cooperation with SCL. SCL typically assesses the feasibility of new rate structures through pilot rates, which may be utilized for an extended period of time to determine impacts. As a next step, the Port and SCL should leverage the SWCES findings to study the need for and feasibility of rate design measures, such as pilot rates, to achieve shared goals with regards to specific technologies.

Potential applications: Shore power, electric harbor vessel deployment, CHE charging, truck charging, electric locomotive deployment.

Special Purpose District Authorities: The Port currently operates under state statutory authority as a Port District (RCW Title 53) providing for the acquisition, construction, maintenance, operation, development and regulation of harbor, rail, transfer, storage and related activities. This includes the ability to establish industrial development districts (including the direct provision of power, as is the case for the airport) and pollution control facilities (including air and water pollution). These authorities should be reviewed for opportunities to align the ports' emissions reduction and clean air goals with the ports' ability to invest in policies, programs and activities which incent private party deployment of pollution reducing technologies and clean fuels. The ability to provide incentives across maritime activities is a significant limiting factor in the ports' programs and would add an important tool which is already available to competing ports in other states as well as British Columbia. Similarly, such an evaluation should also consider the authorities of ports to invest in new clean fuel technologies, such as green electrolytic hydrogen production and its derivatives such as methanol, and the associated production, distribution, and sale of clean fuels to end users.

Recommended next steps include an evaluation of the needs, opportunities, gaps, and expected benefits of one or more approaches including consideration of the legal, legislative, and financial mechanisms that may be required.

Potential applications: low and zero emissions technologies, clean maritime fuels.

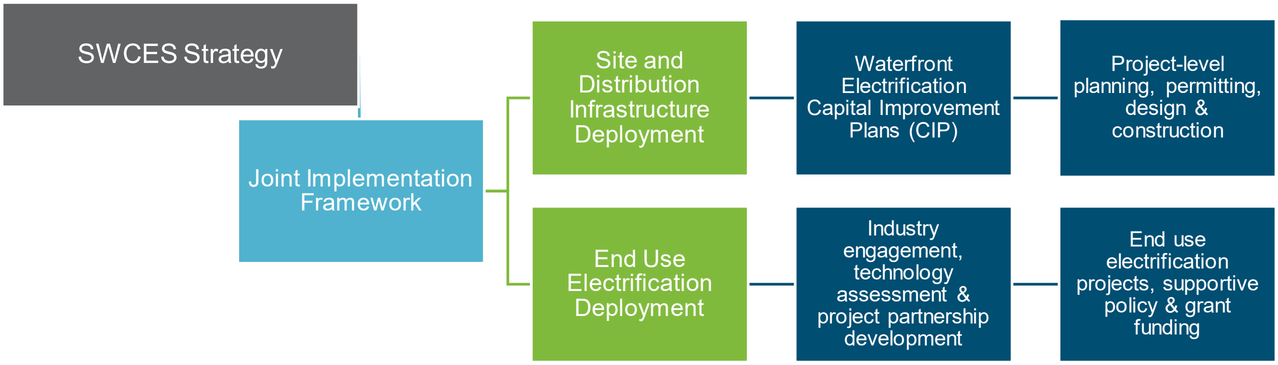
Preparing for Deployment: Joint Strategy Implementation Framework

A joint Port, NWSA, and SCL execution strategy will be critical to effectively implement the SWCES. Design, permitting, construction, and sequencing of utility distribution system investments, on-terminal port electrical equipment, and demand-generating electrified end uses across multiple port locations will need to be coordinated. Work with industry stakeholders will be vital to inform technology deployment options and timelines, and large, long lead-time capital investments will benefit from a clear, collaborative, and coordinated approach.

Implementation of the SWCES involves two major workstreams – one focused on infrastructure deployment and another focused on end-use electrification (e.g., installing shore power connections, charging infrastructure, electric vehicles and equipment, etc.). See Figure 14 below.

The Site and Distribution Infrastructure Deployment workstream will be vital for timely permitting, design and construction of infrastructure as well as managing available capacity. Ongoing monitoring, project planning, and design of load serving strategies would drive investments to be evaluated for incorporation into Capital Improvement Plans on an annual basis. A Joint Capital Planning and Implementation Team involving key staff from the Port, NWSA, and SCL should be established to provide for effective coordination and implementation on an ongoing basis.

