Washington State Ferries

System Electrification Plan

WSDOT Washington State Ferries

December 2020

Table of Contents

Appendices

WSF System Electrification Plan

Executive Summary

Washington State Ferries (WSF) is undertaking an ambitious initiative to electrify their system with plug-in hybrid-electric vessels and terminal enhancements to achieve reduced environmental impact and energy costs. As the largest ferry system in the U.S.—carrying nearly 25 million people each year on 10 routes—WSF is leading the way in the marine industry by outlining and acting on a plan that will allow substantial emissions reductions that exceed the requirements of Executive Order 20-01 and the Revised Code of Washington. As the largest single consumer of diesel fuel in the State Government, implementation of this System Electrification Plan is vital for Washington State to lead by example to address climate change. The benefits of system electrification extend beyond the government, ferry system, and ferry riders by improving air quality in the Puget Sound region and contributing to the significant greenhouse gas reductions required globally to support a sustainable future.

System electrification planning approach

This System Electrification Plan (SEP) provides high-level feasibility and guiding requirements through a 20-year planning horizon. Planning-level considerations and costs are outlined for capital improvements and operating elements, including workforce training and energy costs. Environmental benefits are identified in terms of emissions reductions and the monetized value of those reductions.

The Plan	Capital improvements	Operating elements	Implement & invest

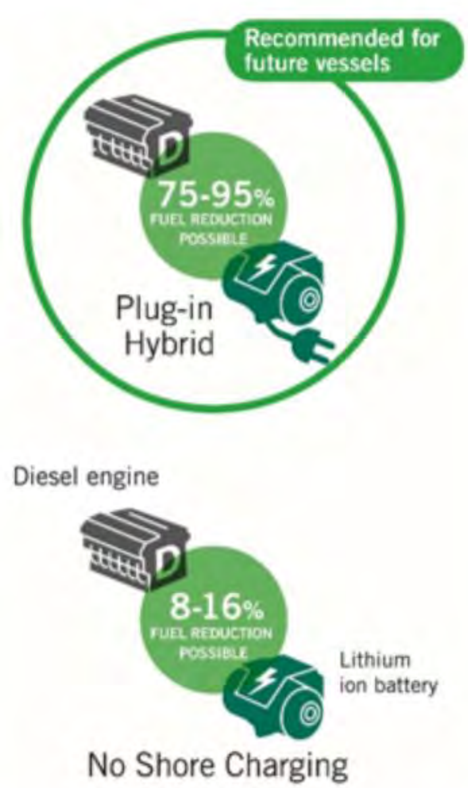
The SEP builds on WSF's 2040 Long Range Plan (LRP), which calls for fleet stabilization by delivering 16 new vessels to replace aging vessels and retrofitting six (6) existing vessels. Many interrelated factors were considered to define vessel and terminal functional requirements and will need to be further refined as the future hybrid-electric vessel designs are developed. The goal of system electrification is to maximize emission reductions with the least impact to service while being as financially efficient as possible. The plan was developed with the best available information, but hybrid propulsion technology is continually improving and will allow for greater opportunities during implementation. Current service levels and schedules are assumed to be maintained for the analysis, but thoughtful schedule and operational improvements can present additional opportunities to achieve even greater emission reductions. The planning factors presented are a starting point for implementation and will be refined with each vessel and terminal engineering project over the next two decades.

Meeting emission reduction regulations

The opportunity for emissions reduction is great: the current WSF fleet of 21 vessels is the largest single consumer of diesel fuel within the State Government, with many older, diesel vessels due for replacement in the near future.

In general, nearly every route within the WSF system can be served by a hybrid-electric vessel. The extent to which each vessel can maximize the advantage of its electric propulsion technology depends on a variety of elements, such as route length, vessel size and weight, amount of time spent at the dock to charge the vessel, and power availability at the terminal.

Converting to a hybrid-electric propulsion fleet also takes advantage of Puget Sound's clean power sources including hydro-electric, wind and solar. Development of this Plan included analysis of greenhouse gas and toxic pollutant emissions for two scenarios, elaborated below:



1—with shore charging: charging infrastructure is installed at the terminals to support a fleet of plug-in hybrid vessels.

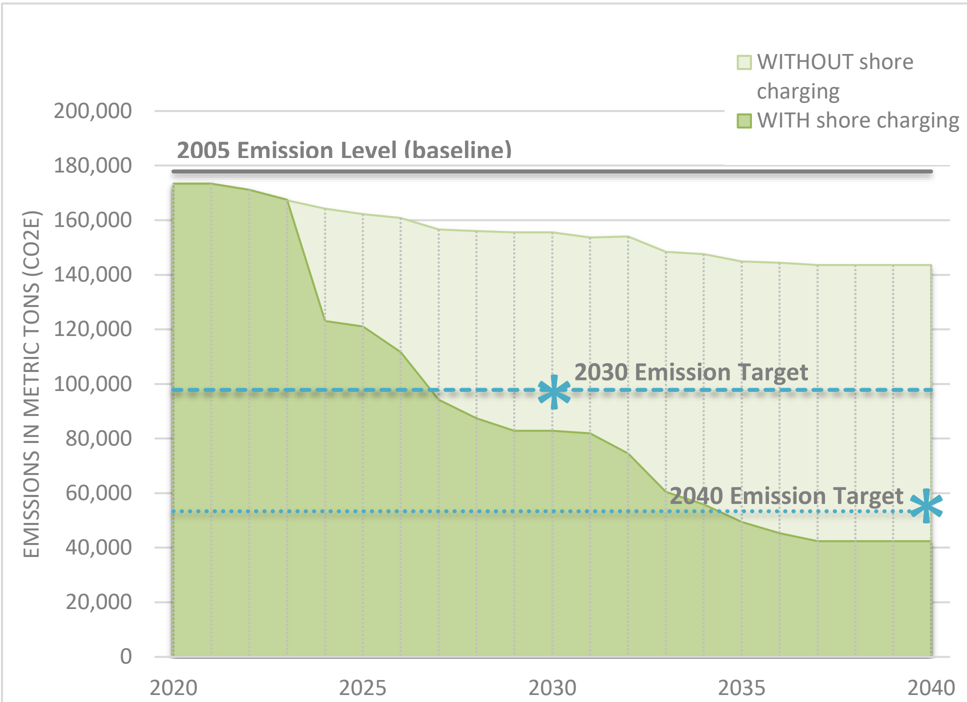
2—without shore charging: charging infrastructure is not installed at the terminals to enable the use of plug-in hybrid vessels, also referred to as "no shore charging".

Each WSF hybrid-electric vessel will still include at least one diesel generator on-board for system redundancy and operational flexibility.

The with shore charging scenario meets and exceeds the required emissions reduction in the planning horizon through investments in terminals, vessels and the workforce. Reductions of 53% greenhouse gas emissions (CO_2e) by 2030, and 76% by 2040, from baseline 2005 emissions levels are estimated. This exceeds the requirements of RCW 70A.45.050 of 45% reductions by 2030 and 70% by 2040.

The "no shore charging" scenario does not meet required emissions reductions.

Emission reduction estimates by scenario



53%
decrease in (CO_2e) by 2030 with shore charging

76%
decrease in (CO_2e) by 2040 with shore charging

59%
decrease in toxic pollutant emissions by 2040 with shore charging

While the complete conversion to a hybrid-electric fleet will take some time, the benefits will be seen almost immediately with the planned retrofit and upgrade of the Jumbo Mark II Class vessels, the largest source of emissions in the fleet, and a 27% fleet-wide emissions reduction from 2023 to 2025.

Electrification implementation schedule

The vision for the 2040 fleet, as identified in the Long Range Plan, is a fleet of 26 vessels, 22 of which are plug-in hybrid-electric vessels. This includes 16 new vessel builds and six (6) existing vessel conversions.

To meet the emissions reduction goals outlined in RCW 70A.45.050, this plan recommends electrification of every domestic route with further study required for the San Juan Island routes.

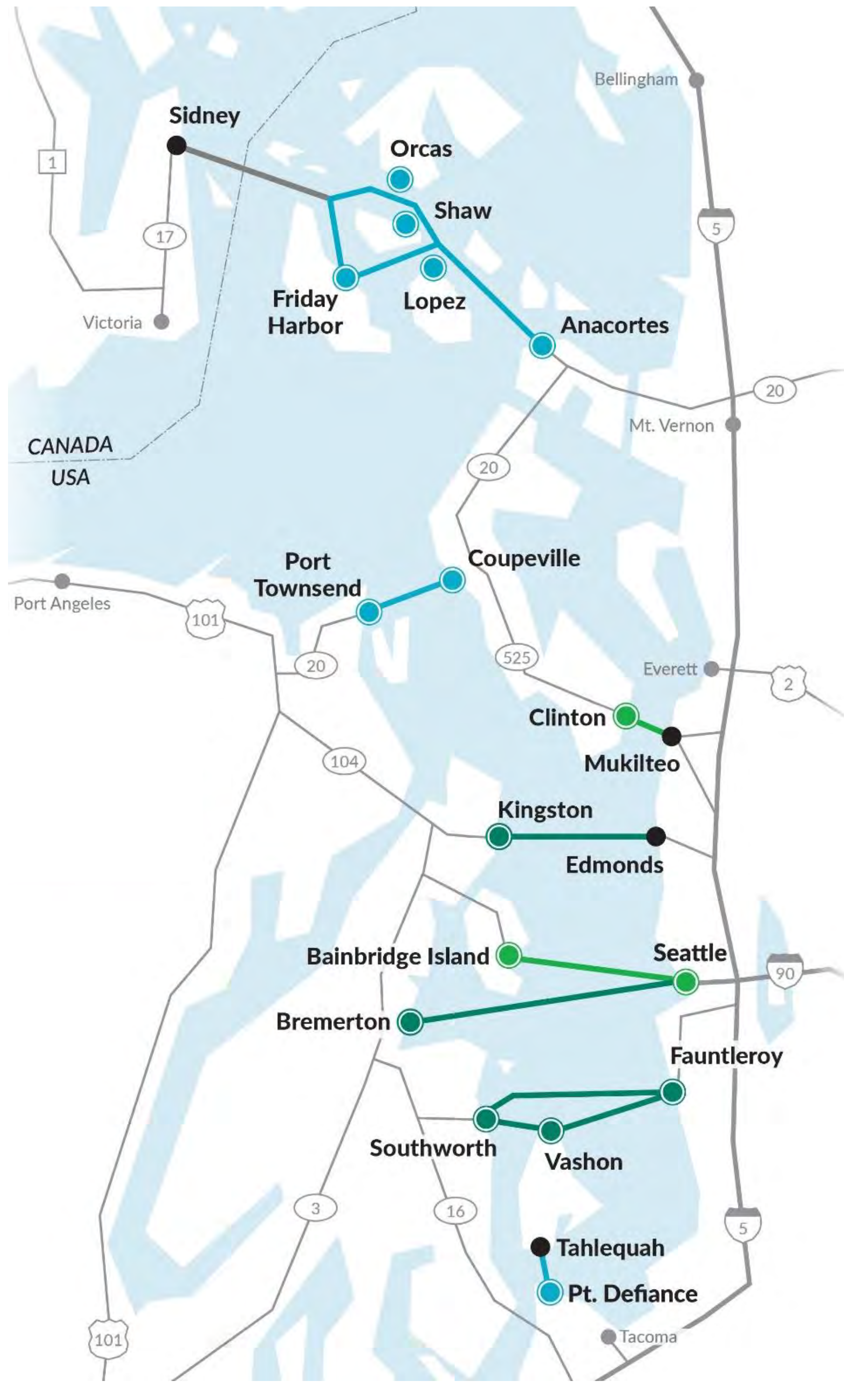
This includes the electrification of 16 terminals. Electrification of the San Juan Islands are programmed later in the planning timeframe in the anticipation that technological advancements and lessons learned from simpler route configurations will make electric operations in the islands more successful.

For planning purposes, timeframes have been grouped into the following terms:

- Near Term (0-5 years)
- Medium Term (5-10 years)
- Long Term (10-20 years)

The map identifies when terminal improvements to deliver power would be made and a vessel conversion or construction would be delivered to enable plug-in hybrid-electric route operations. This identifies when diesel fuel consumption and resulting emissions outputs will be at their lowest.

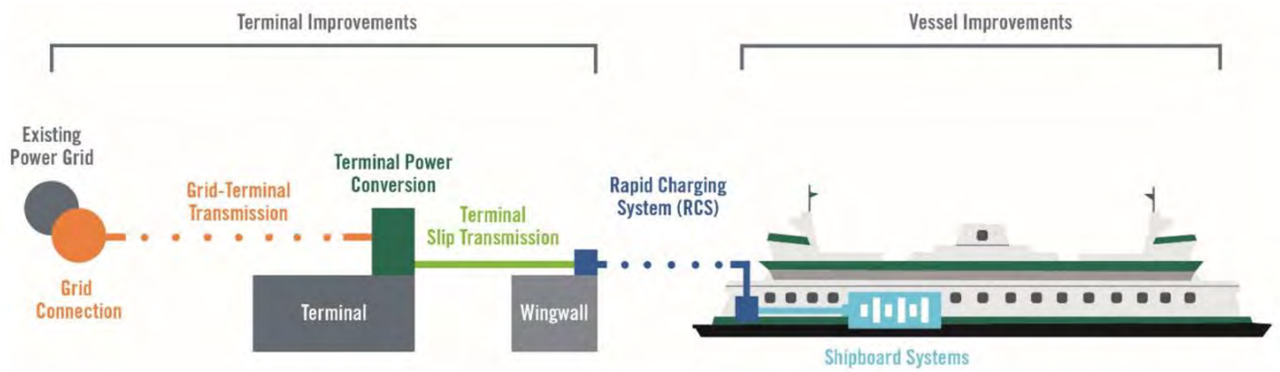
System Electrification Plan by Timeframe



Note: This improvement schedule has been developed with the best information available during the SEP coordination, however there is a strong potential for continued delivery timeline adjustment especially in the near and medium terms.

Electrification infrastructure elements

The system electrification components include elements on the vessel that connect to terminal power supply through a Rapid Charging System (RCS). On the vessels themselves, energy will transition from being supplied by diesel to stored onboard in batteries. The batteries are charged from shore via the RCS, with occasional support by the onboard backup generator. The RCS consists of a mechanical arm located on the vessel that interfaces with the power delivery system on the wingwall of the terminal. A wingwall is the landing element that helps guide and keep the vessel in place once docked at the terminal. In some cases, energy storage capacity is also required at the terminals themselves, which has a space requirement that can present challenges at already constrained terminals.



Graphic depiction of electrification system elements

The SEP reviewed each WSF route in detail to develop recommendations for if, how, and when a route should be electrified.

