Zero Emission Fleet Transition Plan

Island Transit

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1. Executive Summary

In an effort to decrease reliance on fossil fuels and reduce its carbon emissions, Island Transit is considering transitioning its fixed route fleet to zero emission technology. To achieve this goal the agency plans to replace its existing fossil fueled vehicles (19 transit-style buses and 13 cutaways are used for fixed-route service) with a mix of hydrogen fuel cell electric buses (FCEBs) and battery-electric buses (BEBs). In a parallel effort, the agency is also planning to replace the remainder of its fleet of 114 sedans, vans, and cutaways – used for paratransit, ridesharing, and other demand-response service – with battery-electric vehicles.

As one of the primary motivations behind Island Transit's fleet conversion is emissions reduction, the agency explored the transition's emissions impact. The emissions reduction potential for fuel cell vehicles depends heavily on the electricity production technology. With current generation technology, use of FCEBs with "green" hydrogen (an energy-intensive production method) will only decrease emissions by 22%. However, if state goals for carbon-neutrality are met, emissions reductions will rise to 99%, yielding a fleetwide emissions reduction of 97%.

Island Transit also analyzed the transition's impact on total cost of vehicle and infrastructure ownership. In general, any transition to zero-emissions vehicles requires additional upfront capital spending, as the vehicles are more expensive and require specialized charging or fueling infrastructure. In most cases, recurring costs (operations and maintenance) remain constant or decrease. Although the newly installed infrastructure must be maintained – for a hydrogen station, at significant expense – lower maintenance and charging costs outweigh this additional spending. Over a 12-year vehicle lifecycle, the total cost of ownership is expected to increase by 7%.

Given the results and other key qualitative concerns such as safety, technological maturity, resource availability, construction feasibility, operational logistics, and workforce readiness presented in the Technology Assessment Report, Island Transit prefers to adopt a mixed fleet, with FCEBs on Whidbey Island and BEBs on Camano Island. With this strategy, the agency will have to commission a hydrogen fueling station at the Whidbey Depot in 2026 and begin replacing the fleet with FCEBs as quickly as funding limitations allow. Island Transit will construct charging infrastructure at the Camano depot and begin purchasing BEBs for that island by 2028. According to this plan, the transition will conclude by 2035. However, as the zero-emissions bus market is rapidly evolving, the agency is encouraged to stay up to date on the latest developments and revise its fleet transition plans accordingly.

2. Introduction

Island Transit provides fare-free transit and paratransit service on Whidbey and Camano Islands in northwestern Washington State. The agency has committed to reduce its emissions and its fossil fuel dependence while continuing to offer its riders sustainable and reliable transportation. The agency started its journey to a carbon-free future by adding hybrid-electric buses and propane cutaways to its fleet. In addition, Island Transit ordered five, all-electric sedans to test the vehicle's feasibility to support the agency's on-demand services. To continue this transition and make an even larger impact, Island Transit commissioned a study to evaluate the feasibility of battery electric and fuel cell electric buses for its fixed route operations. The study aimed to develop a fleet transition strategy as part of Island Transit's commitment to FTA's "Sustainable Transit for a Healthy Planet Challenge."

The Federal Transit Administration (FTA) also requires that all agencies seeking federal funding for "Zero-Emissions" bus projects under the grants for Buses and Bus Facilities Competitive Program (49 U.S.C. § 5339(b)) and the Low or No Emission Program (49 U.S.C. § 5339(c)) complete a fleet transition plan. Specifically, the FTA requires that each transition plan address the following:

- Demonstrate a long-term fleet management plan with a strategy for how the applicant intends to use the current request for resources and future acquisitions.
- Address the availability of current and future resources to meet costs for the transition and implementation.
- Consider policy and legislation impacting relevant technologies.
- Include an evaluation of existing and future facilities and their relationship to the technology transition.
- Describe the partnership of the applicant with the utility or alternative fuel provider.
- Examine the impact of the transition on the applicant's current workforce by identifying skill gaps, training needs, and retraining needs of the applicant's existing workers to operate and maintain zero-emissions vehicles and related infrastructure and avoid displacement of the existing workforce.

As part of this study, Island Transit's operation was analyzed in detail to determine the right zero emissions technology for the agency's unique operating environment. Based on the analysis, a fleet transition plan was developed to serve as a roadmap for Island Transit. The transition plan also addresses details on building electrical capacity, building spatial assessment, emissions impacts, resiliency, and financial implications.

2a. Existing Conditions

Island Transit is a fare-free transit agency in Island County, Washington providing fixed route services to Whidbey Island and Camano Island. The agency currently owns and operates a fleet of 146 vehicles for both revenue and non-revenue use; these vehicles are powered by gasoline, diesel, propane, or hybrid propulsion systems. 114 of these vehicles are used for demand-response applications, including paratransit and rideshare service. The agency plans to introduce its first five electric vehicles in 2023: Tesla Model 3 vehicles are on order for future vanpool/rideshare usage and will be charged and stored at the Whidbey Island facility.

The agency's fixed-route operations fleet primarily consists of 19 transit buses. Cutaway shuttle vehicles are also used for the fixed route services, though the vehicles are often diverted to serve paratransit customers as necessary. Table 1 below shows Island Transit's bus and cutaway fleet. Of these vehicles, approximately 32 are used for transit service (including spares) at any one time, with the remainder operating paratransit service.