Figure 14: Strategy Implementation Framework



The End Use Electrification Deployment workstream will be vital to increase the electrification of vehicles, vessels, and equipment, and drive adoption in line with emissions reduction goals. This effort should tie in with interim liquid fuel strategy options noted above. Ongoing monitoring will be important to inform capital project investment, and effective implementation strategies for industry engagement, technology assessment, grant funding, and partner development will be necessary for successful implementation. Figure 14 outlines the major workstreams anticipated with the implementation of the SWCES and Table 6 identifies key implementation aspects.

Cruise ship plugging into shore power at Smith Cove Cruise Terminal | May 2022

Table 6: Key Implementation Aspects

Implementation Aspect	Parties	Roles
Overarching strategy monitoring, partnering agreement oversight, establish joint implementation framework, strategy review and update	Port, NWSA and SCL leadership	• Periodic review of implementation progress, lessons learned, status of loads, available capacity, and emerging issues and conditions • Direct strategy review and update in 3-5 years as needed
Site and Distribution Infrastructure Deployment	Planning and engineering groups from the Port, NWSA and SCL	• Port leads site master planning • Utility leads system planning • Convene Joint Capital Planning and Implementation Team • Coordination and review of long-lead projects including major infrastructure • Monitoring of available capacity and project status. • Minimum of annual recommendations for capital investment.
Capital Investment Plan (CIP)	Port, NWSA and SCL finance teams	• Annual updates to Port, SCL and NWSA CIPs, incorporating new projects and adjusting timing on a rolling 5-year basis
Project-level planning, permitting, design and construction	Port, NWSA and SCL project delivery and permitting	• Coordinated project delivery • Quarterly advance planning meetings to review and coordinate upcoming projects, periodic meetings as needed for ongoing coordination
Industry engagement, technology assessment and project partnership development	Port and NWSA Sustainability teams and SCL Electrification and Strategic Technologies	• Port and NWSA lead industry engagement • Identification and update of barriers / opportunities • Assess pace of technology adoption, identify new projects and opportunities to pilot technologies • Vetting of potential projects and identification of potential power system impacts • Periodic review of end use and non-wires technologies and costs
End use electrification projects	Port and NWSA Sustainability teams and SCL Electrification and Strategic Technologies	• Project development support for vetted projects • Clarify project requirements, identify system planning or capital investment needs • Identification of supportive policies, incentives, business models, and partnerships to advance projects • Develop grant ready projects, pursue as appropriate • Inform infrastructure planning and deployment aspects above, including certainty, location, timing, and size of electrification deployment projects

A periodic review and update of the SWCES in the three to five year timeframe is recommended to guide iteration of investments and ensure that the recommendations remain timely and actionable. Key elements of the strategy to review in the next cycle include:

- Revisiting the SWCES load and electrification forecast relative to actuals to calibrate the model and identify site-wide and feeder-level trends in Port and Near-port load conditions
- Review of relevant policy developments that could affect forecast conditions (e.g., new/amended decarbonization mandates or incentives)
- Review of tenant needs and highest priority electrification projects that will drive load growth
- Technology readiness (e.g., commercial availability) of vehicle, vessels, and equipment
- Review of energy storage costs
- Updated capital project recommendations

Conclusions and Next Steps

Building on the Partnering Agreement

The project partners entered into a Partnering Agreement in October 2021 to facilitate the successful development and implementation of the SWCES. The Partnering Agreement memorialized a shared vision for a clean energy future and established commitments for holistic joint planning, innovation, cooperation, and SWCES project management.

The Partnering Agreement[13] was forward looking and established an initial ten-year term of collaborative work, anticipating a transition from planning to implementation. With the completion of the SWCES, the parties have established not only a strong working relationship, but also a solid foundation of data and insights to guide future investments and implementation of recommendations.

The SWCES is intended to be a core element of the ports' implementation plans for the Northwest Ports Clean Air Strategy, creating the enabling infrastructure necessary for achievement of port and community goals. As growth in electrification of non-port sectors advances, due in part to state level policy drivers and regional ambitions, a regular assessment of progress and review of available capacity will be vital to ensure findings continue to be current and actionable.