Route specific SEP assessment:

- Estimated power and energy needs to make a sailing (crossing energy)
- Recommended dwell time (time at the terminal for loading and unloading) and charging rates
- Possibility of one-sided charging vs two-sided charging (where applicable)
- Estimated utility costs by terminal (if available)
- Terminal layout and footprint at near-term terminal electrification projects to inform space availability and feasibility of incorporating charging infrastructure

Additional SEP analysis:

- Vessel assignment, procurement schedule and terminal improvement over the 20-year LRP time horizon
- Understanding of high-level workforce duties and training needs associated with the electrification plan
- Capital and operating costs of implementing the plan over the 20-year LRP time horizon

Overseeing a long-term, phased program

6 existing vessel conversions

16 new hybrid-electric vessels

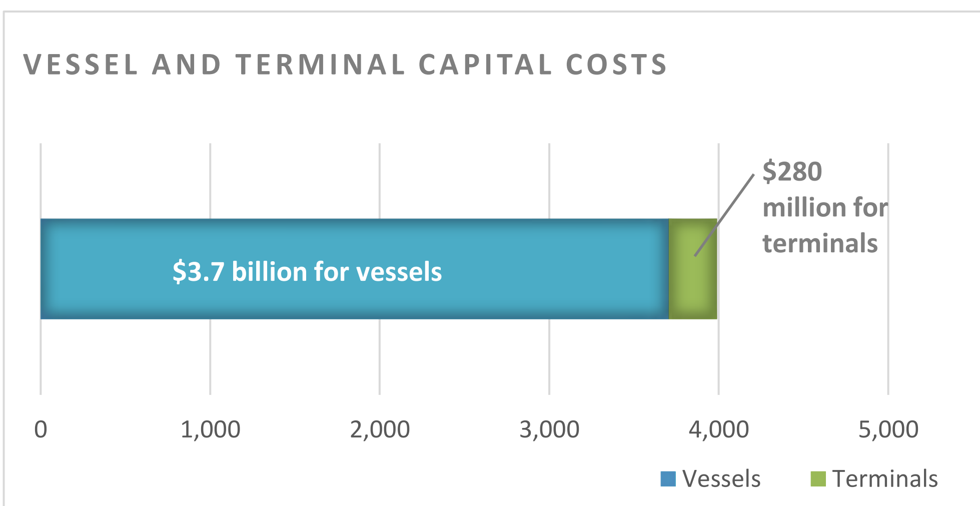
17 terminal electrification projects

Electrification of the WSF system will require a phased approach and coordinated effort from all departments. This effort will require capital improvements in terminals and vessels, as well as training efforts for changing workforce duties related to service operations and maintenance. The implementation of this effort will span approximately 20 years, with planning, design, construction and delivery of vessels and terminal improvements.

WSF must staff for both the initial design and construction phases of new technology and invest resources in training both WSF and local fire service employees while maintaining communication and education to riders and surrounding communities. It is a major, long term, multi-dimensional undertaking that will place new and evolving demands on the workforce. A construction initiative of this complexity with numerous integrated projects requires a centralized project management strategy. This is best accomplished with a designated overall program manager accountable to executive management and supported by assistant program managers for vessel and terminal engineering.

Investments in infrastructure and training

Planned capital investments have a large price tag and address challenges beyond reducing emissions, particularly for vessels where timely replacement and fleet expansion is a cornerstone of the LRP and WSF's future success. The new vessel construction program will stabilize the fleet and build a solid foundation for reliable service with adequate time for vessel maintenance. The ideal time to adopt hybrid propulsion is when a new vessel is being built or during major vessel preservation activities. The additional cost of electrification is a relatively small part of the total cost of construction. For terminals, the electrification cost is a notable investment and where possible is aligned with planned preservation and improvement projects.



Total capital investments ($ in millions) through 2040

Vessels

WSF has an ongoing heavy load of infrastructure investment to replace its aging fleet to maintain system reliability. Electrifying these needed vessels presents an added cost *and* opportunity for reduced emissions and fuel consumption. For each new vessel added to the fleet, WSF has estimated the additional cost for electrification is approximately $14 million. This represents approximately 6.5% of the estimated total vessel investment called for in the LRP and updated for the SEP at $3.7 billion. The **near-term** vessel electrification capital improvements are:

- **Hybridization of the Jumbo Mark II vessels**—this effort will reduce fleet-wide emissions by 27% once shore charging is available.
- Extension of the Olympic Class vessel construction contract for **five new hybrid-electric vessels**—this effort will provide the next largest increment in realizing the overall system electrification benefits.

Medium and long-term vessel electrification capital improvements include four new 124-Car Class vessels and delivery of three Kwa-di-Tabil conversions and seven new 144-Car Class vessels.

Terminals

To fully realize and meet the emission reduction targets, terminal charging infrastructure must be in place. This terminal improvement is required at nearly every terminal, representing $280 million of total capital investment over the 20-year planning period. Energy storage systems (ESS) are anticipated at four terminals: Clinton, Kingston, Bremerton, and Seattle. The ESS is needed when grid capacity cannot meet the charging demand directly.

Operational investments

Electrification of the system will impact the duties of various day-to-day functions of many WSF departments. Because much of the technology and electrical systems are new and unique to WSF, it is anticipated there will be a learning curve in their use. The workforce will need to be trained in the new systems while also retaining the skillsets to operate the existing diesel systems. While additional training and changed duties will be required, the number of employees on the vessel is not anticipated to change.

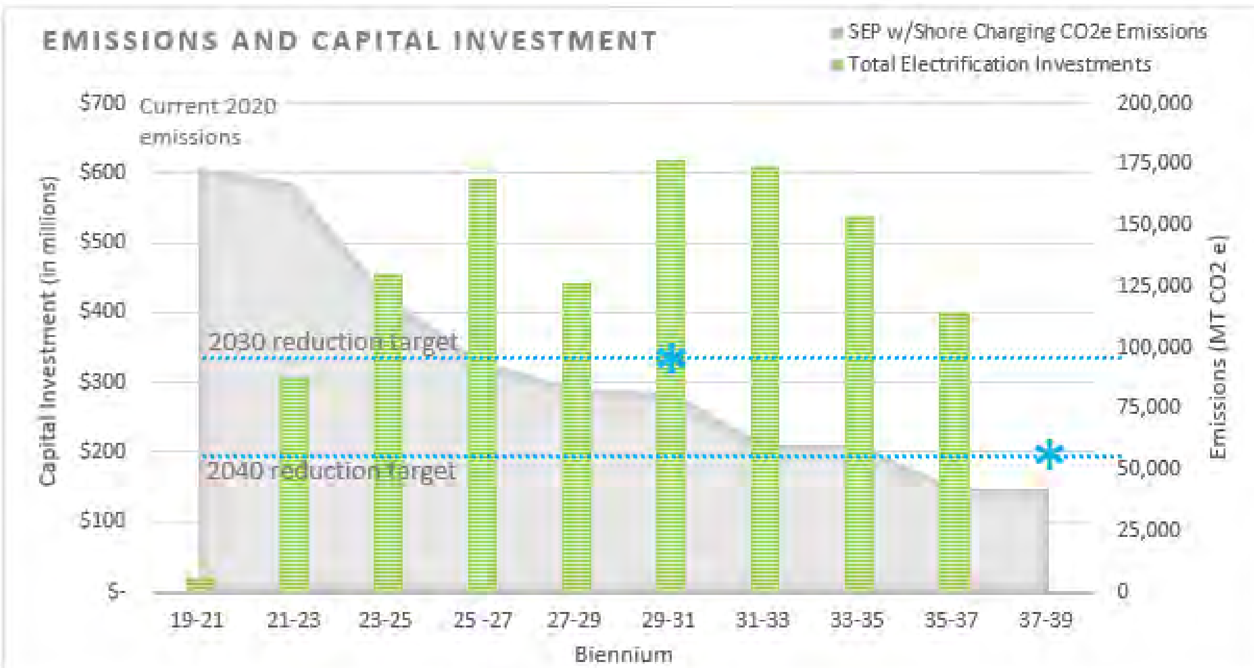
Additional staff is anticipated for maintenance with the introduction of new systems. The length of the implementation phase, approximately 20 years, results in a mixed fleet configuration, with some existing diesel vessels and new hybrid-electric vessels. This dynamic fleet mix will require expertise for operations and maintenance of the traditional diesel vessels, as well as the addition of new knowledge to build, operate and maintain the hybrid-electric vessels. Therefore, new workforce functions to facilitate the management of the electrification program and necessary training will be required right away.

Outcomes of investment

Emissions reduction

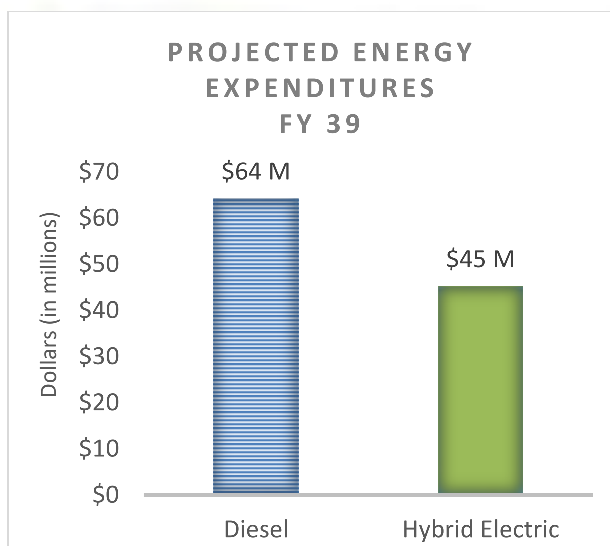
The investments called for in this Plan will result in great societal benefits with estimated annual carbon emission reductions of nearly 180,000 metric tons. Air quality will improve for those who work on and ride the vessels and residents and visitors of the greater Puget Sound region. The monetized value of these emission reductions–the social cost of carbon emissions that will be alleviated–is nearly $12 million per year. Further, this investment in electric vessels reduces reliance on fossil fuels and volatile diesel costs.

Emission reductions and capital investment by biennium



Reduced fuel consumption

The most profound change to WSF operating expenditures occurs as reliance on diesel propulsion is replaced by hybrid-electric propulsion. Current energy costs account for approximately 14% of WSF's annual operating costs. Energy expenditures of WSF's fully electrified system in fiscal year (FY) 2039 will be 30% lower than they would be with diesel propulsion.



Annual fuel cost savings in FY39

Conclusions and Areas for Further Study

System electrification is an ambitious plan to deliver 16 new vessels, six (6) diesel conversions and 17 terminal electrification projects with the opportunity for dramatic emissions reductions and to exercise leadership within the greater maritime industry. Investments in the fleet are already necessary to replace aging vessels to build and maintain system reliability and resiliency. New vessel delivery brings opportunities to adopt new technology and more efficient systems which are the only way to achieve the emission reductions required by Executive Order 20-01. This investment in infrastructure will improve the overall air quality and health of people living in our region, state, and world and save energy costs over time. This undertaking will require investment in the management of the program itself, training the workforce and informing the public on the technology and associated environmental benefits.

More detailed planning is also recommended by the System Electrification Plan to inform the longer-term implementation. In the near term, the following studies are anticipated:

Vessel focused

- **124-Car Class – Triangle Route Study** to assess two vs. three-sided charging on the route.
- **Kwa-di Tabil (KDT) Hybridization and Maneuvering Study** to understand and improve upon maneuverability of the Class during hybridization, which will add weight (and therefore draft) to the vessel. The KDT Class vessel is the only vessel in the fleet that can serve the Coupeville terminal due to its tidal conditions and resulting shallow water approach.
- **San Juan Islands Electrification Study** to assess financial feasibility and determine strategic improvements to provide electric charging at terminals in the San Juan Islands. Findings will inform design of the new 144-Car Vessel Class.
- **Vessel pre-design studies** to finalize route specific requirements for electrification, including crossing energies, passenger and vehicle capacities and vessel dwell time.

Terminal focused

- **Seattle Terminal Space Planning Study** to assess siting options for terminal charging equipment, battery storage and transmission routing through the terminal.
- **Terminal pre-design studies** to address site/route specific requirements for electrification, including:
  - Power Demands
  - Utility Coordination
  - Equipment Siting Constraint

Section 1:

Introduction and Background

Washington State Ferries (WSF) is undertaking an initiative to electrify their fleet to reduce environmental impact and energy costs. Marine electric propulsion systems are a rapidly evolving technology that have been employed in various passenger and ferry vessel services around the world. As the largest ferry system in the U.S.—carrying nearly 25 million people each year over 10 routes—WSF is leading the way with the implementation of this technology on large ferries serving both vehicles and passengers on its diverse system.

As a division of Washington State Department of Transportation (WSDOT), WSF has shared an increased emphasis on sustainable transportation in recent years. In 2018 Governor Jay Inslee signed Executive Order 18-01[1], directing WSF to begin the transition to a battery-electric ferry fleet. The opportunity for emissions reduction is great, as the current fleet is the single largest consumer of diesel fuel in the State Government and converting to hybrid-electric propulsion takes advantage of Puget Sound's clean hydro-electric energy sources. This conversion provides an opportunity for environmental benefits that extend beyond WSF customers.

Electrification of the WSF system will require a phased approach and coordinated effort from all departments. Planning must also incorporate other WSF goals, such as maintaining service reliability and strengthening and supporting the workforce that keeps the service running. This System Electrification Plan (SEP) provides high-level guidance and implementation planning towards the electrification of the system through a 20-year planning horizon.

Purpose

The objective of the SEP is to determine feasibility and identify guiding requirements for vessel and terminal improvements, along with timelines and schedules for fleet-wide electrification. This includes capital investments in terminal and vessel infrastructure, training and workforce needs, and future studies to support the implementation and continuous evolution of this Plan over the next two decades.

The WSF system is complex, with each route having unique operating needs. The SEP must account for the diversity of the fleet and terminal characteristics. This document serves as guidance for implementation and further planning efforts to realize full system electrification—providing key information to decision-makers about the opportunities, challenges, costs, and benefits of system electrification.

Service reliability and emergency response capability are priorities for WSF. To support these goals, the Plan builds around current service levels and retains the option of back-up diesel generators. This assumption allows flexible operation to meet service needs and maintain

[1] Executive Order 18-01 has been superseded by Executive Order 20-01.

WSF's emergency response capability.

Previous planning efforts

The SEP builds upon the 2040 Long Range Plan. Released in January 2019, the 2040 Long Range Plan (LRP) considered WSF's future over a 20-year planning horizon and identified vessel, terminal, and operating requirements to maintain or improve current service levels. System electrification was a key recommendation of the LRP, providing an opportunity to reduce emissions and lower operating costs. The LRP financial models were built upon high-level assumptions available at the time.

Recommendations from the LRP related to system electrification include:

- Terminal electrification at most WSF terminals
- Procurement of 16 new hybrid-electric vessels to replace retiring vessels and support maintenance needs
- Extension of the Olympic Class vessel construction contract for five new hybrid-electric vessels
- Hybridization of the Jumbo Mark II vessels to align with the propulsion control system upgrade schedule
- Streamlining the fleet composition to realize enhanced efficiency and redundancy

The recommendations to extend the Olympic Class vessel construction contract and hybridize the Jumbo Mark II Class required rapid action from WSF to meet the desired timeline. This resulted in a Jumbo Mark II hybrid-electric conversion study, an Olympic Class hybridization feasibility study, and life-cycle cost analysis for several routes.

Electrify the fleet

The following implementation elements from the 2040 Long Range Plan Sustainability component include:

> "WSF will electrify all terminals to serve electric-hybrid vessels, with the exceptions of Shaw and Lopez Islands and Sidney, BC."

> "This investment will bring down fuel consumption and therefore reduce carbon emissions significantly over the 20-year planning horizon."

2040 Long Range Plan

Electrification Planning Overview

The SEP provides an opportunity to dig deeper into the opportunities and constraints, and the financial and workforce needs, to plan, build, train, operate, and maintain an electrified fleet through project start-up and ongoing implementation.

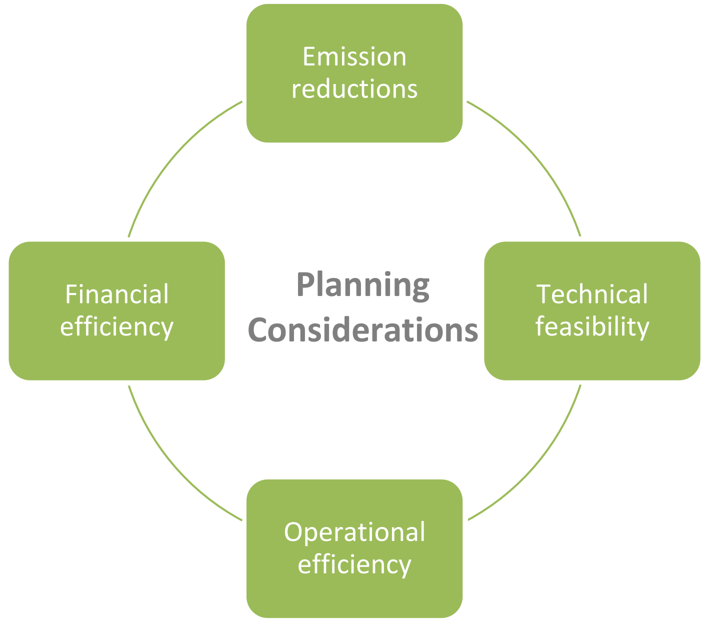


Figure 1: SEP Planning Considerations

Many interrelated factors were considered to define preliminary vessel functional requirements and will need to be further refined as future hybrid-electric vessel designs are developed. The goals of vessel design are to maximize the benefits of fleet electrification with the least impact to service while being as financially efficient as possible. This relationship of planning elements for considerations can be shown in Figure 1.