Table 1 Current Vehicle Roster

Make	Model	Year	Type	Quantity	Fleet Numbers	Fuel Type
Gillig	Phantom 35	2003	Bus	1	118	Diesel
Gillig	Phantom 40	2007	Bus	4	119-20, 122-3	Diesel
Gillig	Low Floor 40	2009	Bus	2	124-5	Diesel
Gillig	Low Floor 40	2011	Bus	4	126-9	Diesel
Gillig	Low Floor 29	2019	Bus	2	130-1	Diesel
Gillig	Low Floor 35	2020	Bus	3	132-4	Hybrid
Gillig	Low Floor 29	2021	Bus	2	135-6	Diesel
Gillig	Low Floor 35	2022	Bus	1	137	Diesel
Chevrolet	Kodiak Goshen	2009	Cutaway	2	250, 259	Diesel
Ford	E450 Glavel	2019	Cutaway	5	265-9	Propane
International	-	2012	Cutaway	1	411	Diesel
Freightliner	Legacy SC2	2018	Cutaway	20	413-32	Diesel
Chevrolet	C3500 Goshen	2012	Cutaway	3	505, 512, 514	Gasoline
Chevrolet	C3500 Goshen	2018	Cutaway	5	515-9	Gasoline
Ford	E450 Eldorado	2019	Cutaway	10	520-9	Propane

Island Transit operates 16 fixed routes: 11 on Whidbey Island and five on Camano Island. No routes directly connect the two islands. The agency currently operates six days a week, with plans to add Sunday service, and expanded evening service, in the near future. Except as noted otherwise, the remainder of this study considers seven-day service with the expanded evening service. The services currently operated are as follows:

[Whidbey] Route 1

- Roundtrip service between Oak Harbor and Clinton Ferry.
- Operates approximately every 30-60 minutes Mondays to Fridays.
- Operates approximately every 60-90 minutes on Saturdays.

[Whidbey] Route 2

- Services Whidbey Island, connecting Harbor Station, Oak Harbor High School, Ault Field Road, and Senior Center/Pool.
- Operates typically every hour Mondays to Fridays.

- Operates approximately every one-two hours on Saturdays.

[Whidbey] Route 3
- Services East Oak Harbor on Whidbey Island.
- Operates five round trips Mondays to Fridays.

[Whidbey] Route 411W
- Roundtrip service between Oak Harbor and March’s Point.
- Operates approximately every hour Mondays to Fridays.
- Operates approximately every two hours on Saturdays.
- Connecting service to Skagit Transit at March’s Point.

[Whidbey] Route 6
- Roundtrip service between Oak Harbor and Coupeville Ferry.
- Operates Mondays to Fridays, with headways between 30 minutes and two hours.

[Whidbey] Route 9
- Services West Oak Harbor on Whidbey Island.
- Operates approximately every hour Mondays to Fridays.

[Whidbey] Route 10
- Services Central Oak Harbor on Whidbey Island.
- Operates approximately every 15-30 minutes Mondays to Fridays.
- Operates approximately every 15-60 minutes on Saturdays.

[Whidbey] Route 58
- Service between Clinton Ferry and Scatchet Head.
- Operates two roundtrips for AM service Mondays to Fridays.
- Operates two roundtrips for PM service Mondays to Fridays.

[Whidbey] Route 60
- Roundtrip service between Bayview and Clinton Ferry.
- Operates approximately every 30-60 minutes Mondays to Fridays.
- Operates approximately every 60-90 minutes on Saturdays.

[Whidbey] Clinton Commuter
- Roundtrip service connecting Clinton Ferry to Clinton P&R and Humphrey Rd. Park and Ride.
- Operates approximately every 30 minutes Monday to Friday afternoons.

[Whidbey] NASWI Commuter
- Roundtrip service connecting Harbor Station to Naval Air Station on Whidbey Island.
- Operates two roundtrips for AM service Mondays to Fridays.
- Operates two roundtrips for PM service Mondays to Fridays.
- Service provided to NASWI personnel only.

[Camano] Route 1

- Services West Camano.
- Operates approximately every 30-75 minutes Mondays to Fridays.
- Operates approximately every hour on Saturdays.

[Camano] Route 2

- Services East Camano.
- Operates approximately every 30-75 minutes Mondays to Fridays.
- Operates approximately every hour on Saturdays.

[Camano] Route 3

- Roundtrip service connecting Camano and Stanwood.
- Operates approximately every 30-60 minutes Mondays to Fridays.
- Operates approximately every hour on Saturdays.

[Camano] Route 411C

- Roundtrip service connecting Camano and Mount Vernon.
- Operates seven round trips Mondays to Fridays.
- Operates three round trips on Saturdays.
- Connecting service to Skagit Transit at Skagit Station.

[Camano] Route 412

- Roundtrip service connecting Camano and Everett Station.
- Operates five round trips Mondays to Fridays.
- Connecting service to Sound Transit at Everett Station

3. Technology Options

The agency considered both battery-electric and hydrogen fuel cell vehicles for its fixed routes. Island Transit's long routes, comparatively unreliable electrical supply, space-constrained terminals, and remote asset deployment challenges indicated that neither technology was immediately obvious or correct solution. Therefore, a feasibility study considered all vehicle types outlined below for its fixed route operation. The fixed route operation is served by a mix of transit buses and cutaway shuttles while the paratransit service is served by the cutaway shuttles. Island Transit plans to phase out the cutaway shuttles in the future due to the changes in the ridership demand and a limited options for zero emission alternatives. Some fixed routes that are served with cutaway shuttles today will be served by 35' or 40' zero emission transit buses. The duty of the cutaway shuttles for the paratransit service will be fulfilled by vans in the future. Since electric vehicles are the only viable zero emission vehicles in the market for vans, the portion of the cutaway shuttles that are currently used for paratransit operation will be replaced with electric vans in the future.

3a.Battery Electric

Today, a wide range of BEBs are available on the market. Compared to conventional diesel buses, these vehicles eliminate the diesel propulsion engine, most of the transmission, and other associated components. The buses are equipped with large batteries, typically mounted under the floor or on the roof, that supply power to the traction motors. One of the primary differentiating factors between models is the available battery capacity, ranging from 160 kWh to 738 kWh on common bus models available today. This wide capacity range primarily presents a cost and maintainability tradeoff. Although more capacious batteries allow the bus to travel farther, they cost significantly more to purchase and place additional weight on the bus. This added weight increases the strain on axles, suspension, and other components. To ensure maximum competition during procurement and minimize the agency's exposure to risk associated with industry-leading technology, this study assumed a battery capacity of 492 kWh, which is representative of the products offered by a range of established vendors. The market is changing quickly, with a battery capacity increase of approximately three percent per year; vehicles procured later will likely have larger battery capacities than the ones available today.

A consideration for both current and future batteries is that the advertised "nameplate" capacity is not entirely usable for daily operations. To ensure that buses can be operated daily throughout their useful life, two types of safety margins were subtracted from the nominal battery capacities. First, due to aging, the battery was assumed to have only 80% available capacity. As batteries degrade over time, their capacity decreases. Typically, if the capacity declines by more than 20% the battery is replaced, either under a battery warranty or at the transit agency's expense. Second, it was assumed the bus needs to return to the garage before its level of charge falls below 20%. This is both a manufacturer's recommendation – batteries have a longer life if they are not discharged to zero percent – and an operational safety buffer to prevent dead buses from becoming stranded on the road. These two margins yield a usable battery capacity of 64% of the nameplate capacity.