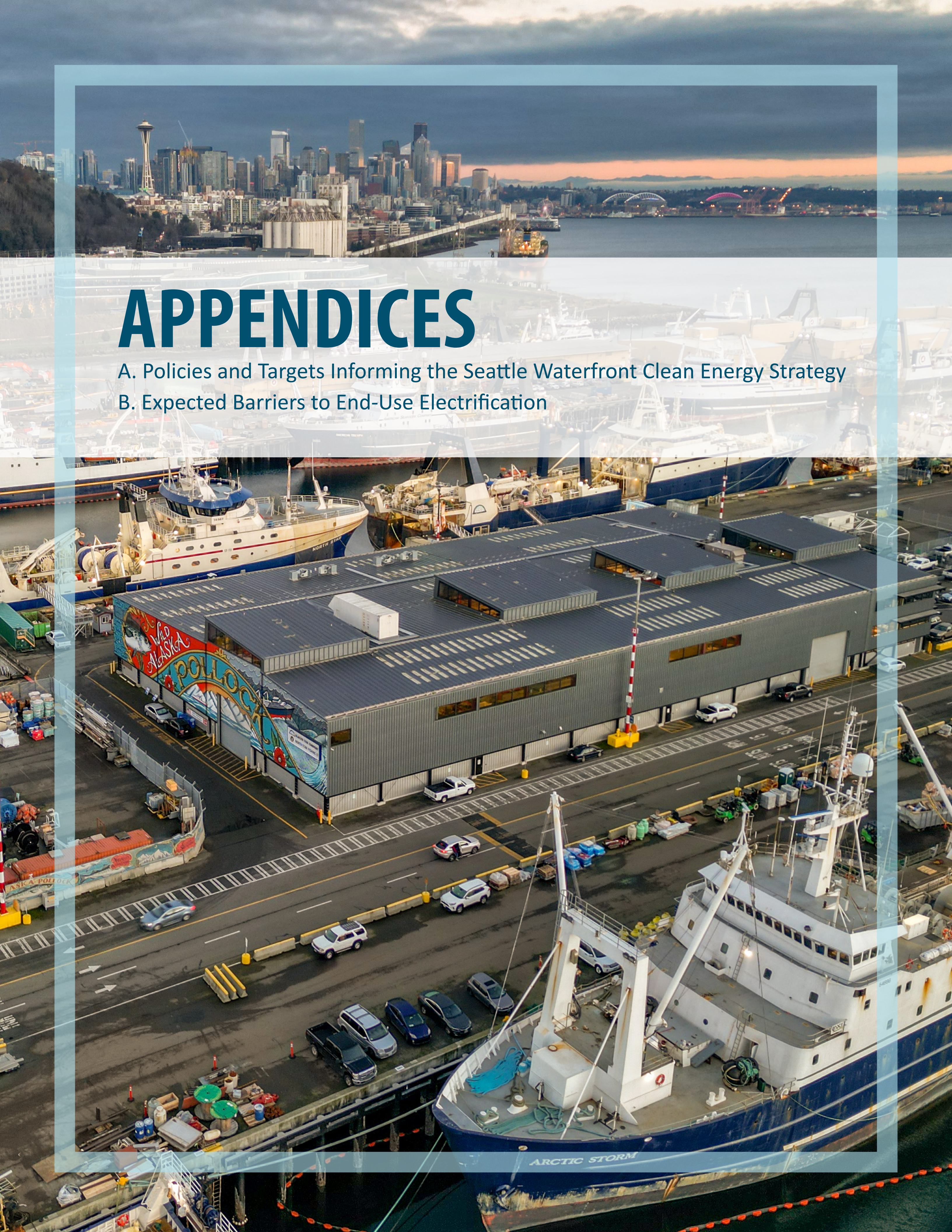
Accordingly, ongoing coordination and effective execution of the SWCES recommendations by the ports and SCL in line with the Partnering Agreement will be critical to ensure the achievement of ambitious emissions, resiliency, and equity targets and meet the new realities of electrified maritime operations, new electrical system configurations, and rapid technology adoption.

[13] The Partnering Agreement covers a 10 year initial term and includes commitments for: joint planning; establishing designated representatives and processes to manage the SWCES strategy development, capital planning and delivery processes; coordinating studies, plans and projects to facilitate integration of the SWCES within broader objectives of the parties; providing for strategic innovative solutions; establishing a framework for ongoing coordination and implementation of capital projects; coordinating communication and engagement with stakeholders; and developing shared funding strategies to support clean energy investments.