Many electric vessels currently provide ferry service around the world. The current state of battery technology makes electric propulsion more beneficial for shorter routes and smaller vessels. To apply available technology to WSF's larger vessels and longer routes, vessel design and system performance expectations require a holistic approach.

As the electrification plan is implemented, there is a need to balance the opportunities and challenges associated with rapid charging of very high-capacity batteries and the goal of maximizing carbon reduction benefits while minimizing capital and operating costs.

Route suitability for hybrid-electric propulsion

In general, nearly every route within the WSF system can be served by a hybrid-electric vessel. The extent to which that vessel can take advantage of its electric propulsion technology depends on a variety of elements, such as route length, vessel size and weight, amount of time spent at the dock to charge the vessel, and power availability at the terminal.

The SEP reviewed each WSF route in detail to develop recommendations for if, how, and when a route should be electrified. There were many trade-off decisions that were identified and considered for each route to balance the competing priorities of cost effectiveness, emission reductions, and schedule and service.

For each route, the SEP identified the following:

- Estimated power and energy needs to make a sailing (crossing energy)
- Recommended dwell time (time at the terminal for loading and unloading) and charging rates. This was based on historical dwell time records and that impact on required charging rates
- Utility provider at each WSF terminal, and the availability and potential costs for energy from that provider (if available)
- Terminal layout and footprint at near-term terminal electrification projects to inform space availability and feasibility of incorporating charging infrastructure
- Opportunities for one-sided (one terminal on a route) vs two-sided (both terminals on a route) charging

Additional SEP analysis included:

- Vessel assignment, procurement schedule and terminal improvement schedule over the 20-year LRP time horizon
- Understanding of high-level workforce duties and training needs associated with the development and implementation of system electrification
- Capital and operating costs of implementing the Plan over the 20-year LRP time horizon

Plan Organization

This Plan is organized by the essential elements required to move system electrification forward and is informed by more detailed technical memos, which can be found in the appendices. This document is a summary, organized for clarity to provide a high-level understanding of the supporting technical analysis. As represented in Figure 2, the document is organized in four sections: The Plan itself (what is to be done and when), Capital Improvements (physical infrastructure needed), Operating Elements (service support functions), and Implement & Invest (what is needed to move the plan forward).

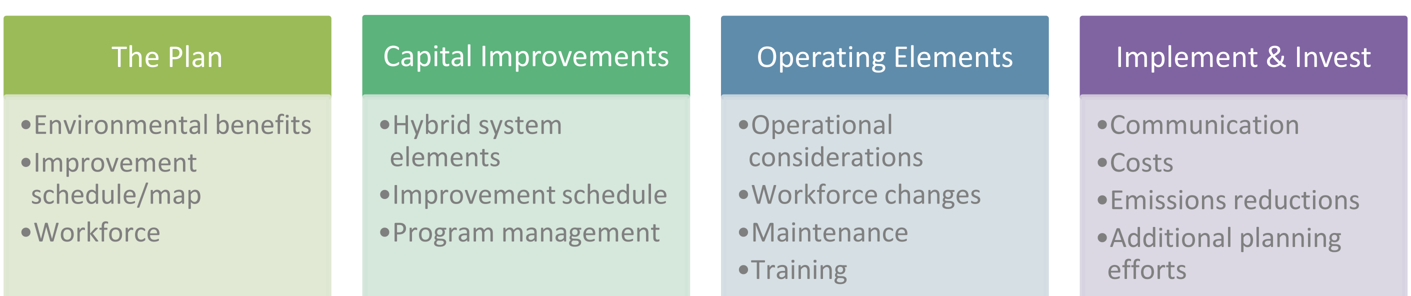


Figure 2: System Electrification Plan Overview

Section 2:

The Plan

WSF recently completed an extensive long-range planning exercise that identifies the need to replace and add to the current fleet of vessels. The result of that effort, the 2040 Long Range Plan, calls for these new vessels to be designed with hybrid-electric propulsion systems, substantially reducing the carbon emissions produced by the system in efforts to meet State emissions reduction requirements and visions for a greener fleet. Alternative power technology systems have been rapidly evolving over the last decade, with leaps made nearly every year. WSF has been tracking this evolving field and identifying opportunities to apply tested technology in the diverse WSF system.

This SEP provides the groundwork for this forward momentum, however there will be ongoing planning work that will continue—both in terms of the hybrid-electric technology, but also new vessel and terminal design. There are also features outside of the propulsion system that reduce impacts to the environment and contribute to safe, efficient and reliable operations.

Table 1: Planned fleet composition through 2040

	2020	2030	2040
Hybrid-electric	0	11	22
Diesel	21	14	4
Total Fleet Size	21	25	26

Environmental Benefits

New vessels provide the opportunity for multiple new systems that will contribute to an overall more energy-efficient and environmentally friendly vessel. The environmental benefits of fleet electrification will extend

Sustainability goals from the 2040 Long Range Plan

- **Invest in electric-hybrid propulsion and terminal electrification infrastructure:**

  Invest in converting six existing diesel propulsion vessels to electric-hybrid, and design new vessels to use electric-hybrid propulsion with shoreside charging in order to achieve a significant reduction in fleet emissions.

- **Reduce vessel noise:**

  Pursue materials and methods to maximize energy efficiency and provide opportunities for quieter operations to protect marine life.

- **Plan a vessel design charrette:**

  Convene different disciplines and technical experts for a vessel design charrette prior to design and construction to ensure they have evaluated all components of future vessels and their systems for minimizing environmental effects.

Greenhouse gas emissions reduction requirements

The Revised Code of Washington (RCW 70A.45.050) sets greenhouse gas reporting and reduction requirements for state agencies in Washington. WSDOT reports emissions to the Department of Ecology.

As a part of WSDOT, WSF is required to reduce agency emissions by set levels at target years.

CO_2e REDUCTION TARGETS*:

↓ 45% by 2030

↓ 70% by 2040

↓ 95% by 2050

** All reductions calculated from a 2005 emission level baseline*

beyond WSF and its users and positively impact both the population and environment of the Puget Sound.

Carbon emission reduction

WSF is the largest consumer of diesel fuel in the Washington State government at over 18 million gallons each year. Because of this, WSF operations are a contributor of carbon and other greenhouse gas emissions within the state transportation system.

Executive Order 20-01, which supersedes the previous Executive Order 18-01, aims to reduce government spending on energy, decrease the release of harmful pollutants into the atmosphere, and support climate change initiatives by utilizing clean-energy vehicles in all aspects of State Government, including the WSF fleet. The levels of emissions reductions that WSF is required to meet are detailed to the left.

The development of the SEP included analysis of greenhouse gas and toxic pollutant emissions for two scenarios: with shore charging and without shore charging. Appendix G provides a full explanation of the two scenarios and the inputs used to calculate emissions.

As shown in Figure 3 on the following page, the scenario with shore charging, this analysis found that greenhouse gas emissions (CO_2e)[2] would decrease by 53% by 2030 and 76% by 2040. This meets and exceeds the requirements of RCW 70A.45.050 of 45% emissions reduction by 2030 and 70% by 2040. Toxic pollutant emissions[3] will decrease 59% by 2040 with shore charging.

The scenario without shore charging can provide modest greenhouse gas emissions (CO2e) reduction of approximately 20% by 2040. This is not compliant with RCW 70A.45.050.

WSF must develop a fleet of hybrid-electric vessels and supporting electrified terminals to achieve adequate levels of reductions and meet state requirements. While this conversion to an all hybrid-electric fleet would take time, the benefits can be seen almost immediately with the planned retrofit and upgrade of the Jumbo Mark II Class vessels, the largest source of emissions in the fleet.

[2] CO_2e refers to carbon dioxide equivalents and combines the global warming potential of all greenhouse gas emissions. Please refer to Appendix G for more information.
[3] Toxic pollutant emissions include Nitrogen Oxides (NOx) and Particulate Matter (PM). Please refer to Appendix G for more information.

Figure 3 presents estimated future annual fleet emissions relative to existing annual fleet emissions. The total, cumulative reduction in emissions from the fleet will continue to improve over time, with the investments in new and retrofitted vessels and terminal electrification projects. New vessel hybridizations without terminal investments do not meet emission reduction targets.

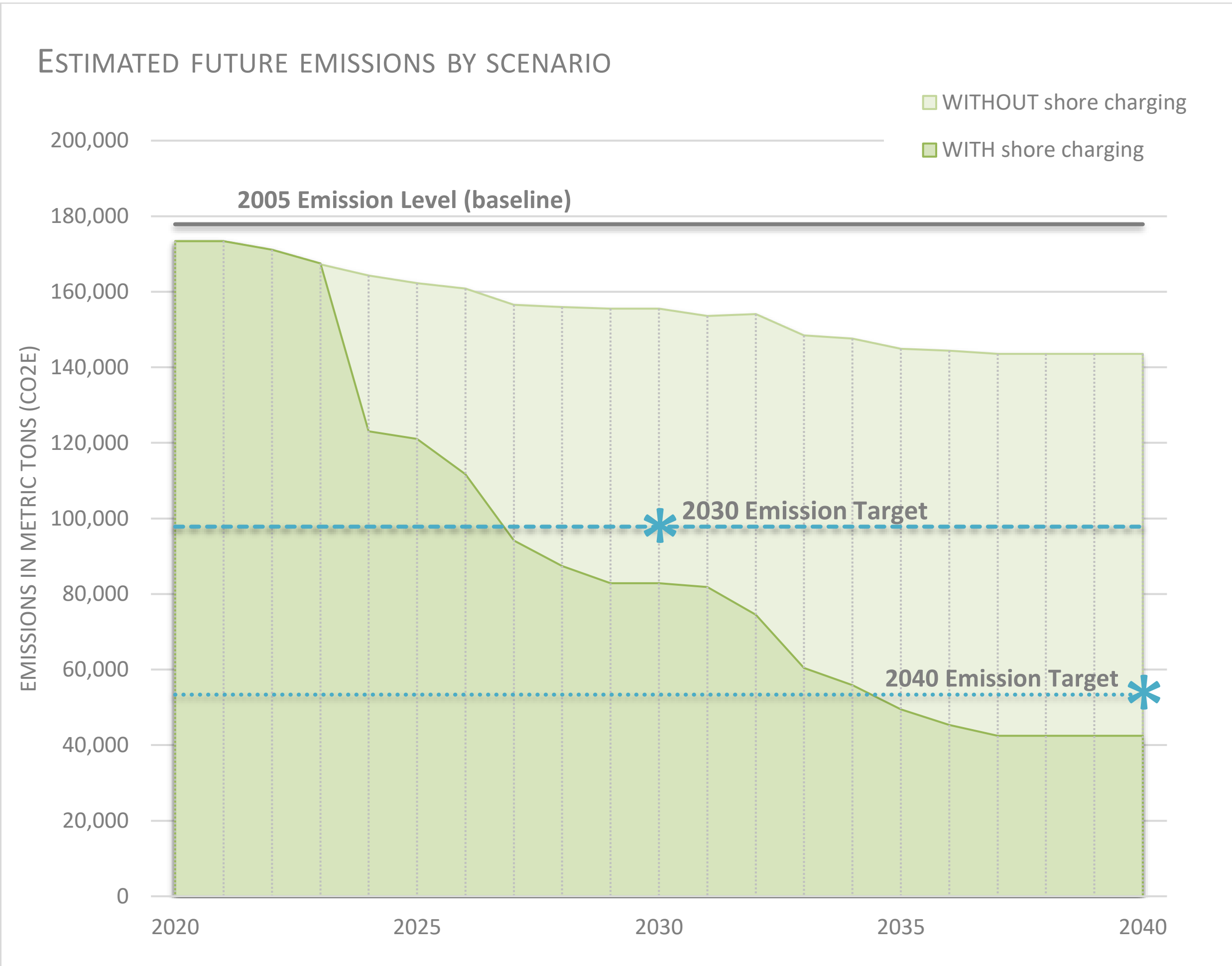


Figure 3: Estimated Future Emissions Reductions

Note that RCW 70A.45.050 has emission reduction goals beyond the time horizon of this SEP, specifically a reduction of 95% by 2050. While these emission estimates show that the SEP is providing an appropriate foundation to meet the near-term goals, WSF will need to continue to seek emission reduction opportunities to meet the ambitious goal of 2050. The estimates included in the SEP are based on conservative estimates for use of battery power. Opportunities to further improve emission reductions can be realized through detailed route-by-route and vessel-by-vessel optimization.

Noise reduction opportunities

Governor Inslee has identified protection of Southern Resident Killer Whales as a priority and established a dedicated task force through Executive Order 18-02. As a result, all future vessels are encouraged to obtain a DNV GL Silent-E, or similar, notation which certifies the vessels are acoustically sensitive. A benefit of electrifying the fleet is the greater ability to attain this notation due to the quieter propulsion system. The reduction of diesel engine noise as a result of hybridization will also improve the passenger experience. However, a recently completed noise study showed underwater radiated noise that is harmful to marine life is primarily generated by propellers during cavitation. Vessel electrification along with emphasis on quiet propeller design and operation will improve noise levels for both passengers and marine life.

Other environmental considerations

WSF had identified in the LRP that design charrettes may be a valuable tool during the individual vessel design phases to explore a host of possibilities for environmentally friendly vessel design.

Additionally, while lithium-ion batteries allow WSF vessels to take advantage of the abundance of clean hydro-electric power in the region, there are environmental considerations associated with battery production and disposal. WSF has already begun brainstorming and investigating opportunities for battery recycling and repurposing.

Electrification Implementation Schedule

To meet the emissions reduction goals outlined in RCW 70A.45.050, the SEP recommends electrification of every route, with some further study needed to detail requirements for the complex San Juan Island routes. The electrification of the San Juan Islands terminals are scheduled in the second half of the LRP in anticipation technological advancements and lessons learned from simpler route configurations will make electric operations in the islands more successful.

The LRP discussed the importance of constructing new vessels as soon as possible to stabilize the aging fleet and maintain service reliability. While the goal of the implementation schedule is to align vessel delivery and completion of terminal electrification, the initial hybrid-electric vessel construction contracts have already been awarded and as a result, terminal electrification is expected to lag vessel delivery in the near term. The hybrid-electric vessels will still be able to operate and provide modest environmental benefits with the onboard generators until the necessary shore charging infrastructure is in place. However, the significant emissions reductions and lower energy costs associated with shore charging will not be fully realized until the terminal electrification is complete and shore charging is available.

Converting select existing vessel classes and building new hybrid-electric vessels is anticipated to be more than a 15-year effort. The vessel delivery schedule, as detailed later in this report is phased slightly differently than the Long Range Plan to account for time that has passed since the development of that Plan. The SEP planning time horizons include:

- Near Term (0-5 years, 2020-2025)
- Medium Term (5-10 years, 2026-2030)
- Long Term (10-20 years, 2031-2040)

Changes from Long Range Plan

There are a few deviations from the LRP planning vision for terminal electrifications, which include:

- The addition of terminal charging infrastructure at Lopez and Shaw Islands.
- Revision from double-sided charging to one-side terminal charging at Clinton for the Clinton/Mukilteo route, Point Defiance for the Tahlequah/Pt. Defiance route and Kingston from the Edmonds/Kingston route. This refinement takes advantage of the energy storage capacity of the vessels on these routes and reduces impact to terminal operations.
- Update of near-term vessel delivery schedule to align with known project schedules currently underway.

The System Electrification Map shown in Figure 4 shows planned electrification of terminals and routes within the planning timeframe. More detail can be found in the capital improvements section of this report and Appendix C.