3b. Hydrogen Fuel Cell

FCEBs are less common in the US transit market; only two major vendors offer them today. In fact, the market is so small that no 35' FCEBs are currently available. Although this is expected to change in coming years as the technology matures and more vendors enter the market, in the near-term Island Transit may be compelled to adopt 40' vehicles for its fuel cell bus procurements.

FCEBs are nearly identical to BEBs: an onboard battery supplies their electric traction motors with power. However, unlike BEBs where battery size determines the range, FCEBs are equipped with a hydrogen storage tank. The hydrogen passes through a fuel cell to generate electricity used to replenish the battery (which can be smaller than on a BEB as a result). Although this additional step decreases drivetrain efficiency significantly, this is mitigated by the additional range that is made available. Hydrogen storage tanks are typically made as large as reasonably practical because bus components, such as the fuel cell itself, contribute to most of the cost and weight of a fuel-cell bus independent of the required vehicle range. A representative bus on the market today can accommodate 37.5 kilograms (kg) of hydrogen. Like BEBs, this capacity is a theoretical maximum and must be reduced to account for real-world conditions. However, unlike batteries, hydrogen tanks do not lose capacity over time and do not degrade when they are fully drained. Therefore, a capacity reduction of approximately five percent is appropriate for daily operations, yielding a usable hydrogen capacity of 35 kg.

4. Operations Planning

Island Transit's current operating model for fixed-route services is similar to that of most transit agencies. Buses typically leave the depot in the morning, operate for as long as they are needed, and then return to the depot in the evening. Although Island Transit's schedulers must account for operator-related restrictions like lunch breaks and maximum shift lengths, the vehicles are assumed to operate for as long as they are needed. This assumption will be invalidated for zero-emissions vehicles; both hydrogen and batteries are low-density means of energy storage that do not provide the same vehicle range as gasoline or diesel fuel. In addition, seasonal factors become much more significant for zero-emissions vehicles, particularly for BEBs. Even when diesel heaters are installed, as was assumed in the feasibility study, icy road conditions and cold temperatures degrade the performance of the vehicles. Although practices to extend range like pre-conditioning the bus before leaving the depot are recommended, winter conditions will present challenges to zero-emissions vehicle operation. Island Transit's operating model will need to account for these limitations as service must operate year-round.

4a.Operations Simulation

A simulation was conducted to predict how zero-emissions vehicles would perform on Island Transit's routes. Simulation was necessary because the available range estimates – typically provided by vehicle manufacturers – are maximum values that ignore the effects of gradients, road congestion, driver performance, severe weather, and other agency-specific factors. Island Transit's network was analyzed on a route-by-route basis through the creation of "drive cycles" for several routes representing the agency's typical modes of operation, ranging from slower-speed urban routes to higher-speed routes through more rural areas. For each representative route, the full geography (horizontal and vertical alignment), transit infrastructure (location of key stops and transit hubs), and road conditions (vehicle congestion, traffic lights, stop signs, crosswalks, etc.) were modeled. The performance of both battery-electric and fuel cell vehicles was simulated in worst-case weather conditions to create a drive cycle. These Island Transit-specific drive cycles were used to calculate hydrogen or battery energy consumption per mile. This analysis provided information regarding the total hydrogen or battery energy consumed by a vehicle on each route.

Island Transit currently operates its vehicles across both fixed-route and demand-response services; a given vehicle can switch between fixed-route and demand-response operation several times a day. In the future the agency plans to eliminate this type of operation; vehicles will spend the full day on either fixed-route or demand-response services, but not both. As a result, this study used vehicle blocks exclusively for fixed-route operations, provided by Island Transit, and assumed that these would be operated whether zero-emissions vehicles were used or not. Figure

1 below presents the hydrogen / battery energy consumption for each of these current blocks, with the green line denoting the theoretical maximum capacity of the vehicle and the orange line denoting the practical capacity, accounting for operating margin as discussed in Section 3.