APPENDICES

A. Policies and Targets Informing the Seattle Waterfront Clean Energy Strategy

B. Expected Barriers to End-Use Electrification



APPENDIX A: POLICIES AND TARGETS INFORMING THE SEATTLE WATERFRONT CLEAN ENERGY STRATEGY

Washington State

- Washington State Zero Emissions Vehicle (ZEV) Standards: Identifies required EV sales schedule for passenger vehicles and class 2b-8 MD/HD vehicles through 2035.
- Washington State Clean Buildings Performance Standard: Mandated energy performance standards for commercial buildings larger than 50,000 square ft, establishing energy use intensity targets (EUI).

City of Seattle

- Seattle Building Emissions Performance Standards: Draft standards (2022) were included in the forecast, aimed at reducing emissions in large commercial buildings through GHG intensity targets for specific building types aligned with the SWCES forecasting periods.
- City of Seattle Energy Code: Standards applicable to non-residential commercial buildings are integrated in the building energy modeling of the forecast and assume new technology and energy efficiency improvements are incorporated into applicable buildings over the forecast timeframe.

Northwest Ports Clean Air Strategy, NWSA Implementation Plan and Port of Seattle Maritime Climate and Air Action Plan (2021)

Emissions

- Phase-out all emissions (GHG and criteria air pollutants) by 2050
- Zero absolute emissions from building and lighting energy use (Port and tenant facilities) by 2050

Shore Power

- Shore power infrastructure installed at all major cruise and container ship berths by 2030
- Complete design of T18 shore power by 2025
- Within 2 years of shore power infrastructure availability, 50% of shore power capable vessel calls plug-in (80% within 3 years)
- 100% of home port cruise ship calls connect to shore power by 2027[14]

Cargo Handling Equipment

- By 2030, sufficient infrastructure is in place to enable transition to zero-emissions cargo handling equipment
- 100% zero emissions cargo handling equipment by 2050

[14] The Port's target for cruise shore power connections was advanced from 2030 to 2027 with adoption of a Shore Power Order in 2024.

Harbor Vessels

- By 2030, sufficient infrastructure is in place to enable transition to zero emissions harbor vessels
- 100% zero emissions harbor vessels by 2050

Trucks

- 100% zero emissions trucks by 2050
- Infrastructure for zero emissions trucks by 2050

Rail

- Infrastructure for zero emissions on-terminal rail by 2030
- 100% zero emissions switcher engines adopted by 2050

Fleets

- 100% of Port-owned light duty vehicles are electric or use renewable fuels by 2030
- 100% of Port equipment (HD vehicles, equipment and vessels) are zero emissions by 2030
- 100% of Port equipment (HD vehicles, equipment and vessels) are zero emissions by 2050

Buildings

- No fossil natural gas use in Port-owned buildings (eliminate fossil gas use and no new connections) by 2030

Fishing trawlers plugging into shore power at Terminal 91 | May 2022

Port of Seattle Century Agenda

Goal 1 - Position the Puget Sound region as a premier international logistics hub

- Objective 1 - Meet the Puget Sound region's int'l trade and cargo needs in an efficient and sustainable manner
- Objective 2 - Support the continued success and competitiveness of the NWSA

Goal 2 - Advance this region as a leading tourism destination and business gateway

- Objective 3 - Continuously improve the operational efficiency and customer experience at SEA
- Objective 4 -Strengthen the competitiveness of SEA in the regional and global marketplace

Goal 3 - Responsibly Invest in the Economic Growth of the Region and all its communities

- Objective 6 - Increase career and business opportunities for local communities in all port-related industries
- Objective 7 - Advance maritime industries through innovation, strategic investment and capable management of Port facilities
- Objective 8 - Expand the economic, cultural and community benefits of Cruise operations while preserving industrial lands

Goal 4 - Be the greenest and most energy-efficient port in North America

- Objective 9 - Meet all increased energy needs through conservation and renewable sources
- Objective 11 - Reduce air pollutants and carbon emissions

Goal 5 - Become a Model for Equity, Diversity and Inclusion

- Objective 14 - Ensure that all internal and external programs, structures and practices provide equitable opportunities for all

Goal 6 - Be a Highly Effective Public Agency

- Objective 16 - Advance the Port's dedication to employee engagement, safety, innovation, and financial stewardship
- Objective 18 - Partner and engage with external stakeholders to build healthy, safe and equitable communities
- Objective 19 - Set the standard for high-quality, cost-effective, and timely delivery of capital programs

Solar panels on Pier 69 | April 2019

SCL Strategic Plan - Business Strategies[15]