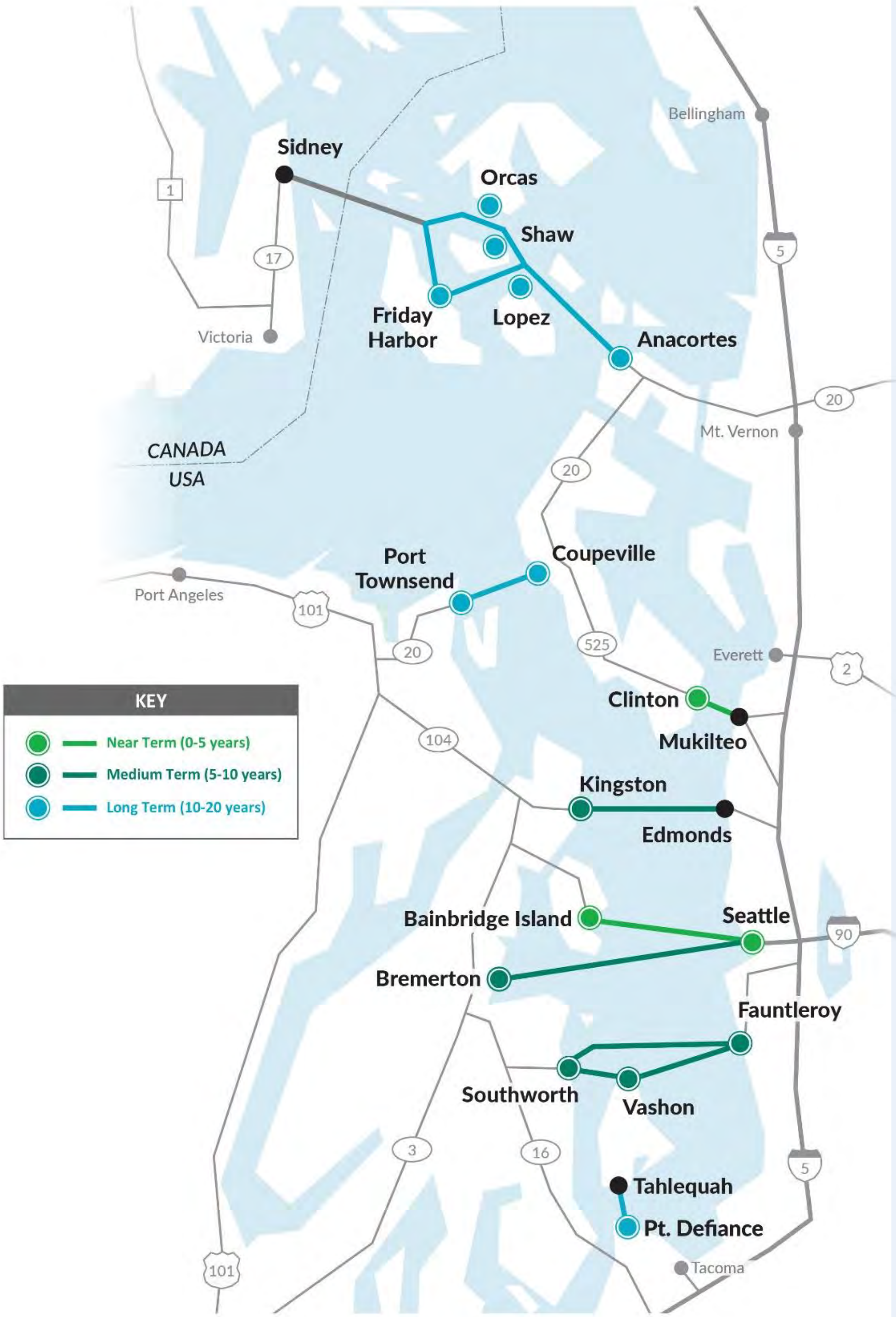


Figure 4: System Electrification Map

Dedicated San Juan Island Electrification Study Needed

San Juan Island routes have the following additional complexities that must be addressed by a dedicated electrification study:

- Complex route assignments of four or more vessels operating in non-linear, non-repetitive route assignments.
- Large service level changes depending on season.
- Cascading impacts of schedule adjustments to every vessel operating on the island routes.
- Additional weight from SOLAS requirements, long crossing distance, and ongoing privatization study makes the international route a non-ideal candidate for electrification.

More information can be found in Appendix B.

Note: This improvement schedule has been developed with the best information available during the SEP coordination, however there is a strong potential for continued delivery timeline adjustment especially in the near and medium terms.

Workforce

Electrification of WSF vessels and terminals is complex. In addition to the typical design and construction phases for both vessels and terminals, electrification will add challenges to the implementation and commissioning phase. Although vessels can operate in hybrid mode without shore charging, to reach state emission reduction goals the shoreside charging facilities must be coordinated with the introduction of hybrid vessels on a route-by-route basis. Furthermore, select vessel and maintenance employees will need training in the new hybrid propulsion system while maintaining knowledge of traditional diesel systems. WSF must staff for the initial design and construction phases of a new technology and also invest resources in training both WSF and local fire service employees while maintaining communication and education to riders and surrounding communities. It is a major, long term, multi-dimensional undertaking that will place new and evolving demands on the workforce.

To achieve the maximum benefits as quickly and cost effectively as possible, WSF should fully integrate vessel construction and deployment, shoreside electrification, workforce preparation and system operation. Such integration will require a comprehensive implementation plan and a strong project management approach that will align the various departments responsible for delivering the components of the electrified system, monitoring progress, and making timely adjustments to ensure on time-delivery of multiple initiatives.

An undertaking of this complexity requires a centralized project management strategy best accomplished with a designated overall program manager accountable to executive management and supported by assistant program managers for vessel and terminal engineering. The three program management positions would work closely with key department directors and designated staff.

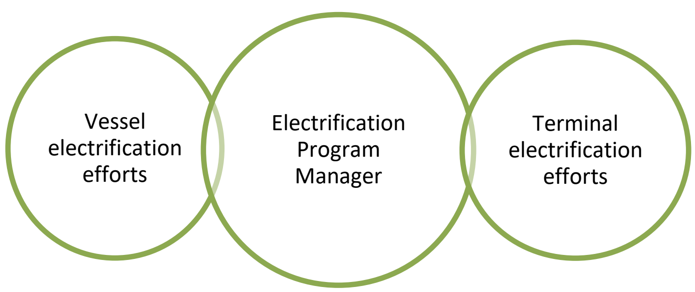


Figure 5: Graphical Representation of Centralized Project Management Strategy

More detail as to workforce needs for capital improvements and system operations can be found in Appendix E and in the Implement and Invest section of this report.

Section 3:

Capital Improvements

A large-scale vessel design and construction effort, along with vessels retrofits, are called for in the LRP. This is needed to maintain system reliability and levels of service—all while meeting the emissions regulations set forth by the Revised Code of Washington and Executive Order 20-01. The SEP further refines those timeframe and cost assumptions. To do that, a feasibility analysis was completed that identified future hybrid-electric vessel and terminal functional requirements. Vessel considerations included current programmed service hours, schedule, loading and unloading times, route assignments and unique vessel properties such as size, speed, propulsion power and capacity for pedestrians and vehicles. Similarly, terminal utility availability, costs, and space considerations at terminals, were all elements of the terminal feasibility analysis.

This information is foundational to the Plan—informing the vessel and terminal schedule for improvements, energy consumption expectations and ultimately the ability to meet legislative requirements to lower the emissions of the fleet over time. A graphic representation of these inputs is shown below in Figure 6.

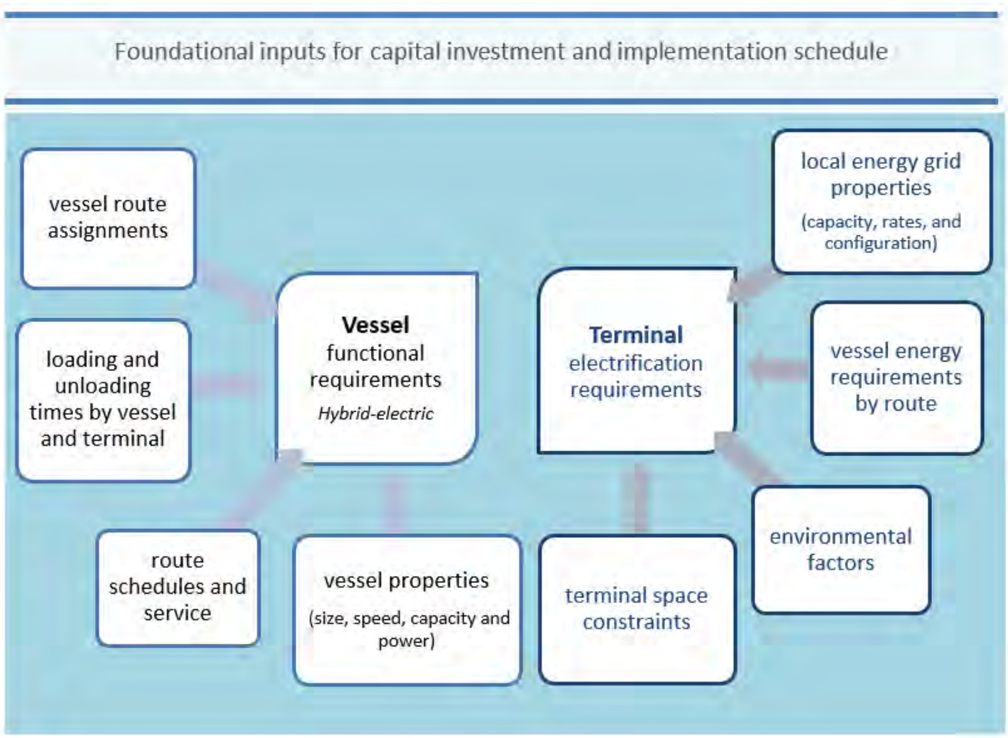


Figure 6: Graphical Representation of Foundational Inputs for the SEP Analysis

Hybrid-Electric Technology System Elements

To achieve the goal of electrifying the WSF fleet, and the associated environmental benefits, utility and terminal improvements are needed across the system to transfer electric power from the existing grid to the operating slips for vessel charging. While hybrid-electric charging technology is in use elsewhere with multiple successful configurations, WSF will be applying this technology to much larger vessels, requiring higher power levels, and in a more diverse fleet, through a common design standard.

The new hybrid-electric systems will create opportunities for automation, real-time data reporting, and increased ship-to-shore communication. The majority of the hybrid-electric infrastructure will be on the vessel itself, with power transmission coming from the shore through electrical improvements to existing wingwalls. Upland configurations will vary with terminal location. Figure 7 identifies the overall configuration for an electric-hybrid vessel and its terminal interface, which includes:

On the vessel:

- Below deck: Lithium-ion batteries, converters, inverters, and power distribution and control systems
- Above deck: Rapid charging system—robotic arm located on each end of the vessel

At the terminal:

- Rapid charging system receptacle located on the wing wall
- Medium voltage equipment located on the terminal property
- Shoreside energy storage (only present at select terminals)

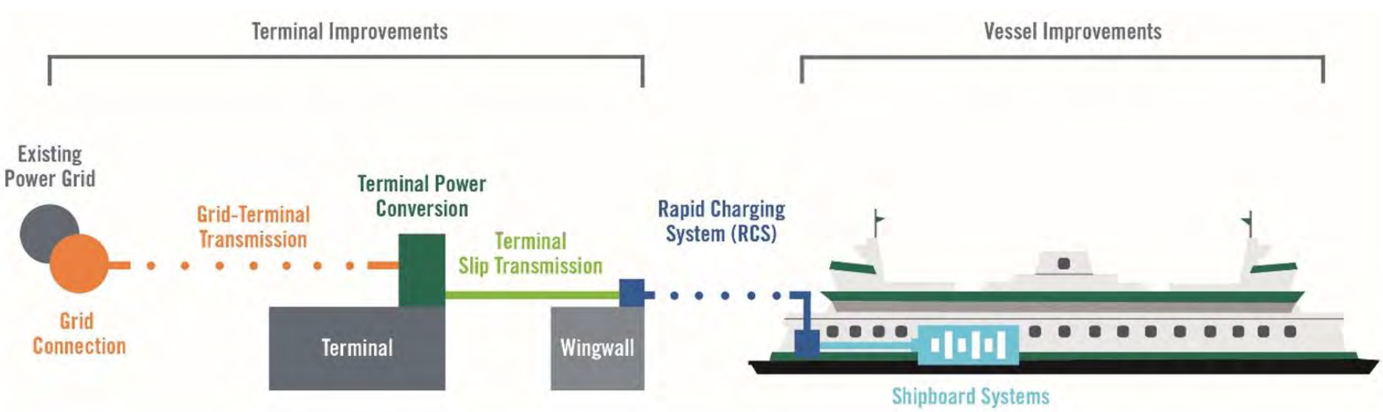


Figure 7: Hybrid-Electric Technology System Elements

Terminal and utility components

To achieve maximum carbon emission reductions, and meet the RCW requirements, charging equipment will be utilized at many of the WSF terminals. These components require improved connections to the local utility service provider as well as infrastructure improvements at the terminals themselves.

The new equipment, including transformers, switchgear, and batteries, will require the relocation of existing functions, utilities, or buildings at each terminal. In addition, conduit will be needed to connect the new switchgear to the rapid charging system (RCS) at each slip. This will be run either in underground duct banks or rigid galvanized steel conduit installed under existing trestles to a combination catwalk/cable tray between the trestle and the wingwall. The catwalk will also allow personnel access to the RCS for inspection, maintenance, and repair.

The RCS will be mounted on the existing wingwall reaction structure to minimize the need for additional in-water structures and to provide good visibility as the ferry approaches the terminal. Although the design of the RCS system was not fully completed at the time of this report, it is expected that it will require daily visual inspections and regular maintenance.

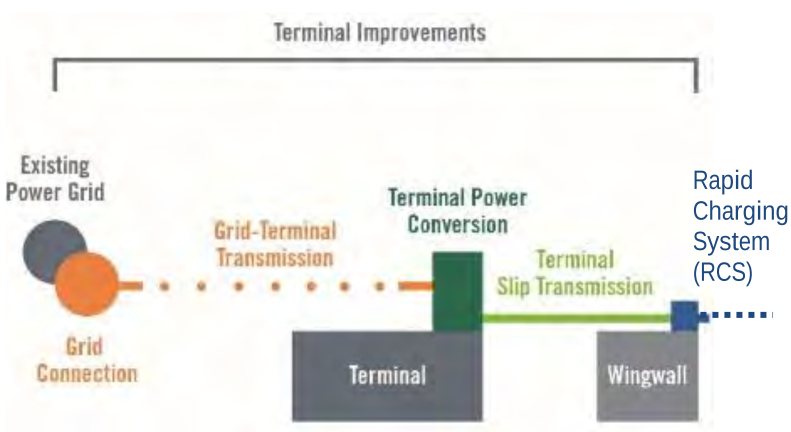


Figure 8: Terminal Electrification Elements

Terminal electrification requirements identified through the SEP

- Utility improvement and right of way requirements
- Terminal power conversion requirements
- Terminal energy storage requirements
- Number of slips requiring electrification
- Over-water construction requirements
- Terminal modifications to support electrification (e.g., change to passenger overhead loading, dolphins, wing walls, etc.)
- High-level information infrastructure investments needed to support electrification

The body of work that supports this plan included detailed feasibility analysis. This analysis was developed from the best available information. Complete documentation can be found in the appendices.

Shoreside electrification improvements include:

- Grid connections from a local utility substation and distribution lines to the terminal
- Terminal power conversion equipment, switchgear, and batteries
- Terminal to vessel (slip) distribution (at a wingwall, or the structures that aid in the mooring of the vessel at the terminal)
- Connection to the Rapid Charging System (RCS)
- Shoreside energy storage systems (ESS) at select terminals

When siting any terminal electrification equipment, sea level rise and floodplain hazard zones will need to be considered. Coordination with other planned terminal improvement should also be considered.