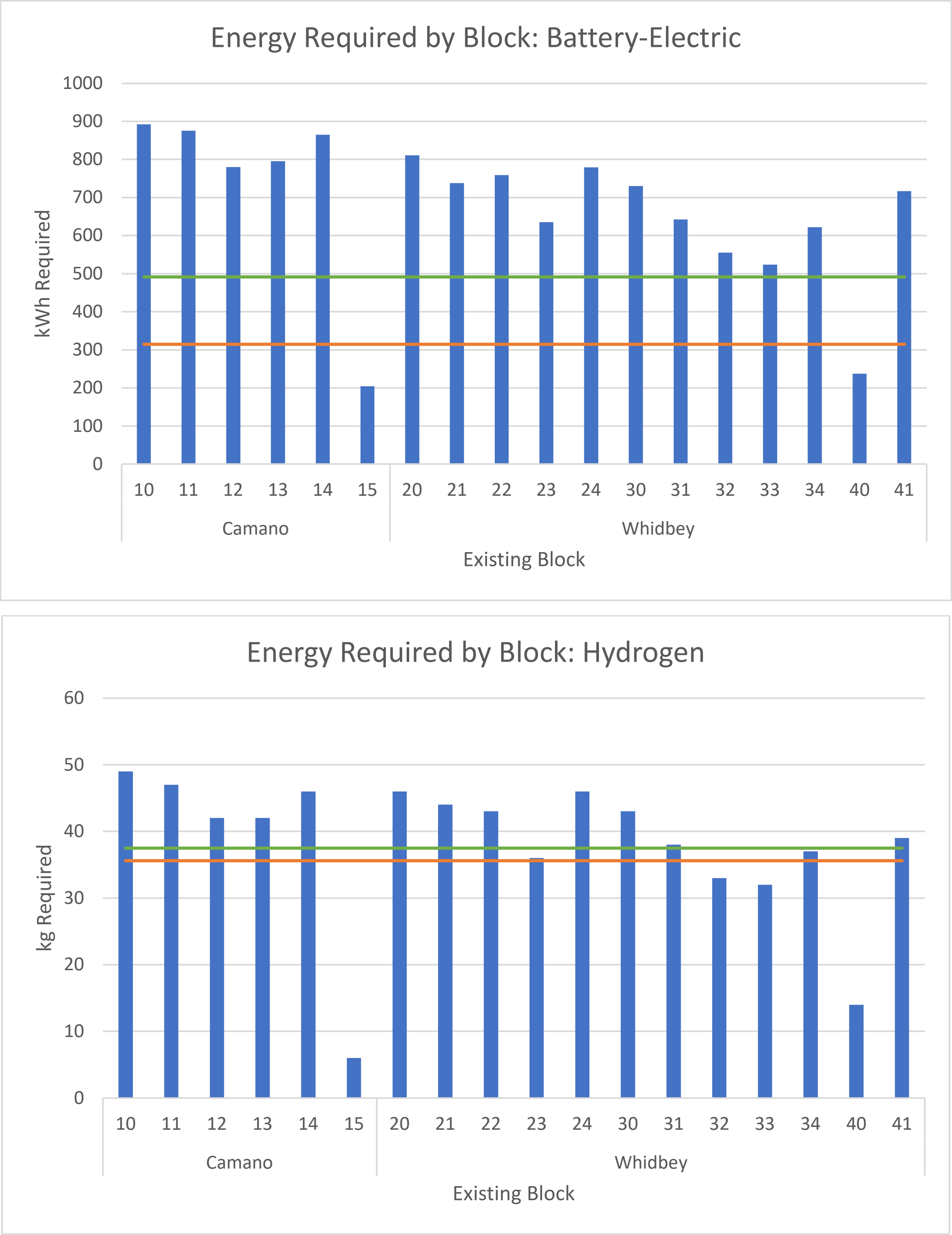

Figure 1 Energy Required for Operation of Existing Blocks

As shown in Figure 1, zero-emissions vehicles do not have sufficient range for most blocks currently operated by Island Transit. To address these limitations, Island Transit will have to operate the existing blocks to the extent possible and replace buses that have exhausted their range with fresh vehicles from the depot. Swapping buses in and out of service throughout the day allows the length of each block to be balanced with the available range of each vehicle. In addition, this “depot swapping” option allows service operation without reliance on “field” infrastructure. However, the primary downside of this option is the additional deadheading required to cycle buses in and out of the depot. Particularly in cases where the depot is far away from the route terminal – as on Whidbey Island – additional energy use and driver time would be required. Additionally, despite extra deadheading time all passenger trips would still require service; this will necessitate an increase in fleet size. The use of FCEBs will partially mitigate this concern, as they have longer range than BEBs, but some degree of deadheading will still be required for all zero-emissions vehicles. Another option for BEBs is to install on-route chargers at the hubs and use layover times to extend vehicle range. However, this option requires reliance on “field” infrastructure to be installed and maintained, often in coordination with external stakeholders.

The block schedules shown in Figure 1 are for Island Transit’s current operation. However, as mentioned above, the agency is expanding its service starting in May 2023. Although the future schedules have not yet been developed, the impact on the blocks and resulting total service fleet was estimated for the above-described operating scenarios based on the scope of the proposed expansion.

For efficient operations, the schedule (and perhaps even the route structure) would require modifications. For example, buses recharging or refueling while drivers are taking a lunch break or starting/ending their shifts ensures that drivers are not waiting unproductively while their vehicles’ range is replenished. Interlining is also important to minimize unproductive deadheading time. On Whidbey Island, the hubs are located far away from the depot, requiring significant deadheading for midday recharging or refueling. However, Route 6’s southern terminal at the Coupeville Ferry Terminal is less than a ten-minute drive from the depot. Therefore, buses on Route 6 can be swapped out for fresh vehicles with little wasted time or mileage. Introducing interlining between Route 6 and the other Oak Harbor routes will allow those routes to be operated efficiently as well; buses with nearly exhausted range would operate a trip on Route 6, be replaced with a fresh bus at the depot, and return to Oak Harbor to continue service on another route, while a separate bus would operate the next Route 6 trip. Although such tweaks increase operating complexity, they help minimize wasted mileage and driver time.

Given the operational limitations outlined above, and the impracticalities associated with installation of on-route charging, Island Transit has selected a mixed-fleet operating model. The agency will operate FCEBs on Whidbey Island, fueling them at the depot in Coupeville, and operate BEBs on Camano Island, charging them at the smaller facility there.

4b. Infrastructure for Hydrogen Operations

Hydrogen storage and fueling infrastructure is required for FCEB fleet operation. On-site hydrogen production is also an option for consideration. However, the daily usage of hydrogen must be significant in order to achieve the economies of scale required to make on-site production economical and feasible. Therefore, hydrogen delivery was assumed in this study.

For a hydrogen fueling station, the main variable in configuring its size is the number of vehicles that must be refueled per day. The size of the liquid hydrogen storage tank, the rating for the vaporizer, the number of hydrogen dispensers and fuel delivery frequency is determined based on the daily consumption. On Whidbey Island, the storage tank is estimated to be 12,000 gallons with two dispensers. The hydrogen deliveries are estimated to be on a weekly basis.

4c. Infrastructure for Electric Operations

Charging infrastructure is required for operating battery electric vehicles. There are several complexities to consider when deciding on the charging infrastructure.

The most important parameter is the expected peak charging rate for a given location, as this determines the size of the electrical hardware and affects utility billing. Vehicles typically sit for extended periods overnight at depot so there is room for fine-tuning to decrease agency costs. Charge management systems are typically deployed for this optimization. Without any charge management, vehicles would likely be plugged in to charge at full power (usually 150 kW) as soon as they arrive at the depot. This would potentially expose them to higher-priced electricity, before the overnight period with low power costs begins, and if several vehicles arrived near the same time the peak power rate would increase significantly. On the other hand, with optimal charge management, vehicles would only be charged during the overnight low-cost period, and charging would occur gradually across all vehicles to minimize peak power load. If possible, the charge management system would be programmed with the vehicle schedule for the following day, ensuring that vehicles reach full charge when they are needed for entry into service. Figure 2 below presents an example charging schedule for BEB operation of the current schedule on Camano Island assuming that charge management is fully utilized at the depots. Without charge management systems the peak demand – and therefore the size of the required utility feed – would be significantly higher than shown here.