- *Improve the customer experience.* Seattle City Light prioritizes our customers and strives to tailor our services to meet their needs and exceed expectations. We are investing in improvements that will make our services more accessible and provide more options. Whether we're enhancing our programs or introducing new ones, our goal is to better serve our customers.
- *Create our energy future.* The future of energy is arriving ahead of schedule and is dramatically impacting the energy landscape. Disruptive forces have accelerated, and we must be prepared to address climate change, a shift from using fossil fuels to clean electricity, and an increase in electricity demand from electric vehicles and building standards. These changes impact our infrastructure from generation to how we connect to your home or business. We are improving our systems and infrastructure to meet our capacity needs now and in the future.
- *Develop workforce and organizational agility.* As our industry and customers rapidly change, we must invest in our people and processes to enable them to respond, adapt, and thrive. We are creating a flexible and responsive organization by focusing on change management, training, and new technology. Our efforts aim to attract, train, and keep talented staff. We want to see higher employee engagement, more career opportunities, and staffing that supports our organizational priorities.
- *Ensure financial health and affordability.* Financial stability is crucial to our future. It allows us to create innovative energy solutions, invest in critical infrastructure, and keep our rates affordable. We are committed to setting rates in a way that is sustainable and predictable over time.
- *We Power.* "We Power" refers to our core mission as a utility — to provide affordable, reliable, and environmentally responsible energy services to our customers. This drives everything we do, and our values guide us in achieving this goal. Our commitment to our core business operations and delivering value to our customers includes: providing the energy services our customers need by taking care of our key assets and infrastructure; prioritizing diversity, equity, and inclusion; and managing and mitigating the challenges, risks, and uncertainties of a changing world.

SCL Mission and Values (multiple documents)

- *Environmental Stewardship*: We care about the environment, and we are dedicated to enhancing, protecting and preserving it for future generations
- *Equitable Community Connections:* We are visible and actively involved in the communities we serve. We are rooted in our commitment to racial diversity, social justice and the equitable provision of services to all.
- *Operational and Financial Excellence:* We prioritize our investments and operating choices to build upon our strong financial foundation and solid, reliable infrastructure.

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15 Strategic Plan and Review Panel - City Light | seattle.gov

APPENDIX B: EXPECTED BARRIERS TO END-USE ELECTRIFICATION

The following table provides a high-level summary of expected barriers to electrification specific to current port conditions. This looks at each category of end-use equipment, summarizing technology barriers (including technology readiness, and operational limitations) and electrical infrastructure constraints identified in the SWCES. Recommendations to support deployment are provided.

End-Use	Technology Barriers	Electrical Infrastructure Constraints	Recommendation
Buildings	**Low**; building electrification technologies are mature and implementation has already begun and is being planned at Port properties. Building energy use at most Port properties is mostly electric.	**Low**; most natural gas use is concentrated at Pier 66, Terminal 18, Terminal 115, Fishermen's Terminal, and Terminal 91. Conversion from natural gas to electricity will increase peak demands, which will be more significant on building-dominated sites such as Pier 66, requiring on-terminal electrical upgrades.	• Buildings are not a major contributor to overall port load growth. Continue to evaluate opportunities to increase efficiency and reduce overall site loads. Solar PV should be assessed, prioritized, and implemented. Where cost-effective, efficiency is a no-regrets measure that will help reduce overall loads.
Shore Power	**Low**; shore power technology is mature and has already been installed at several port properties.	**High**; increased use of shore power and additions at cargo and near port locations (USCG), are the largest drivers of load increases in the near-term, and contribute to overload conditions in the southern portion of Elliott Bay in particular.	• Monitor shore power data at Terminal 5 to refine forecasts and design for T18, T30, and T46. • Continue to monitor developments for the USCG site and adjust load forecasts as appropriate.
Cargo Handling Equipment (CHE)	**High;** although certain types of electric CHE such as yard trucks are widely available, many types are still being evaluated. Deployment of hydrogen fuel cell CHE at scale will require hydrogen supply and fueling infrastructure, which is anticipated, but 3-5 years away.	**High;** electrification of CHE is expected to result in significant load growth, surpassing shore power as the largest demand at cargo terminals. CHE will contribute to overload conditions at multiple sites.	• Work with marine terminal operators to sponsor grant applications to reduce costs of CHE deployment. • Coordinate early planning for siting of charging infrastructure on terminal to identify barriers and reduce deployment delays.
EV Charging (fleet, public, and ground transport)	**Low;** EV technology is mature for most types of passenger fleet vehicles and options are emerging for medium- and heavy-duty weight classes. Port fleet assets are being replaced with EVs at retirement. EV charging equipment may present siting and space challenges.	**Medium;** while EV charging demands are currently small relative to other use categories, the rapid growth in this category over time will result in overload conditions. Locating fleet and public EV infrastructure is also expected to be challenging.	• Consider managed charging, off-peak charging, and batteries to reduce coincidence of EV charging and other loads (e.g., CHE charging, shore power).
Harbor Vessels	**High;** full electrification is currently only suitable for a subset of harbor vessels, and all-electric or hybrid electric tugs have not been deployed in Puget Sound. Technological fit and readiness, high capital costs, and regulatory uncertainty are key challenges.	**High;** charging for harbor vessels represents the second-largest contributor to peak demand after shore power. Harbor vessel electrification at Port and Near-port sites will drive the need for significant electrical infrastructure upgrades (Terminal 46 North, Pier 16-17).	• Consider support for early deployments of electric and hybrid electric harbor vessels to demonstrate feasibility in Puget Sound operating conditions. • Shared-use charging infrastructure on Port-owned properties may facilitate deployment multiple vessels.