Battery capacity at terminals

Where the grid capacity cannot meet the charging demand directly, a shoreside Energy Storage System (ESS) will be required. An ESS consists of a battery or battery bank and the power conversion and management equipment necessary to convert current between AC and DC as well as step up and down the voltage to suit the other elements of the vessel charging system. The terminal batteries and power management equipment can be provided in typical 20' ISO standard containers and may require the reconfiguration of terminal structures or traffic flow.

Vessel (shipboard) systems

Systems on the vessel will include lithium-ion batteries, a rapid charging system (RCS) to transfer power from the terminal to the vessel, and transformers and other electric conversion equipment. These systems are supported by distribution systems, power management systems, battery monitoring and control systems, battery cooling systems, and fire suppression systems.

All hybrid-electric vessels will be equipped with diesel generators for redundancy, as shown in Figure 9. This allows the generator to provide supplemental power in the event that battery power runs low, or as contingency when utility power is unavailable, or the RCS connection cannot be made.

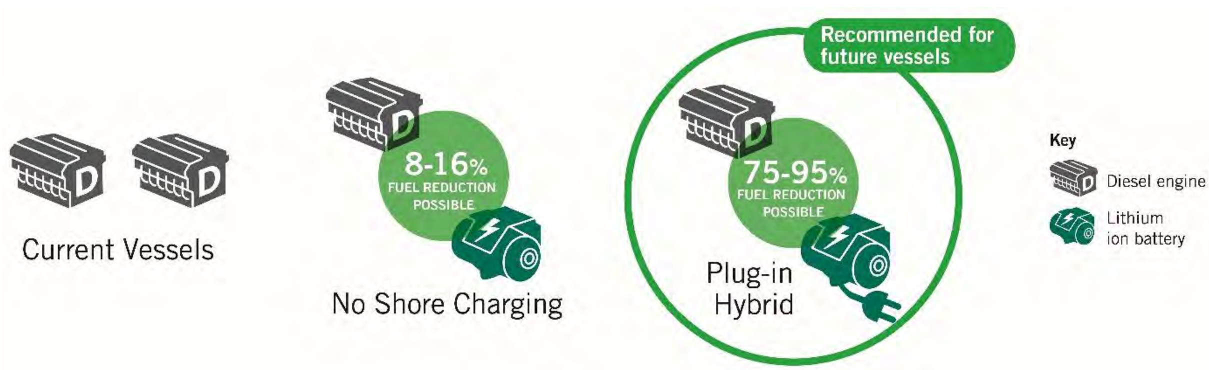


Figure 9: Propulsion Configuration Options

An overreliance on diesel generator power would result in vessels carrying more fuel, increasing vessel weight and thereby power consumption. While reducing the electrical system capabilities would similarly reduce capital costs, it would also reduce the environmental benefits of electrification. Conversely, eliminating the diesel generator eliminates redundancy and introduces reliability risk to system. Thoughtful schedule design and vessel operations will lead to optimal emission and fuel consumption reductions.

The new hybrid-electric vessel designs will also require additional non-propulsion shipboard systems to support the hybrid-electric equipment, including:

- Fire and gas detection and suppression
- Off-gas ventilation system for lithium-ion batteries
- Liquid cooling systems for the lithium-ion batteries and power conversion equipment
- Additional compartment heating, ventilation, and air conditioning (HVAC)

Battery racks

Hybrid-electric operation will require specialized equipment on board, such as battery racks.

Rapid charging system

The RCS serves as the connection between the terminal and vessel, with an active robotic component located on the vessel and a static plug-in receptacle at the terminal. The Jumbo Mark II ferries on the Seattle / Bainbridge route will receive the first RCS of the fleet and will serve as the model for future installations.

The RCS should be compatible with all vessel classes and electrified terminals. There may be opportunities to realize some cost savings by having a different RCS configuration on the Kwa-di Tabil Class vessels on the Port Townsend / Coupeville and Point Defiance / Tahlequah routes with lower power levels and consistent vessel assignments.

Information technology

With the transition to hybrid propulsion systems, increased levels of automation will be necessary to ensure all control systems respond to the operator inputs. At a minimum, each vessel will have the following:

- Power Management System
- Battery Management System
- RCS Connection / Disconnection System

Due to the increased automation requirements, hybrid propulsion systems will incorporate more computer-based equipment than previous vessels. Third party remote diagnostic or monitoring is an emerging service to aid vessel owners in tracking onboard equipment health and troubleshooting problems.

More information on IT requirements can be found in Appendix B.

Improvement Schedule

A variety of elements were considered through the development of the SEP implementation schedule for capital improvements.

Construction of terminal infrastructure to support hybrid-electric vessels is planned to coordinate with the introduction of new vessels to realize the benefits of reduced emissions as early as possible. Where possible, the terminal electrification work is coordinated with other maintenance and preservation projects to minimize service disruptions.

Implementation factors

- Proximity to urban areas (therefore eligible for VW funding)
- Fuel reduction potential
- Passenger volume
- Predictable dwell times
- Existing and available utility infrastructure
- Utility rates

The goal of the implementation schedule is to align vessel delivery and completion of associated terminal electrification when possible. However, this alignment is not always perfectly possible due to funding, permitting, and design constraints. An example of this is the currently funded design and construction of the initial hybrid vessel which will be complete before the first terminal electrification project. Terminal electrification is expected to lag vessel delivery in the near-term. The hybrid vessels will still be able to operate with the onboard generators until the necessary shore charging infrastructure is in place. However, the significant emissions reductions and lower energy costs associated with shore charging will not be realized until the terminal electrification is complete and shore charging is available.

The identification of vessel and terminal improvements by year can be found on the following pages. The improvement schedules have been developed with the best information available at the time of the SEP coordination. Delivery timeframes may vary and are dependent on a variety of factors.

Hybrid-electric vessel delivery

The vessel construction schedule has been updated from the LRP with new vessel delivery dates for 16 new vessels and six (6) vessel conversions to hybrid-electric over the 20-year planning period.

The **near-term** vessel electrification capital improvements are:

- **Hybridization of the Jumbo Mark II vessels** to align with the propulsion control system upgrade schedule
- Extension of the Olympic Class vessel construction contract for **five new hybrid-**

electric vessels

Engineering efforts for the Jumbo Mark II Class and Hybrid-Electric Olympic (HEO) Class vessels are already underway, including the onboard energy storage system and an RCS specifically designed for the unique WSF application.

For the Jumbo Mark II vessels, two diesel propulsion generators will be removed and replaced with lithium-ion batteries in conjunction with planned propulsion control system upgrades. These Jumbo Mark II vessels are the three largest vessels in the 21-vessel fleet, which account for 26 percent of total fuel consumption (five million gallons of fuel/year) and carbon emissions of the system.

The original Olympic Class vessel build contract was awarded in 2007 and added four vessels to the WSF fleet. Extension of the existing contract provided an opportunity to build additional vessels in the short timeframe needed to maintain service reliability, reducing the design, procurement and construction process which can take up to seven years. Expanding the Olympic Class provides an opportunity for standardization of the fleet under a common hull design, and the navigability and capacity of the vessel size is flexible to serve nearly any route in the system.

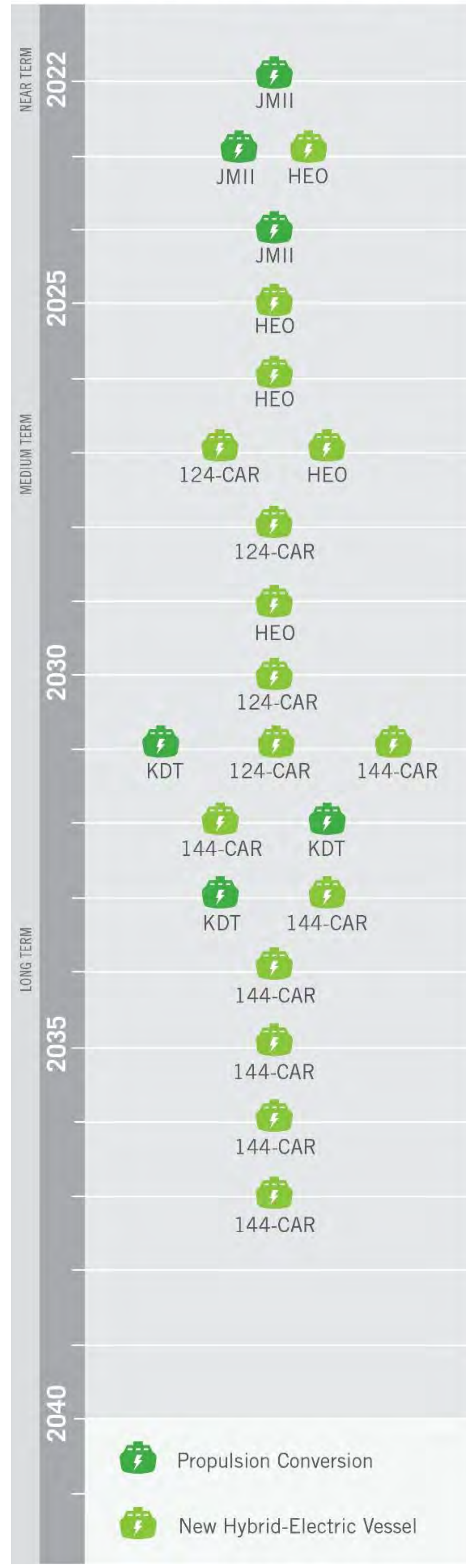
The LRP outlines vessel functional requirements, and the SEP outlines vessel hybridization requirements for each new vessel class that is identified. These design requirements will be refined as the Plan is implemented.

In the **medium term**, four **New 124-Car Class** vessels are planned to replace the Issaquah Class vessels on the Fauntleroy / Vashon / Southworth route. The first delivery is planned for FY 27 with the final vessel completed in FY 29.

Longer term investments are planned for two vessel classes.

- **Kwa-di Tabil (KDT)** - the three KDT vessels will be converted to hybrid-electric over the three consecutive winters of FY 31 through FY 33
- **New 144-Car Class (New 144)** – seven new 144-car vessels will be built with the first vessel completed in FY 31 and the last vessel in FY 37

Hybrid-Electric Vessel Delivery



Terminals

Electrifying a terminal requires both grid improvements by the local utility to transfer power to the terminal and new equipment and infrastructure at the terminal. WSF and local utilities will need to collaborate closely to develop cost-effective plans for providing sufficient power to charge the vessels within the scheduled dwell time directly or by storing power in shoreside batteries.

Delivering power to urban terminals such as the Seattle terminal at Colman Dock and Bremerton will require installation of new underground duct banks, which are very expensive and disruptive to local traffic. Power to other terminals will likely be delivered via overhead lines unless local ordinances require the use of underground lines. In both cases, additional transformers and other equipment at the nearest substation may also be required, depending on the charging demand loads.

The **near-term** terminal electrification capital improvements are at the following terminals:

- Clinton, Bainbridge and Seattle terminals

The **medium-term** terminal electrification capital improvements are at the following terminals:

- Kingston, Bremerton, Southworth, Fauntleroy and Vashon terminals

The **long-term** terminal electrification capital improvements are at the following terminals:

- Point Defiance, Coupeville, Port Townsend, Anacortes and San Juan Island terminals

Terminal Electrification Delivery

Energy Storage Systems needed at select terminals

The power grid in downtown Seattle adjacent to Colman Dock is close to capacity with insufficient power to simultaneously power the Bremerton and Bainbridge Island hybrid-electric vessels that operate from the terminal. Currently, Seattle City Light is providing a feeder cable to meet the demands of the Bainbridge route charging needs. However, additional power will be needed to serve an electrified vessel serving the Bremerton route. This is especially true when the sailing schedule requires two vessels to be charged simultaneously, which occurs several times a day. A supplemental battery bank is proposed to meet the demands of the second electrified route. WSF is currently collaborating with the Seattle City Light, the Port of Seattle, Kitsap Transit, and the King County Marine Division to locate the necessary transformers, primary switchgear, and batteries on the uplands of Pier 48, immediately south of the Seattle Terminal.

Based on the best available estimates of local grid capacity, it is assumed Clinton, Kingston, Bremerton, and Seattle are likely to require an ESS. The cost of this equipment has been included in this Plan. A map of terminals identified for ESS are shown in Figure 10.

This plan assumes none of the slips at the Eagle Harbor Maintenance Facility (EHMF) will be electrified. However, Appendix C outlines the opportunity to house the transformer and switchgear needed for the terminal electrification at Bainbridge Island at this neighboring maintenance facility.

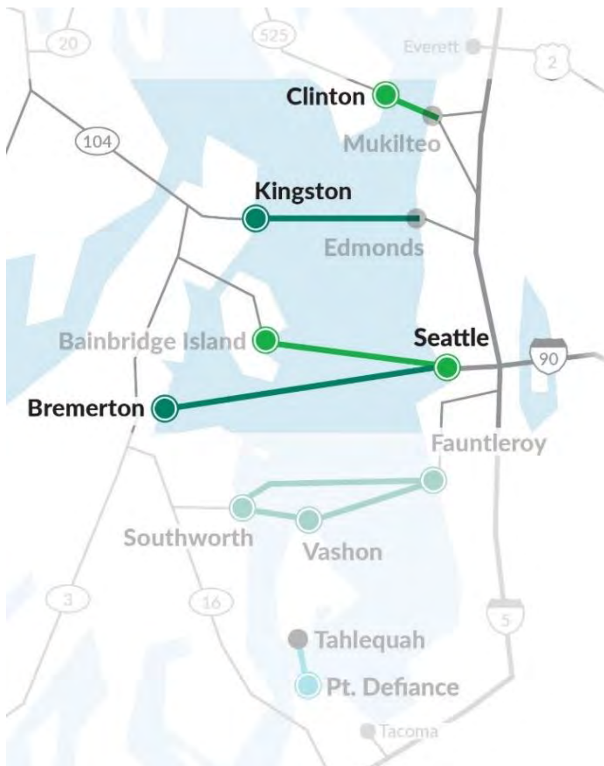


Figure 10: Terminals Currently Identified for Energy Storage Systems

Capital Program Management

Planning, designing, and building the vessel and terminal infrastructure to support system electrification will require a considerable level of work beyond current and on-going terminal improvement and preservation projects. This effort is in addition to the many other facets of pre-design planning, design and delivery for 16 new vessels, six conversions and 17 terminal projects over a 20-year planning timeframe.

Vessel and terminal construction

Vessel projects will require significant coordination with the vendor, shipyard, and project oversight, along with design/engineering review, for each vessel. This design and construction process can take up to seven years for each vessel class. The design, construction and commissioning of new vessels take dedicated staff time from vessel engineering and crew and engine room representatives. This plan outlines three new vessel classes and conversion of two separate vessel classes within the 20-year timeframe.

The fleet electrification requires infrastructure improvements at nearly every WSF terminal. The improvements vary in scope at each location, but will involve design, permitting, and construction for terminal electrification and utility upgrades, estimated to be a two-year process or longer. Prior to design, the Terminal Design Manual requires a pre-design study that will take several months and explore trade-offs and solutions of proposed improvements and project phasing for continuance of ferry operations during construction. Any construction will require support for permitting, mitigation, and coordinating with agencies, tribes, and stakeholders. Design of improvements may be done in-house or contracted, but both will require extensive project management and coordination.

To support these efforts, an overall electrification program manager should assume a coordinating role and be supported by a terminal electrification program manager and a vessel electrification program manager. In addition to this dedicated team, support from a wide array of WSF groups will be needed to assist with contracting, permitting, communication, schedule modifications during construction, etc. Figure 11 below reflects the number of capital projects and their associated planning and construction workload for SEP infrastructure delivery.