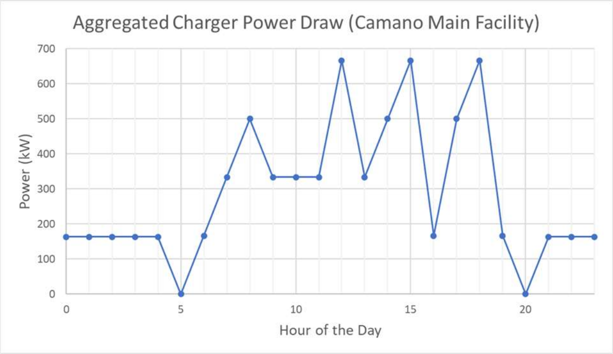

Figure 2 Optimized Charging Schedules

5. Facility Evaluations

Either battery-electric or fuel-cell vehicles represent a substantial transition for Island Transit's typical mode of operations. Accordingly, the agency's facilities must be able to accommodate the new vehicles and required supporting infrastructure. This section details the spatial and electrical ability of the depots to accommodate electrical charging or hydrogen storage and fueling for fixed-route vehicles.

5a.Spatial Capacity

Island Transit has two main facilities. The Whidbey Island facility, located at 19758 Route 20 in Coupeville, is comprised of two buildings for Administration and Maintenance. Agency vehicles can be stored outside, as shown in Figure 3, but vanpools are typically parked overnight at operators' homes. A PSE utility survey was conducted to determine the infrastructure conditions and needs to support future electric vehicle charging, including that of the five Tesla rideshare vehicles currently on order. The initial evaluation indicated that the facility has the capacity to support up to five DCFCs, which the agency intends to install for the vanpool vehicles. Even after these chargers are installed, there is ample space on the facility grounds to install a hydrogen fueling station for fixed-route vehicles. Because of the different vehicle classes and power requirements, these assets would likely be separate from the planned charging stations for a large-scale electric demand-response fleet, which would likely be placed on existing curbs in the southeastern parking lot.

Figure 3 Whidbey Island Facility Maintenance Building and Outdoor Vehicle Storage

Additionally, the maintenance building will need substantial upgrades. The upgrades could include installation of hydrogen sensors, upgrades to light fixtures, new electrical wiring, and upgrades to the HVAC system among other things. The HVAC system will make up a large portion of the total building modification costs. Island Transit is already considering upgrades to the HVAC system in the maintenance building (shown in Figure 4) since the current geothermal heating system is proving inadequate for colder days. The agency could consider the transition to hydrogen fuel cell vehicles as the opportunity to make the necessary upgrades and share the upgrade cost between both projects.

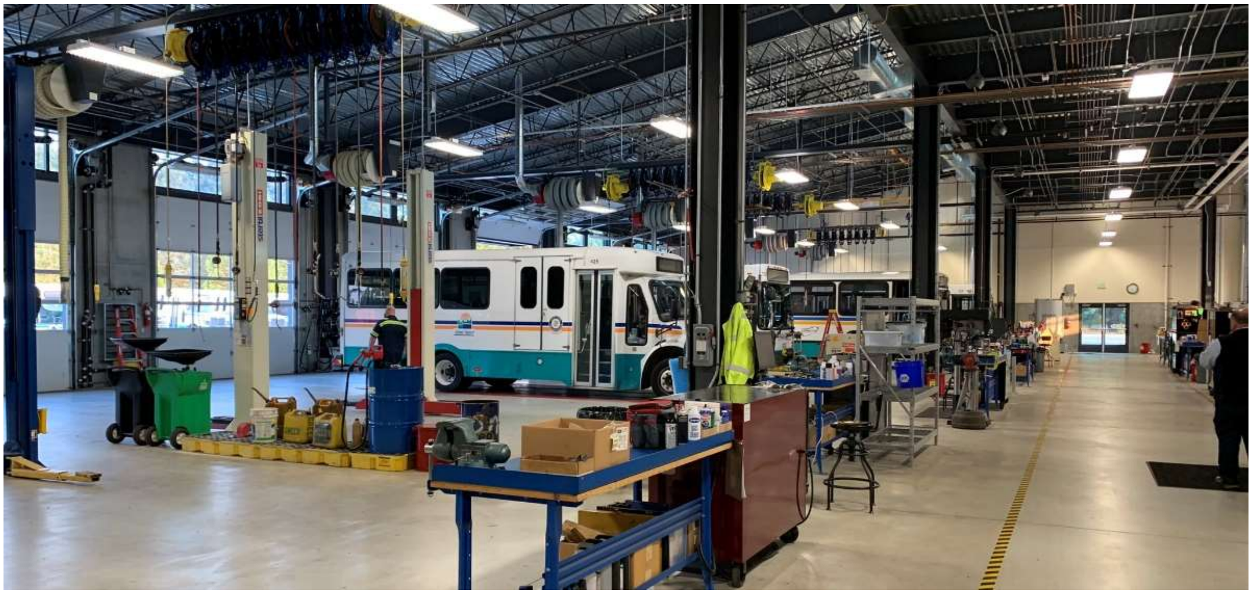

Figure 4 Whidbey Island Facility Maintenance Building Interior

The Camano Island facility, located at 198 N Can Ku Rd. in Camano and shown in Figure 5 below, has limited space for potential fueling or charging stations. All fueling is currently done off-site at a nearby Island County facility. Electric vehicle chargers could be installed in several locations on the property, including the north side of the employee parking lot, the southern edge of the vehicle parking area, or a new mid-lot curb.

Figure 5 Camano Island Facility

Because of land ownership issues, route scheduling, use of FCEBs on Whidbey Island, and expected vehicle range, Island Transit's transit hubs, such as Oak Harbor, Clinton Ferry, and Terry's Corner, were not considered for on-route charging.

5b. Electrical, Infrastructure, and Utility Capacity

Island Transit's two facilities have different utility providers. Puget Sound Energy (PSE) is the utility provider on Whidbey Island, including the depot in Coupeville. Snohomish County Public Utility District (PUD) is the utility provider for the Camano Island facility. As part of the development of this transition plan, Island Transit partnered with both utilities to communicate its projected future utility requirements at each of the locations.