			• Work with harbor vessel operators to sponsor grant applications to reduce risk of deployment.
Refrigeration plugs (eTRUs)	**Low;** reefer plugs are technologically mature and available at Port terminals.	**Low;** reefer plug loads are expected to increase over time in alignment with growth in cargo activity. Increases are anticipated to be limited relative to CHE electrification.	• As heat pump technology improves, applications in TRUs should continue to be tracked and loads monitored. Importantly, TRUs are also a driver of cargo shore power loads.
Truck and Motorcoach Charging	**High;** zero-emission trucks and motorcoaches are currently at a significant cost premium relative to conventional vehicles, and operational characteristics such as range, duty cycles and a lack of available space for charging on terminals may further impede deployment.	**High;** the spot load sites that have been identified as prospective truck charging locations (Harbor Island Right-of-way, West Marginal Way, and Terminal 25) are expected to experience overload conditions or are in need of upgrades. Capital costs for necessary upgrades will depend on the design of the facilities and extent of opportunity versus extended charging.	• Continue to leverage private sector interest and investment in truck deployment models and charging infrastructure. • Evaluate Port-owned properties as opportunities to reduce barriers to entry and initiate market transformation activities. • Consider innovative business models such as trucking as a service and charging as a service with any deployment of charging infrastructure on Port-owned properties. • Evaluate motorcoaches charging needs for maritime and aviation sites, consider charging site design capability at HD truck locations.
Ship-to-Shore Cranes (STS)	**Low;** electric STS crane technology is already widely available. All STS cranes operating at the Port are electric.	**Low;** Port terminals are already equipped with STS cranes and additional deployments are expected to occur gradually.	• Consider demonstration and deployment of capacitors, flywheels and other technologies to alleviate peak loads.
Rail	**Medium;** zero-emission switcher locomotives are not widely used but have recently become commercially available with deployments in WA. Significant cost premium vs diesel-fueled locomotives. Long asset life means opportunities for adoption of new technologies are limited / infrequent.	**Low;** no on-terminal capacity constraints were identified for Terminal 86. Constraints on the SCL feeder are primarily driven by Terminal 91 load growth but can be alleviated by feeder upgrades in the near-term.	• The switcher locomotive at T86 is planned to be replaced with a Tier 4 locomotive, which will reduce GHG emissions by over 70% and criteria air pollutants by over 90%. • Encourage use of renewable diesel to further reduce lifecycle GHG emissions. • In the long-term, work with tenant to replace with all-electric once technology has been widely deployed.

Table Legend	
(green)	**Low barriers to deployment:** Full implementation is planned and/or expected to be achievable in the near-term with current technology, and current or planned infrastructure upgrades are sufficient to support electrification.
(yellow)	**Medium barriers to deployment:** Full implementation will require minor to moderate levels of technological advancement and/or moderate levels of Port or utility infrastructure investment.
(orange)	**High barriers to deployment:** Full implementation will require high levels of technological advancement and/or high levels of infrastructure investment. Other barriers exist (siting, regulatory uncertainty, lack of business models, etc.)