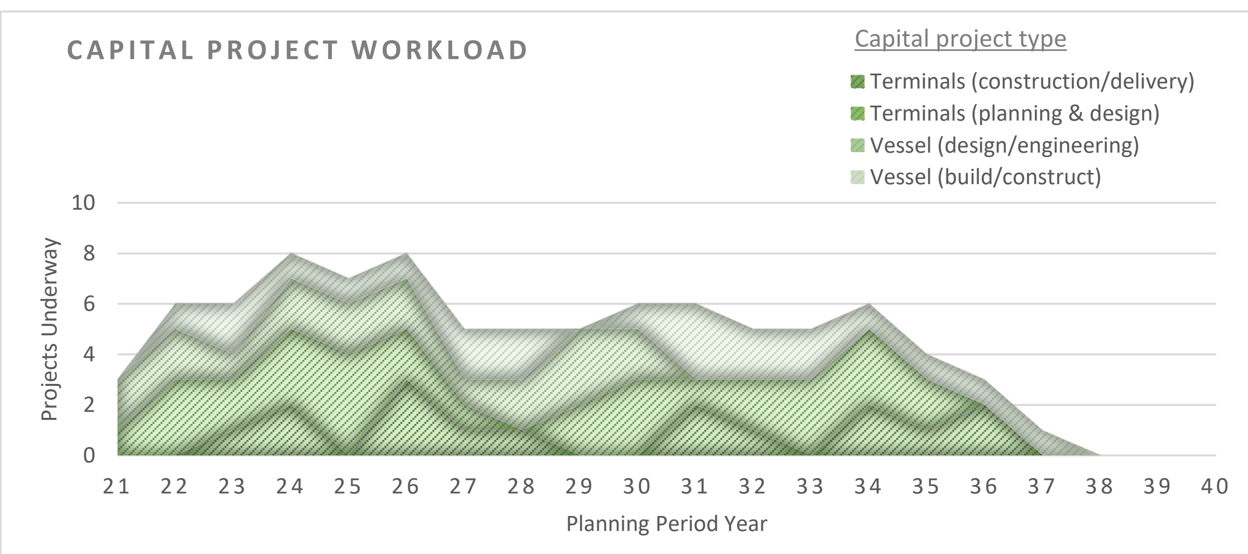


Figure 11: Capital Projects with Assumed Planning, Design and Construction Lead-times

Section 4:

Operating Elements

To operate 10 routes between 20 terminals, WSF employs a large and complex workforce of over 1,900 employees throughout the Puget Sound region on vessels, in terminals, at the Eagle Harbor Maintenance Facility, and at its headquarters. As WSF works toward electrification of the fleet, the supporting workforce will be central to its success.

The length of the implementation phase, approximately 20 years, results in a mixed fleet configuration, with some existing diesel vessels and hybrid-electric vessels. This dynamic fleet mix will require expertise for operations and maintenance of the traditional diesel vessels, as well as the addition of new knowledge to build, operate, and maintain the hybrid-electric vessels. Therefore, new workforce functions to facilitate the management of the electrification program and extensive training will be required right away.

Operational Considerations

The operational effectiveness and efficiency of an electrified ferry system are dependent upon both asset and workforce factors.

Redundancy

Safety and reliability are two pillars of the WSF operation. To maintain both, standards of redundancy for the new, more complicated propulsion systems need to be addressed. The hybrid-electric vessels will be designed with system redundancy that will allow them to continue operating in a variety of potential scenarios including failure of a single motor, single battery room, single engine, or shore charging equipment.

Charging times

Dwell time is the time a vessel needs to spend at the terminal. Historically, dwell time was driven by the need to unload then load passengers and vehicles, and the need to meet schedule. As a result, historical dwell times are irregular and did not necessarily stick to planned schedule. In the future, dwell time will also need to consider the need to fully charge battery banks to leverage clean energy sources as much as possible. From an emissions reduction perspective, ideally, the dwell times would consistently reflect the "design dwell times" identified in Appendix B. Note that design dwell time is a significant driver of battery bank size and consequently hybridization cost. This SEP does not assume any schedule changes and uses conservative emission calculations. Thoughtful schedule and operational optimizations are opportunities for even greater emission and operating cost reductions.

U.S. Coast Guard requirements

Each WSF vessel receives a Certificate of Inspection (COI) from the U.S. Coast Guard (USCG) Officer in Charge, Marine Inspection (OCMI). One of the important elements of this document is the identification of how many crewmembers are needed on the vessel and what types of credentials the crew is required to carry.

Hybrid-electric technology is relatively new to ferries, and the USCG does not currently have unique crewing or credential requirements for hybrid-electric vessels. It is anticipated that WSF will work closely with the local OCMI to establish requirements, potentially in advance of the issuance of USCG minimum standards. While not anticipated, if the minimum crewing levels outlined on the COI are different than what is currently used, WSF will have to adjust their workforce accordingly.

Workforce trends

WSF's workforce is shaped by the inherent complexities of the system's operating environment, with considerations such as geography, seasonality, safety, fleet mix, and route characteristics. Electrification of the fleet has varying impacts to each of these categories, with many having an impact on the skills, training, recruitment, and dispatch of the WSF workforce.

New or Changed Workforce Functions

Electrification of the system will change the duties of various day-to-day functions of many WSF departments. Because much of the technology and electrical systems are new and unique to WSF, it is anticipated there will be a learning curve in their use. The workforce will need to be trained in the new systems while also retaining the skillsets and training to operate the existing mechanical systems. The chart below provides a view of the fleet configuration by propulsion type over the planning horizon. New propulsion systems are introduced in 2023 and become the dominant propulsion system in the fleet after deliveries in 2031, where the fleet mix would reflect 12 diesel and 14 hybrid-electric vessels, as shown in Figure 12.

Workforce impacts of vessel electrification must consider the challenges WSF is already facing, such as:

- Recruitment and hiring
- Accelerated retirement of workforce
- Additional staffing needs for increase in service levels outlined by the LRP
- Increased maintenance demands of aging vessels and terminal infrastructure

Figure 12: Changing Fleet Configuration over Planning Period

To support the vessels and terminals, the Eagle Harbor Maintenance Facility will also need to have the infrastructure and personnel assets to inspect and maintain pertinent equipment.

Additionally, supporting all functions is the management infrastructure at WSF headquarters with functions such as finance, human resources, security and training, vessel engineering, operations dispatch, capital program management, planning and scheduling, customer service, and information technology. The following graphic identifies new or changed workforce functions for vessel and terminal staff.

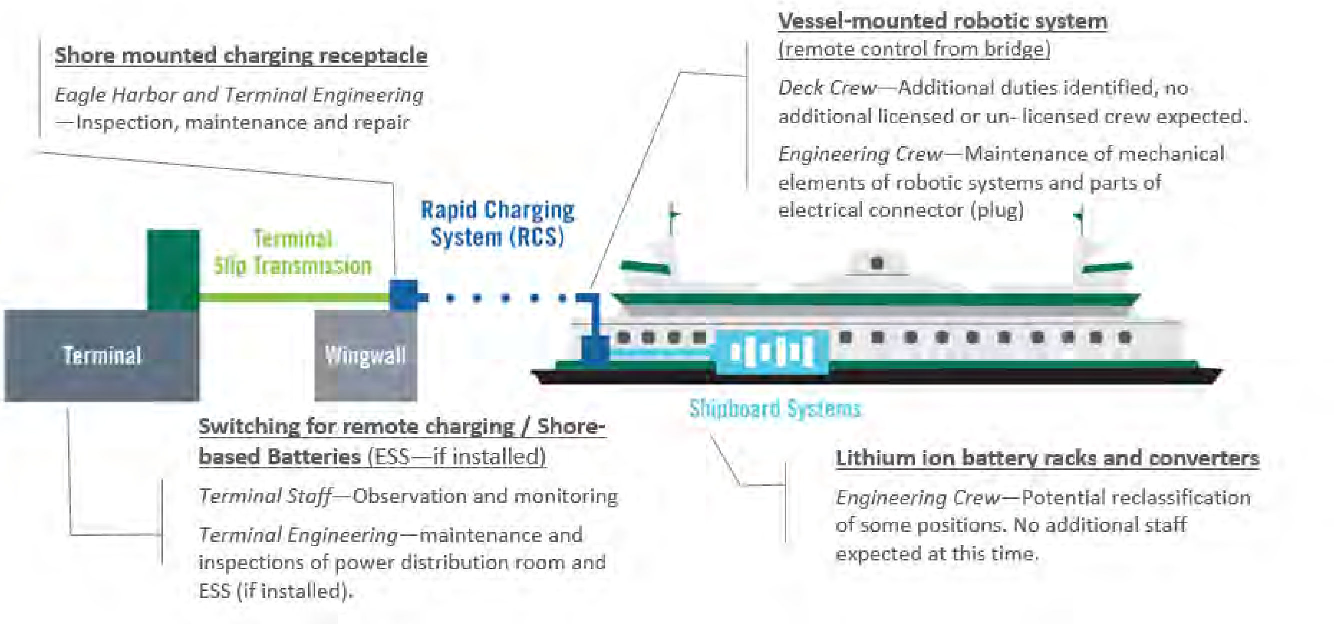


Figure 13: Overview of Potential Changes to Workforce

Operations

For operating divisions, additional personnel are only anticipated in maintenance and engineering roles at this time, labor changes are outlined in Figure 14 below. Engine crews will need to become proficient in the power management system, battery management system, batteries, power conversion equipment and fire suppression systems of the new vessel. While many positions may have changed or added new responsibilities, additional employees are not anticipated in the Deck and Terminal departments. Please refer to Appendix E for more detailed, department specific information gathered through WSF staff working groups during the SEP planning process.

Port Engineering

- System controls vendor onboarding and security monitoring
- Real-time data tracking and reporting

Eagle Harbor Maintenance

- Increase mechanical and electrical workforce
- Inspecting and maintaining charging equipment on wingwalls
- Power distribution room inspections (shared with terminal engineering)

Figure 14: Overview of Operational Labor Changes

Maintenance Program

Each of the three maintenance levels will have new or changed workforce functions related to maintenance of the hybrid-electric fleet, performed by professionals at the Eagle Harbor Maintenance Facility, the engine room crew on the vessels and terminal engineering (for some terminal infrastructure related inspections).

Vessel maintenance

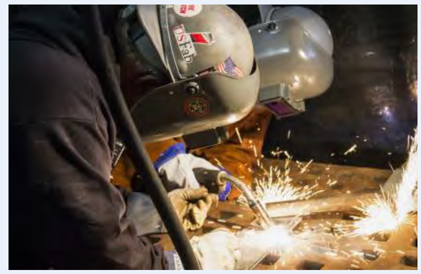
It is anticipated there will be a learning curve associated with troubleshooting, features, and challenges of new equipment. Eventually some mechanical functions will shift to electrical, but the workforce will need to be trained in both diesel and hybrid propulsion systems. The new hybrid systems will require training for troubleshooting and maintenance, and medium/high-voltage safety. Crew will need to frequently inspect batteries, supporting systems, and the robotic charging arms. These additional duties are seen as added responsibility / reclassification of existing positions rather than newly added positions and will be required as each new vessel comes online.

Eagle Harbor Maintenance Facility

To support the vessels and terminals, the Eagle Harbor Maintenance Facility will also need to have the infrastructure and personnel assets to inspect and maintain pertinent equipment. As the fleet size increases and new hybrid-electric vessels are delivered, the workload at Eagle Harbor and required skills will increase significantly. To support the new electrical systems, the Eagle Harbor workforce will need training in vessel systems and higher-level electrical capabilities, including some computer training for new systems. Eagle Harbor workers will also require training to perform maintenance on the robotic charging arm.

The electronics shop was established in December

WSF maintenance program



The program is divided into three levels, based on the competencies, facilities and time required to complete tasks. The three levels are defined as follows:

Organizational (O) Level

- Performed by the assigned vessel crew.

Intermediate (I) Level

- Requires skills, equipment, material or time beyond those available from the vessel's normally assigned crew.

Depot (D) Level

- Requires the vessel to be at a commercial shipyard because the work is beyond the capabilities of the assigned crew or I-Level maintenance activity.

2019, and it is anticipated the current staffing level will be at capacity with the existing workload. Further review of current and planned needs will be needed to determine electronics shop staffing needs.

Training Plan Development

The 2040 LRP called for investment in recruiting, retaining, and developing a skilled workforce. This effort will require added support in administrative, HR, training, and management functions. Training for hybrid-electric technologies is in addition to those efforts focused on workforce attraction, development, and retention.

Initially, training program development may be supported by vendors as the experts in the new technologies and systems. As some of the technologies will be unique to WSF, new training programs will need to be developed. Development and implementation of training programs will require increased personnel resources in administration, training staff, and managers, as well as training budget.

In the past, WSF has budgeted eight weeks of labor for all deck and engine room personnel to cover the time from new vessel acceptance until the vessel is placed in service. Sea trials, testing, and training occur during these eight weeks. It is possible additional training time may be required for some vessel personnel to address new or different knowledge and responsibilities for hybrid propulsion. Once vessel design is sufficiently advanced to develop a training plan, the adequacy of the eight-week labor budget can be confirmed.

In addition to hybrid system training for personnel assigned to each new vessel, it will be necessary to train designated relief personnel to key positions such as Chief and Assistant Engineer, Master, and Mates, which is typical for any new vessel class delivery. Opportunities are present for the training of current and prospective engine crew through the use of a Full Mission Engine Room Simulator, configured to mirror the configuration of one or more of the hybrid-electric vessels. WSF has a training agreement with Seattle Maritime Academy (part of Seattle Community College) that could be leveraged for this purpose.

Additional effort may be required within the training department, particularly at the time the first vessel in each class is delivered, to develop training plans and materials. These additional duties are seen as

First responders

In addition to the training needed by the WSF employees who will work with new equipment and technology, WSF's training plan will be extended to include training and safety protocol development with agencies who may respond to incidents on vessels or at terminals involving or located near electrical charging equipment, including fire departments and USCG. Coordination with these agencies will ensure that emergency responders have the information and training necessary to keep themselves safe and ensure the safety of WSF customers and employees should an emergency occur.

a newly added position during program development and implementation phase of the electrification work. This operational training will be complimented by agency-wide training/communication plans communicating how the technology works to answer questions and plan effectively. This is separate from the robust public engagement and communication that is discussed in the Implementation section of the report.

Dispatch

The addition of new vessel technology will further complicate the necessary crew scheduling. Only deck and engine room crew with vessel-specific training, including on-call and relief employees, can be assigned to electrified vessels. This requirement will lead to workforce decisions regarding the balance between the flexibility afforded by training more workforce on the electrified vessels and routes, and the cost savings of having fewer trained crew available to schedule. Current labor agreements require crew to remain with a new vessel, or a similar vessel in the class for a period of two years after delivery. The dispatching of crew to vessel classes with evolving propulsion systems will become more challenging as the fleet mix evolves over the planning horizon. This is compounded by the complexities WSF already faces with its workforce.

Public Communications

As WSF implements new hybrid-electric systems on its ferries, the communications team will take on the effort of informing customers of the new systems and safety procedures. A robust public information campaign will be needed prior to and throughout implementation to focus on educating the public regarding perceived risks of new technology, as well as real functions and benefits. An important aspect of public communication will be demonstrating that safety procedures are based on fact and science within evolving technologies. As always, safety is paramount for WSF. It is this culture and preparedness that will need to be clearly communicated so that customers with questions understand the systems in general terms—how they work and how the crew is trained and prepared should emergency response be needed.

WSF has set a precedent of clear and frequent communication with its customers and can utilize these same means and methods as well as additional outreach as needed. This communication effort will ebb and flow with the delivery of new vessels and terminal improvements. This communication and training, where applicable, will also be essential for the nearly 1,900 employees of WSF so questions can be answered in the field and on the customer service lines in representing WSF every day.

Section 5:

Implement and Invest

Electrification of the WSF fleet is a remarkable undertaking that will require planning efforts and investment over multiple decades, but also offers great opportunity. Implementation of the SEP will be supported by both the existing workforce and new dedicated positions. The costs of expanding the workforce and investing in the fleet and terminals are outlined in the following sections, along with an overview of potential funding opportunities and further studies needed.