The storage and maintenance facility in Coupeville has a 480V 3-phase service which is stepped down using a 300kVA transformer, shown in Figure 6 below. The power is distributed within the facility using 480V panels. The current transformer and distribution system is not sufficient for the charging infrastructure's power requirements for demand-response vehicles; even if comparatively low-power 7.2 kW Level 2 chargers are installed, and assuming that 50% of demand-response vehicles charge at the driver's home or another location, roughly 400 kW of power will be required to charge the remainder of Whidbey's demand-response fleet each night.

Figure 6 Whidbey Island Coupeville Facility Distribution Transformer

The peak energy requirement for hydrogen fueling infrastructure is also nontrivial, as the cryogenic pumps usually make up a large portion of the electrical load. Pumps large enough for the Whidbey depot's operational needs would likely range from 350 kW to 700 kW (depending on the manufacturer). Therefore, the current electrical system and utility service will either need upgrades or a new dedicated transformer and outdoor distribution system for any operating scenario.

The depot on Camano Island has a single phase 120/240 V service which is provided from a utility pole located at the north end of the facility on Can Ku Road. The single-phase pole mount service transformer is shown in Figure 7 below.

Figure 7 Service Transformer at the Camano Island Storage Facility

This service is not adequate for or compatible with the power requirements of DCFCs. The service may be adequate for one or two low-power level 2 chargers for demand-response vehicles, but this alone would not meet Island Transit's zero-emissions goals. Therefore, the facility will need a new three phase 480V service, including new metering, to serve both fixed-route and demand-response vehicles. As with PSE on Whidbey Island, extensive coordination with PUD will be required to realize this upgrade.

5c. Risks

Every new vehicle procurement brings about a certain degree of operational risk to the agency. Even when the existing fleet is replaced 'in-kind' with new diesel, gasoline, or propane vehicles, there are new technologies to contend with, potential build quality issues that must be uncovered, and maintenance best practices that can only be learned through experience with a particular bus. Converting to zero emissions vehicles makes some failure modes impossible – for example by eliminating the fossil fuel propulsion engine – but introduces others. For example, the ability to provide service becomes dependent on the continuous supply of electricity to the charging location. To convert to zero emissions vehicles, it is important to understand these risks and the best ways to mitigate them.

The vehicle and wayside technology required for zero emissions bus operation is in its early stages; few agencies have operated their fleets or charging/fueling assets through a complete lifecycle of procurement, operation, maintenance, and eventual replacement. This exposes zero-emissions bus purchasers to several areas of uncertainty:

- Technological robustness: By their nature as newer technology, many zero emissions vehicles (and their associated charging / fueling infrastructure) have not had the chance to stand the test of time. Although many industry vendors have extensive experience with fossil fuel buses, and new vehicles are required to undergo Altoona testing, some of the new designs will inevitably have reliability shortcomings.
- Battery performance: The battery duty cycle required for transit buses – intensive, cyclical use in all weather conditions – is demanding, and its long-term implications on battery performance are still being studied. Though manufacturers have recommended general principles like battery conditioning, diesel heater installation, and preferring lower power charging to short bursts of high power, best practices in bus charging and battery maintenance will become clearer in coming years. This concern is most critical for BEBs, though it also affects the batteries on FCEBs.
- Supply availability: Compared with other types of vehicles, zero emissions buses (particularly BEBs) are especially vulnerable to supply disruptions due to the small number of battery vendors and worldwide competition for raw materials such as lithium. As society increasingly shifts to electricity for an ever-broader range of needs, from heating to transportation, both the demand and the supply will need to expand and adapt. FCEBs have several additional concerns as well: hydrogen availability is a constraint due to the lack of companies producing it, and the market for fuel cells, storage tanks, and hydrogen pumps is similarly limited.
- Lack of industry standards: Although the market has begun moving toward standardization in recent years – for example through the adoption of a uniform bus charging interface – there are many areas (e.g. battery and depot fire safety) in which best practices have not yet been developed. This may mean that infrastructure installed early may need to be upgraded later to remain compliant.
- Reliance on wayside infrastructure: Unlike diesel buses, which can refuel at any publicly accessible fueling station, BEBs require DCFCs for overnight charging and specialized pantograph chargers for midday fast charging. Particularly early on, when there is not a widespread network of public fast chargers, this may pose an operating constraint in case of charger failure. Similarly, FCEBs require reliable access to hydrogen fueling stations for daily operations. There are not currently any hydrogen fueling stations available in Washington State, though two are under construction in Chehalis and East Wenatchee. This small market can pose a constraint on the use of FCEBs if Island Transit’s fueling station requires maintenance or is out of commission for any other reason.

- Fire and explosion risk: As discussed below, both BEBs and FCEBs have some fire and explosion risks (as, of course, fossil fuel vehicles do as well). These risks are low-probability but must still be understood and mitigated.

The batteries on BEBs and FCEBs require special consideration from a fire risk perspective. A bus battery is a dense assembly of chemical energy. If this large supply of energy begins reacting outside of its intended circuitry, for example due to faulty wiring or defective or damaged components, the battery can start rapidly expelling heat and flammable gas, causing a “thermal runaway” fire. Given their abundant fuel supply, battery fires are notoriously difficult to put out and can even reignite after they are extinguished. Furthermore, without prompt fire mitigation the dispersed heat and gas will likely spread to whatever is located near the bus. If this is another zero-emissions bus then a chain reaction can occur, with the heat emanating from one bus overheating (and likely igniting) the batteries of another bus. This can endanger all the buses in the overnight storage area. Mitigations are recommended for these risks. Increasingly sophisticated battery management systems are being developed on the vehicles themselves, ensuring that warning signs of battery fires – such as high temperature, swelling, and impact and vibration damage – are quickly caught and addressed. Though research is ongoing, most battery producers believe that with proper manufacturing quality assurance and operational monitoring the risk of a battery fire can be minimized.

The infrastructure best practices for preventing fire spread with battery-electric vehicles are still being developed. There are partially relevant standards for the storage of high-capacity batteries indoors for backup power systems, such as UL9540, NFPA 70, and NFPA 230, and the primary components of any fire mitigation strategy are well understood. These include detectors for immediate discovery of a fire, sprinklers to extinguish it as much as possible, and barriers to prevent it from spreading to other buses or the building structure. In terms of staffing, it is recommended that staff be located nearby to respond in case of a battery fire and move unaffected buses out of harm’s way.

The use of hydrogen introduces additional challenges. Hydrogen has a greater risk of fire or explosion than gases like methane or natural gas due to its wider flammability limits, lower minimum ignition energy, and higher typical storage pressure. Although fuel cell vehicle designs take these risks into account, depots and storage areas require special design considerations. For example, NFPA and OSHA regulations limit how close a hydrogen storage tank can be placed to property lines, buildings, or other structures. Facilities serving fuel-cell vehicles must also be designed accordingly. For instance, blow-out windows are required to dissipate the force of any indoor explosion before it affects the structural integrity of the building. Hydrogen leakage is another potential issue; gaseous hydrogen is a small molecule so small leaks are common. Hydrogen is colorless, odorless, and tasteless, so leaks are hard to detect. It is lighter than air and highly flammable, so an indoor leak is very dangerous because the hydrogen will accumulate under the ceiling and pose an explosion risk. Hydrogen fuel cell vehicle maintenance and storage facilities must be designed (or retrofitted) with this in mind: unventilated peaks in the roof (such as skylights) are not permitted, and spark-producing equipment (such as light fixtures) cannot be located within a certain distance of a flat ceiling. Unlike battery-electric vehicles, where the infrastructure standards are still being developed, the requirements for hydrogen fuel cell vehicle fueling stations and maintenance depots are well established; however, they typically impose a significant financial burden on agencies with existing, constrained facilities.

All these risks are likely to be resolved, or at least better understood and mitigated, as zero-emissions bus technology develops. Given Island Transit's enthusiasm for zero-emissions vehicles and small fleet size, the agency should consider several strategies to maximize operational robustness:

- As part of vehicle procurements, require the zero-emissions bus vendor to have a technician on site or nearby in case of problems. This is most economical when the technician is shared with several nearby agencies.
- Reach a "mutual aid" agreement with a nearby transit agency that would let Island Transit borrow spare buses in case of difficulties with its fleet.
- Retain a small fossil fuel reserve fleet to ensure adequate backup for zero-emissions vehicles if any incidents or weather conditions require it.
- Develop contingency plans in case any charging or fueling location fails and operation must continue using another location(s).

6. <u>Lifecycle Cost</u>

To calculate the cost of this transition, a life cycle cost (LCC) model was constructed, using the net present value (NPV) method to compare future costs on an equivalent basis. This allows all costs incurred throughout the fleet transition to be considered in terms of today's dollars. The costs are based on the weekday service levels analyzed above and scaled to account for weekends and holidays. They include initial capital as well as operations and maintenance costs of the vehicles and supporting infrastructure for battery-electric and hydrogen fuel-cell fixed-route vehicles. These costs can then be compared to the costs of replacing the existing fossil fuel-based operation with another round of diesel vehicles, which were calculated similarly. Because of uncertainties with timing and scope of demand-response vehicle electrification, no synergies with that project were assumed. Table 2 below outlines the LCC model components, organized by basic cost elements, for fossil fuel, battery-electric, and fuel cell vehicles.

Table 2 Primary Cost Categories by Vehicle Type

Category	Fossil fuel (baseline)	Battery-Electric	Hydrogen fuel cell
Capital	Vehicle purchase	Vehicle purchase	Vehicle purchase
	Mid-life overhaul	Mid-life overhaul	Mid-life overhaul
		Battery replacement/warranty	Battery replacement/warranty
		Charging infrastructure	Fueling infrastructure
		Electrical infrastructure upgrades	Facility upgrades and code compliance work
		Utility feed upgrades	Hydrogen storage infrastructure
Operations	Fossil fuel	Electricity	Hydrogen fuel
			Hydrogen trucking
	Operator's cost	Operator's cost	Operator's cost
		Demand charges for electricity	
		Diesel fuel for auxiliary heaters	
Maintenance	Vehicle maintenance	Vehicle maintenance	Vehicle maintenance
		Charger maintenance	Hydrogen storage and fueling system maintenance
Financial incentives	Grants	Grants	Grants

Like any complex system, Island Transit has a range of ways it can fund, procure, operate, maintain, and dispose of its assets. In coordination with agency stakeholders, the following assumptions were developed to ensure that the cost model reflected real-world practices:

Capital Investment

- The lifespan of a bus is 12 years, in accordance with Island Transit practice.
- The Camano Island facility is not relocated.
- The maintenance building at the Whidbey Island facility is upgraded.
- Backup generators are installed at each vehicle charging location.
- 12-year battery warranties are purchased with the bus, removing the need for battery replacement at vehicle midlife.

Funding

- Federal grants cover 80% of the procurement cost for buses (of all types) as well as charging and hydrogen infrastructure.

Costs

- 3% year-over-year inflation
- 7% agency discount rate

Table 3 lists the operating and capital costs assumed for this study. These are based on Island Transit's figures and general industry trends and have been escalated to 2022 dollars where necessary.

Table 3 Estimated Costs

Asset	Estimated Cost Per Unit (2022 Dollars)
30' Transit Bus: Diesel	$531,000
30' Transit Bus: Battery-Electric	$978,000
30' Transit Bus: Hydrogen Fuel Cell	N/A
35' Transit Bus: Diesel	$546,000
35' Transit Bus: Battery-Electric	$1,009,000
35' Transit Bus: Hydrogen Fuel Cell	$1,150,000
40' Transit Bus: Diesel	$551,000
40' Transit Bus: Battery-Electric	$1,050,000
40' Transit Bus: Hydrogen Fuel Cell	$1,200,000
DC Fast Charger, Depot (Plug-in w/ 3 dispensers)	$270,000
DC Fast Charger, Pantograph Overhead	$635,000
Hydrogen Storage Tank, per kg	$1,000
Hydrogen Vaporizer, per kg per hour	$4,500
Hydrogen Chiller, per kW	$6,900
Hydrogen Fuel Pump	$99,000
HVAC Upgrades for Whidbey Island Building	$1,450,000
Operator Wages, Benefits, and Overhead, per hour	$44.08
Bus Maintenance, per mile: Diesel	$1.30
Bus Maintenance, per mile: Battery-Electric	$0.96
Bus Maintenance, per mile: Hydrogen Fuel-Cell	$1.19
Diesel Fuel, per gallon	$3.00
Hydrogen, per kilogram	$8.86
Generator Unit Cost per kW	$600

Because the transition to zero-emissions vehicles will be gradual, LCC calculations necessarily overlap multiple bus procurement periods. This was addressed by setting the start of the analysis period to the year when the last fossil fuel bus is proposed to be retired (2034), with the analysis period stretching for a full bus lifespan. For buses already on property at the beginning of the analysis period, or for buses with remaining life at the end, a residual value was calculated and added or subtracted as appropriate.