As with the 2040 LRP, the SEP includes a 20-year financial outlook to allow decision makers to evaluate the financial implications of the decision to invest in hybrid-electric propulsion. Some features of which are shown in Figure 15.

The financial outlook incorporates an estimate of, and schedule for, the required capital investment and a forecast of the resulting operating costs. New construction and planned preservation and improvements are included in the capital investment plan. Projected hybrid energy costs, workforce impacts, and the service enhancements proposed by the LRP are included in the operating cost forecast. Appendix F includes a comparison of the costs presented in the SEP and the LRP.

An alternative financial outlook has also been prepared for the no shore-charging alternative. This alternative assumes the same new vessel delivery and investment schedule, but both terminal and vessel investments are modified for the elimination of shore charging and resultant energy cost increases reflect diesel generators charging the lithium-ion batteries.

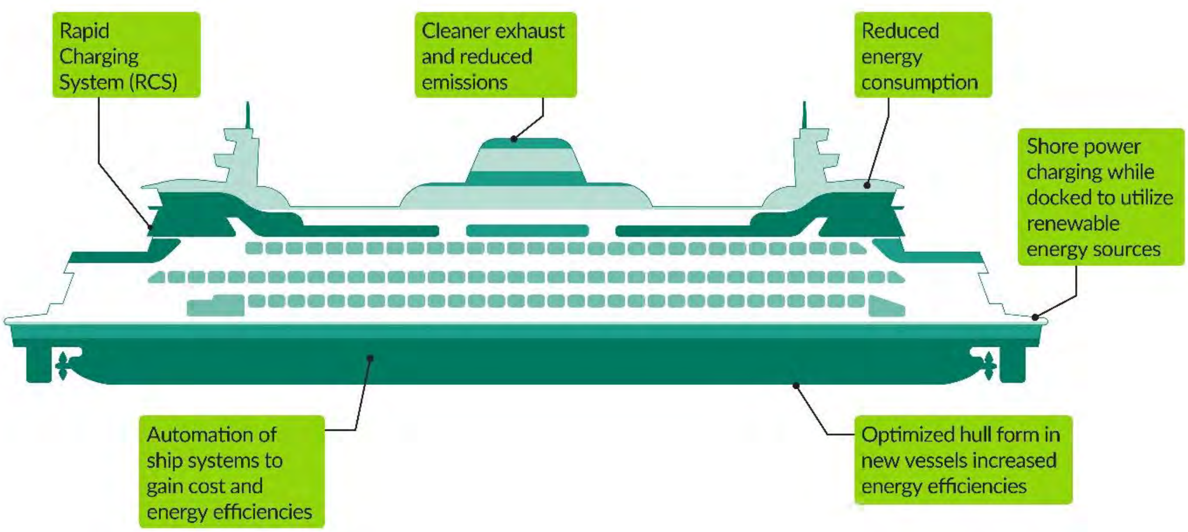


Figure 15: Hybrid-Electric Vessel Features

Capital Costs

53%
decrease in (CO_2e)
by **2030**

Target:
45% decrease

76%
decrease in (CO_2e)
by **2040**

Target:
70% decrease

The capital investments to implement the SEP can be classified into two primary categories: vessels and terminals. The costs associated with these two types of investments encompass environmental review, design, construction, construction management, and program support.

Two capital improvements scenarios were evaluated, one with shore-charging (which requires terminal improvements) and one without shore-charging. Only the shore charging scenario meets the emission reductions requirements in the RCW and therefore is presented as the capital improvements and costs in this Plan.

The capital investments outlined in this Plan address challenges beyond reducing fleet emissions. Vessel deliveries identified in the Long Range Plan are reflected in the SEP, which includes fleet stabilization through timely replacement of aging vessels and expanding the fleet size to provide adequate time for vessel maintenance. The ideal time to adopt hybrid propulsion is when a new vessel is being designed or when an existing vessel is undergoing major preservation. The additive cost of electrification is a small part of the total cost. For terminals, electrification cost is identified as a stand-alone investment and is separate from other planned terminal preservation costs. There may be opportunities for combining terminal electrification with other projects to reduce costs.

As demonstrated in Figure 16 below, while capital investment is high, it is the key to carbon emission reductions on the way to a stabilized fleet through vessel replacement and fleet expansion.

Figure 16: Emissions and Capital Investment

6
existing vessel conversions

16
new hybrid-electric vessels

17
terminal electrification projects

The capital programs for system wide electrification encompasses the conversion of six existing vessels, 16 new hybrid-electric vessels and 17 terminals projects. The total projected cost for these capital improvements is nearly $4 billion dollars. Of this investment amount, nearly $3.7 billion is for vessel conversion and new builds to replace retiring vessels and grow the size of the fleet to maintain system reliability and resiliency. Nearly $300 million is identified for needed terminal improvements. Less than 10% of the total is directly required for system electrification, with the majority associated with normal system recapitalization.

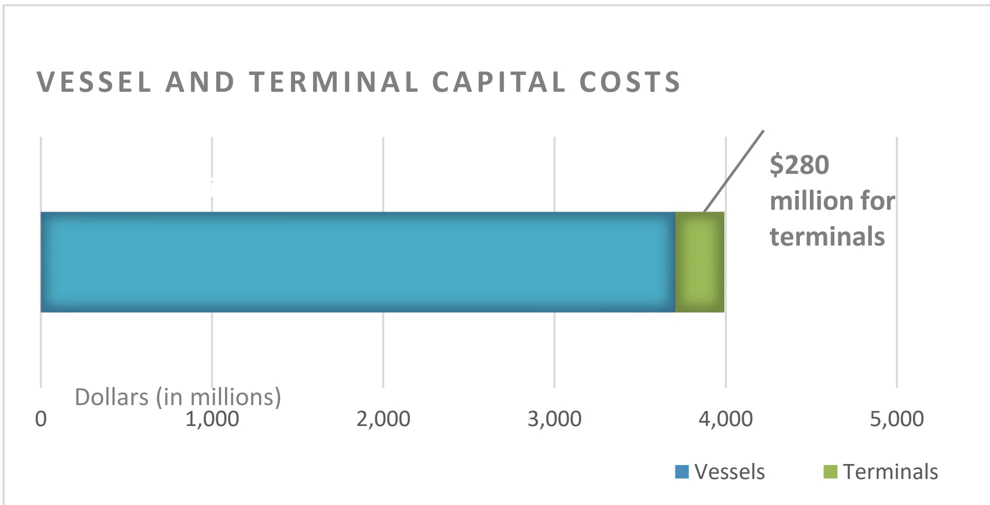


Figure 17: Vessel and Terminal Capital Costs

Program management

Strong, centralized program management will be key to aligning the efforts of various departments responsible for delivering the components of the electrified system, monitoring progress, and making timely adjustments to ensure on time-delivery of multiple initiatives over time. Three positions are proposed, as referenced earlier in the Plan. These positions include one vessel focused electrification project manager (PM) and one terminal focused PM, both reporting to the Electrification Program Manager. Annual funding for the three positions is estimated at $605,000 in FY 20 level dollars. This program management cost is included in the capital investment plan for delivery of 17 terminal electrification projects and 22 vessel builds or retrofits.

Battery replacement

Battery replacement will be an on-going capital expenditure with battery life expectancies between four and 10 years depending on individual service characteristics. There continues to be advancements in battery design which can increase life expectancy and reduce capacity requirements. Opportunities to reuse / recycle marine batteries, i.e. from vessel to terminal ESS or other utility energy storage, are also areas of active research.

Vessels

WSF's vessel capital improvement program, as outlined in the LRP, includes both preservation and improvement of the existing fleet and electrification of the fleet achieved through new builds and conversions. Converting newer, existing vessel classes and building new hybrid-electric vessels are anticipated to be more than a 15-year effort. Total investments for conversion and newly built hybrid-electric vessels are expected to cost $3.7 billion dollars over the planning period. A summary of the total costs of conversions and new vessel builds by class is presented in Table 2.

Of this large investment in system reliability through fleet replacement, only a portion is attributable to the costs of vessel electrification, which includes the cost of batteries, rapid charging system, and other electrification support systems. Vessel costs include components to maintain compatibility with the terminal and accommodate vehicle and walk-on passenger level of service requirements.

WSF has estimated that cost of electrification on the Hybrid Electric Olympic at roughly $14 million per vessel[4]. Extrapolating this to 16 vessels, the marginal cost of electrification for new vessels is only 6.5% of the total new vessel cost, as represented in Figure 18.

Table 2: Electrification Conversion and Construction Cost Estimates

	No. of Vessels	Estimated Cost[1]
Hybrid-Electric Conversion		
JMII	3	$116.1 M
KDT	3	$143.2 M
Total conversion		**$259.3 M**
New Hybrid-Electric		
HEO	5	$1,000.9 M
New 124	4	$727.5 M
New 144	7	$1,716.8 M
Total new hybrid		**$3,445.2 M**
TOTAL Vessel Investment		**$3,704.5 M**

[1] The investment costs displayed above have been adjusted for cost escalation to the year of investment. While total costs do include the cost of program management, this cost is not shown in the table values. Numbers may not sum due to rounding.

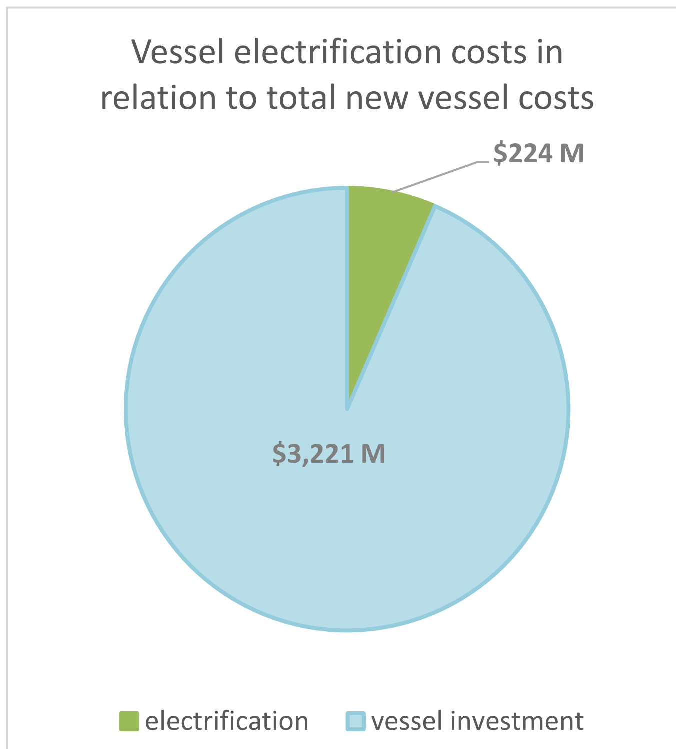


Figure 18: Marginal Cost of New Vessel Electrification

[4] The $14million marginal cost is a preliminary estimate that includes the value of the Rapid Charging System (RCS). There will be variations to the marginal cost of electrification for each new vessel class as a result of individual route variations, battery bank sizes, and RCS configurations.

Terminals

This plan calls for 17 electrification projects at 16 of WSF's 20 terminals to meet the 2030 and 2040 emissions reduction requirements. Total escalated investment cost for these 16 terminals is projected to be $280 million dollars over the planning period.

Planned completion times and fiscal year 2020-level cost estimates for electrification at the 16 terminals are presented in Table 3.

In addition to investment in terminal infrastructure to support this System Electrification Plan, the 2040 Long Range Plan recommended terminal projects include improvements to passenger queuing and processing at six terminals, improvements to accommodate expansion of the reservation system to additional routes, and expansion of vehicle queuing and loading at three terminals. The investment category of terminals also includes maintenance and preservation projects, as well as the Eagle Harbor Maintenance Facility, which plays a critical role in the reliability of the system.

The total capital investments including electrification costs and other preservation and improvements projects can be found in Appendix F.

Table 3: Estimated Terminal Costs[1]

Terminal	Estimated Cost[1]
Near-term	
Clinton	$11.6 M
Seattle	$24.7 M
Bainbridge	$13.9 M
Medium-term	
Kingston	$13.4 M
Bremerton	$12.5 M
Southworth	$15.6 M
Fauntleroy	$13.6 M
Vashon	$18.2 M
Long-term	
Pt. Defiance	$11.7 M
Coupeville	$15.0 M
Port Townsend	$11.7 M
Anacortes	$18.6 M
Orcas	$11.7 M
Friday Harbor	$11.9 M
Shaw	$11.9 M
Lopez	$13.0 M
TOTAL Terminal Investment	**$228 M**

[1]The investment costs displayed above are shown in constant 2020 dollars for comparative purposes. While total costs do include the cost of program management, this cost is not shown in the table values. Numbers may not sum due to rounding.

Operating Costs

The financial analysis conducted for the SEP groups operating program expenditures into three categories: labor, energy, and other. Labor encompasses the largest operating cost. Current energy costs account for approximately 14% of WSF's annual operating costs, roughly $38.5 million. This trend would continue without the implementation of hybrid-electric propulsion, which will reduce the reliance on diesel fuel and result in energy cost savings. However, during implementation, the operating program will incur new expenditures, such as new training for the workforce and ongoing support of the new technology. Simultaneously with the SEP, as outlined in the LRP, WSF will replace retiring vessels, expand its maintenance and reserve fleet, and enhance service levels.

The fiscal year 2020 budget forms the baseline for all future SEP operating expenditures. The impacts of service disruptions and reduced ridership resulting from the corona virus have not been considered. New costs or cost savings associated with the LRP and SEP are added or subtracted from the FY 2020 baseline. Each year's projected annual expenditures are inflated using standard cost escalation factors. Figure 19 shows the projected operating costs for the SEP planning period, which include operating costs with electrification. Of particular note is the relatively level cost of energy over a period of increasing fleet size and service levels, another reflection of operating cost savings from electrification. Full details are included in Appendix F.

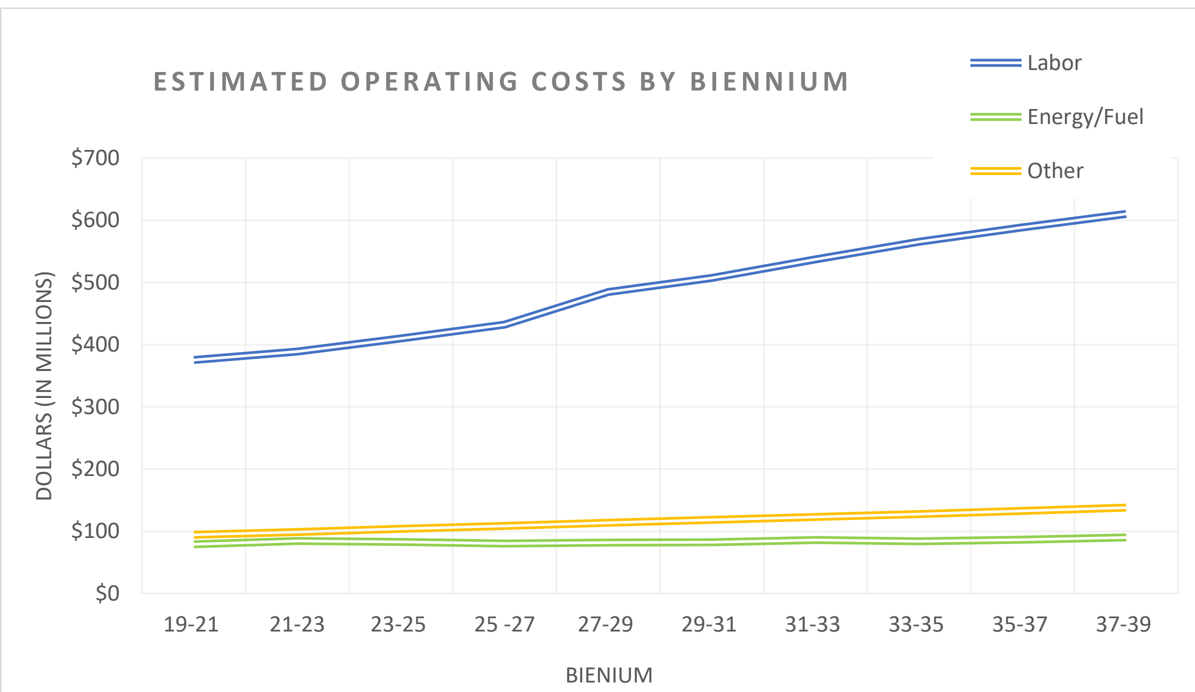


Figure 19: Estimated Biennium Operating Costs by Category with Electrification

Labor

Three primary factors drive changes in the level of labor expenditures. Two of these factors are unrelated to electrification and include service enhancements and expansion of the fleet size. What is unique to the electrification program is the additional training requirement due to introduction of hybrid-electric propulsion. The additional labor expenditures for training are one time for each new vessel delivered to the fleet. Labor changes related to expansion of the fleet and service enhancements are phased and ongoing. As discussed in Appendix E, there may be labor cost adjustments related to new skills and requirements for electrification. However, the financial impact of these potential changes cannot be determined without further analysis and planning and have not been incorporated into the labor cost projections. Electrification program management is incorporated in the capital investment plan and discussed in the capital investment section of the report.

Energy expenditures

The greatest cost savings to WSF operating expenditures occur as reliance on diesel propulsion is replaced by hybrid-electric propulsion. In this time of historically low fuel prices, establishing a base level of expenditure and forecasting future expenditure levels, is particularly challenging. Despite the recent low fuel prices, trends over the last 23-years show a steady increase in cost with some years of extreme volatility in pricing. It can be assumed this price volatility for fossil fuels may continue into the future. In contrast, the history of electricity prices in the Pacific Northwest has been very stable. It is unknown if increased demands for electricity will alter these costs in the future, however the volatility is not in the past or currently represented in electricity pricing data over time.

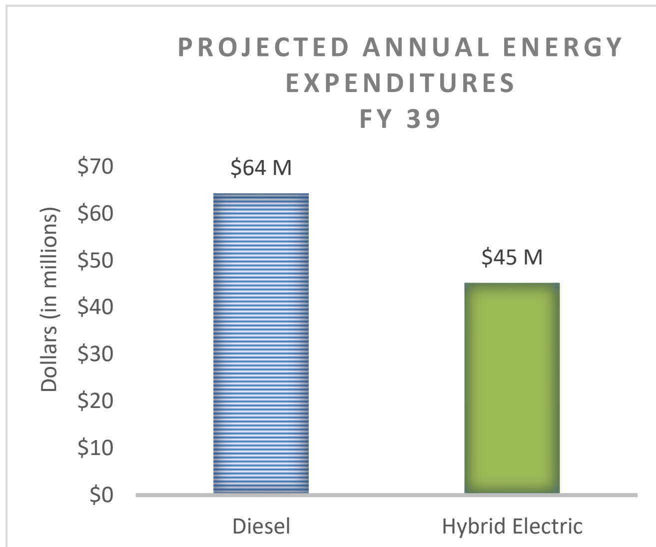


Figure 20: Energy Expenditures in FY 2039

For every $0.10 change in fuel price, WSF experiences an annual fuel expenditure difference of approximately $1.9 million.

As depicted in Figure 20, energy expenditures of WSF's fully electrified system in FY 39 will be 30% lower than they would be with diesel propulsion. Detailed discussion of what is included in projected energy cost calculations is included in Appendix F.

Emissions Reductions

The capital investment outlined in this Plan will ultimately improve WSF's environmental and financial sustainability. While the success of the Plan can be measured in a number of ways, emissions reductions will be a crucial metric that gives WSF an opportunity to have a large-scale positive impact on the population, including non-ferry users. Emissions reductions can be calculated by tons of carbon, as well as the social benefits or "monetized value" of those reductions. This type of calculation is an attempt at highlighting impacts of projects, small and large, to identify social costs[5], or benefits. Through investments in this Plan, the social benefits of emissions reductions are great, reaching nearly $12 million dollars in annualized monetized value by eliminating nearly 180,000 metric tons of carbon emissions and its associated chemicals from the atmosphere. This has a positive impact locally, to those who work on and ride the vessels, live and work near terminals, as well as visitors to the greater Puget Sound. Beyond local and regional benefits are those to the entire state of Washington, the County and the planet as a whole. Figure 21 displays the monetized value of WSF's current reductions in 2020 and the projected annual emissions reductions achievable through implementation of the SEP.

RCW 70A.45.050 establishes a baseline for measuring carbon emissions and emission reduction targets through 2050. As identified in this report, these targets are only achievable by WSF with the investment in hybrid-electric vessels and supporting shore-side terminal charging capabilities which result in carbon emission reductions of 53% by 2030 and 76% by 2040. Additionally, toxic pollutant emissions are estimated to decrease by 59% by 2040.

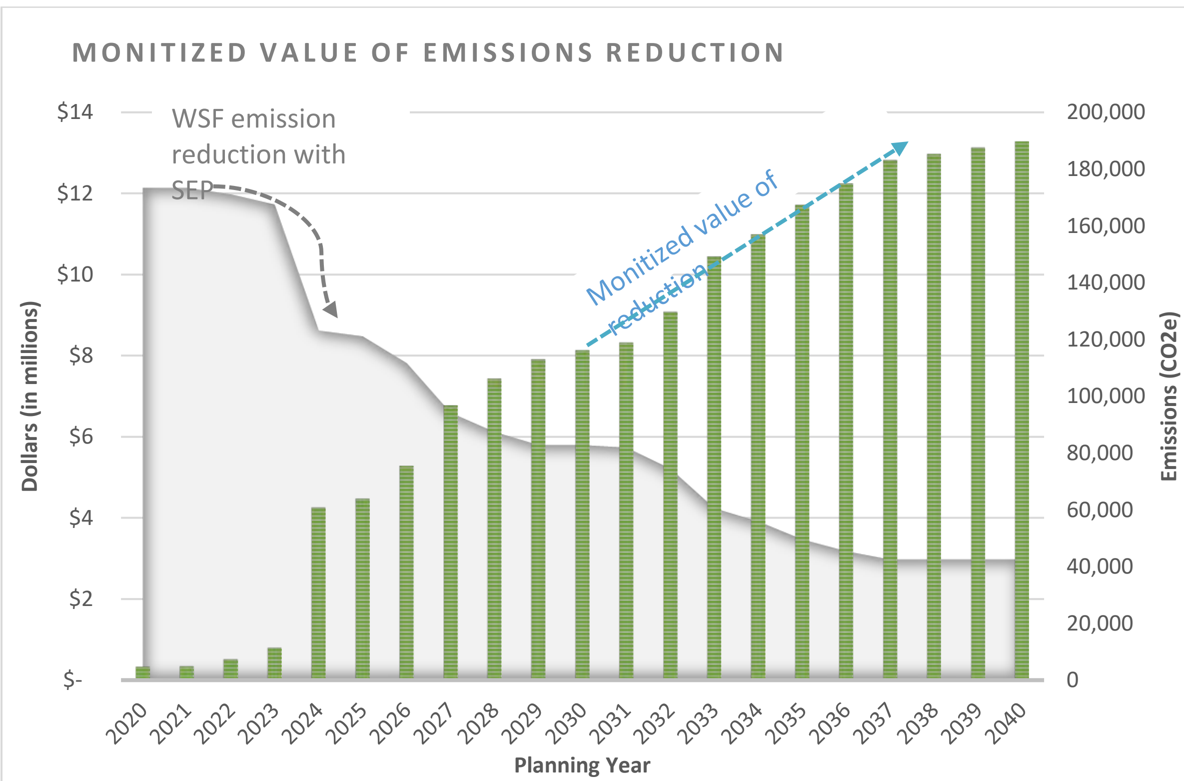


Figure 21: Emissions Reduction and the Associated Monetized Value

[5] Social costs of carbon metric are intended to include (but is not limited to) changes in net agricultural productivity, human health, property damages from increased flood risk, increased heating and cooling costs, etc. The cost factors for the social cost of carbon are published by the US Government Interagency Working Group.

Funding Opportunities

System electrification funding

Many elements of the electrification program will position WSF to compete well in national and regional discretionary funding competitions due to the program's significant reductions in diesel fuel consumption with associated air quality benefits. The Jumbo Mark II (JMII) vessel conversion and terminal electrification on the Seattle / Bainbridge route, in particular, achieved significant milestones by establishing important funding relationships regionally and nationally.

In 2018, WSF applied for and was awarded its first piece of funding for system electrification:

> **$6.5 million** from the PSRC Congestion, Mitigation & Air Quality (CMAQ) program for conversion of two JMII vessels on the Seattle / Bainbridge route. Terminal electrification at Seattle and Bainbridge terminals is on a contingency list for an additional $6 million in CMAQ funding if funds come available in 2023-24.

In 2019, WSF secured a significant Marine Highway Project Designation for the Seattle / Bainbridge route electrification from the USDOT Maritime Administration (MARAD). This designation has set the course for WSF to apply for subsequent rounds of project enhancement funding through MARAD for both vessel and terminal elements of the electrification on that route. WSF was initially awarded:

> **$1.5 million** from MARAD for the development of Plans, Specifications & Engineering for vessel conversion and will continue to develop this funding relationship in subsequent years.

Also, in 2019, WSF signed a grant agreement with the state DOE for $35 million from the VW Settlement Mitigation Fund for the design and conversion of the first JMII vessel serving the Seattle / Bainbridge route. This represents the single largest grant award for a WSF capital project.

WSF should continue to nurture relationships with its current funding partners while also monitoring and evaluating future opportunities for diesel fuel reduction and electrification

Current funding sources

Washington State Ferries (WSF) currently receives formula funding from two federal agencies:

- Federal Highway Administration (FHWA) Ferry Boat Program and the Federal Transit Administration (FTA) Urbanized Area Formula programs.

In addition, project-based competitive grant funding from a variety of sources continue to be pursued, which include:

- FTA's Passenger Ferry Grant program
- Puget Sound Regional Council's (PSRC) Regional FTA and FHWA Discretionary Programs
- Department of Homeland Security's Port Security Grant Program
- State Department of Ecology (DOE) VW Settlement Funding
- Maritime Administration's Marine Highway Program.

funding through Environmental Protection Agency, Department of Energy, and other federal and regional entities. WSF should also cultivate new partnerships (both conventional and non-traditional) such as through local electric utilities who may have access to sources of grant funding not currently available to WSF for the program, as well as local stakeholder agencies, energy services companies, and the private sector.

Funding challenges

Federal grantors and funding programs apply many scoring criteria, rules, regulations, and waivers which vary by agency and which may limit the use of their funding on elements of the System Electrification program.

Buy America/Buy American Requirements (BA) – Buy America (FTA / FHWA) and Buy American (all other federal programs) in general require the use of American made products and materials in federally funded projects. Elements of the electrification program cannot always meet a given agency's BA requirements. WSF will need to strategically evaluate specific elements of the system electrification program to BA requirements as it considers which funding sources it may apply to those elements.

Geographic Preference - Federal regulations prohibit geographical preferences in making contractor selections except for architecture and engineering (A&E) contracts. This has limited the use of federal funding on WSF's new vessel construction which has a build in Washington requirement. It would also exclude from federal funding any future elements of system electrification which incorporate geographic preference.

Financial Capacity/State Matching – Many grant competitions place a significant value on a grantee's financial capacity to leverage a share of its own funding as match for federal funding requests and provide scoring incentives based on the % of matching contribution. In addition, many agencies evaluate the grantee's financial capacity to alternatively fully fund the project. This has presented challenges for WSF recently in securing funding for terminal electrification, as WSF cannot currently point to authorized state matching funds for this element of the Seattle / Bainbridge electrification. It would be incumbent upon WSF to secure both legislative support and approval of new elements of electrification, as well as some level of authorized state funding for those elements, to demonstrate

JMII Conversion balance of funding strategies

As an example, FHWA's Buy America requirements include a waiver for ferry vessels (not terminals) for: marine diesel engines, electrical switchboards and switchgear, electric motors, pumps, ventilation fans, boilers, electrical controls, and electronic equipment. This waiver has allowed WSF to invest FWHA funding (CMAQ) in the equipment procurement and/or retrofit of the JMII vessels. FTA and MARAD do not have such a waiver which has precluded the use of both FTA and MARAD funding for actual vessel conversion and equipment.

the desired financial capacity for potential grantor agencies.

Additional Planning Efforts

Transitioning WSF's fleet to use hybrid-electric propulsion will require planning and investment over the next two decades. As propulsion technology is rapidly evolving, advancements must be continually assessed ahead of design and construction efforts.

Complete implementation of the System Electrification Plan will require more detailed planning efforts. In the near term, the following studies are anticipated:

Vessels:

- **124-Car Class – Triangle Route Study**—to assess two vs. three-sided charging on the route.
- **KDT Hybridization and Maneuvering Study**—to understand and improve upon maneuverability of the class during hybridization, which will add weight (and therefore draft) to the vessel. The KDT Class vessel is the only vessel in the fleet that can serve the Coupeville terminal due to its tidal conditions and resulting shallow water approach.
- **San Juan Islands Electrification Study**—to determine feasibility and required improvements to provide electric charging at terminals in the San Juan Islands. Findings will inform design of the new 144-Car Class.
- **Vessel Pre-Design Studies**—to finalize route specific requirements for electrification, including crossing energies, passenger and vehicle capacities and vessel dwell time.

Terminals:

- **Seattle Terminal Space Planning Study**—the current Seattle Multimodal Terminal at Colman Dock Project was planned and designed before system electrification planning was underway, and further study will be needed to fully understand the infrastructure required to power the Bremerton and Bainbridge routes.
- **Terminal Pre-Design Studies**—This assessment is needed for all WSF projects with program costs greater than five million dollars. Each terminal electrification would qualify above this threshold. There are some instances where electrification projects are scheduled on a similar timeframe as other planned preservation and improvement projects. Any electrification improvement pre-design study should address the following:
    - **Power Demands—**The power demands and operating schedule for each route to be electrified should be reviewed and refined to provide final design requirements for each terminal prior to the design of improvements and selection of electrical equipment.
    - **Utility Coordination**—An Engineering Service Agreement with the utility serving each terminal to be electrified will be needed to conduct additional trade-off

studies to determine the optimum combination of grid improvements and batteries at each terminal, as well as to provide more accurate utility cost estimates.

- **Equipment Siting Studies**—Additional analysis of the existing terminal configurations and electrification equipment requirements is necessary to verify the viability of the locations identified and develop improved cost estimates for the terminal improvements.

Section 6:
Closing Observations

As established in the LRP, investments in the fleet are necessary to maintain levels of service and system reliability. New vessel delivery, as called for in the 2040 Long Range Plan, brings enhanced technology and more efficient systems. When making these large capital investments to replace an aging fleet, the additional investment in electrification can make a big difference in the overall air quality and health of people living in our region, state, and world. The additional cost of electrification on vessels and terminals is relatively minor, less than 13% of the four billion FY20 dollars of capital improvements for converting six vessels, constructing 16 new hybrid electric vessels, and 17 terminal projects. This investment will result in sustained lower energy costs and reduced societal costs for years to come.

Through investments in this Plan, the social benefits of emissions reductions are expected to reach nearly $12 million dollars in annualized monetized value by eliminating nearly 180,000 metric tons of carbon emissions from the atmosphere.

Vessel enhancements alone will not meet mandated emissions reduction. Investments in terminals is necessary to fully realize emissions reduction and meet the requirements of Executive Order 20-01 and RCW 70A.45.050.

This undertaking will require investment in the management of the program itself to deliver 16 new vessels, six diesel conversions and 17 terminal electrification projects at 16 terminals. While ambitious, it should be noted again the vessels and terminals already require recapitalization in the normal course of operating the system, electrification is but a small, targeted improvement during that effort. In addition, workforce training, and a public information campaign on this new technology are required. If successful, electrification of the Washington State Ferry system will be the largest contributor to emissions reductions within the State Government, and an example for ferry system electrification around the world.

WSDOT

Washington State Ferries