The LCC analysis determines the relative cost difference between the baseline (fossil fuel) case and the proposed case. Costs common to both alternatives, such as bus stop maintenance, are not included as they do not have a net effect on the LCC comparison. Thus, the model indicates the change in the LCC and does not represent the full or true cost of the two scenarios. Table 4 and Figure 8 summarize the NPV for the current and proposed future fleet.

Table 4 Life Cycle Cost Estimates

Category	Fossil Fuel Baseline	Future Fleet
Vehicle Capital Costs	$1,985,829	$4,660,973
Infrastructure Capital Costs	$0	$1,356,074
Vehicle Maintenance Costs	$13,661,649	$11,737,968
Infrastructure Maintenance Costs	$0	$1,157,995
Operational Costs	$27,614,182	$27,418,536
Total Life Cycle Cost	**$43,261,660**	**$46,331,545**

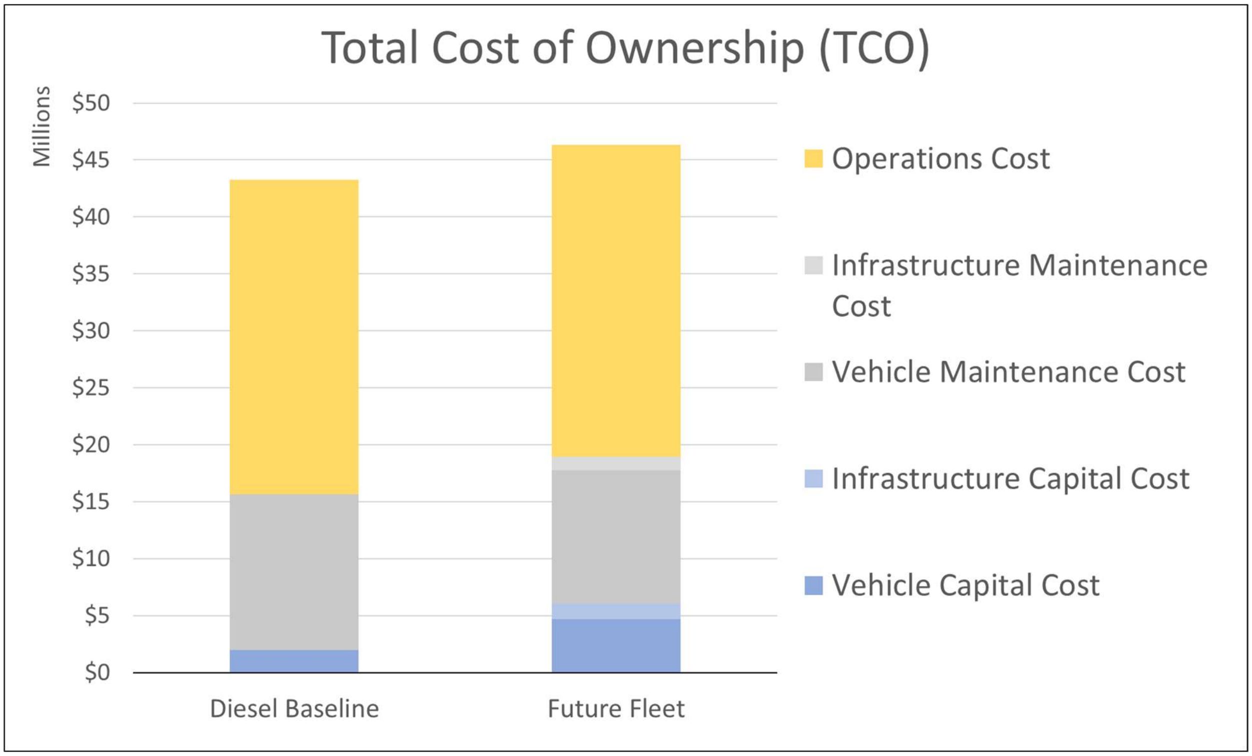

Figure 8 Life Cycle Cost Estimates

Capital costs are substantially higher for the zero-emissions option than for the diesel baseline option, due to both vehicle and infrastructure procurement costs. On a BEB, the primary expensive component is the battery; on a FCEB, the battery is accompanied by a hydrogen fuel cell for additional range extension, which increases the cost further. Consequently, vehicle acquisition cost is expected to increase by nearly 135% compared to the baseline. Infrastructure will contribute to upfront capital spending as well; although Island Transit will generate some economies of scale through the larger fleet on Whidbey Island and through sharing with demand-response vehicles on Camano Island, the cost of the Whidbey Island hydrogen fueling station (including the storage tank, vaporizers, chillers, pumps, safety upgrades, etc.) will overshadow these savings. These factors combine to yield a total capital cost increase of 203%.

On the other hand, zero-emissions vehicles, particularly BEBs, are expected to reduce recurring costs for both maintenance and daily operations. Maintenance costs will likely decline because of the simplified nature of BEBs' and FCEBs' drivetrains, which reduces brake wear, eliminates several maintenance-intensive components, and enables more advanced vehicle diagnostics. Even though the shift to BEBs and especially FCEBs introduces additional infrastructure that must be maintained, total spending on asset maintenance should decrease. Maintenance costs will decrease by approximately 6%, reflecting the balance between less maintenance-intensive vehicles and highly maintenance-intensive hydrogen infrastructure. Operating costs will decrease by 1%. The resulting total cost of ownership for the mixed fleet is estimated to be 7% more than the diesel fleet.

Each alternative requires initial capital spending to reduce recurring cost and achieve strategic goals over the fleet's lifetime. This finding is common to many transit projects and is representative of the transit industry, with nearly all bus and rail systems requiring capital investments up front to save money in other areas (traffic congestion, air pollution, etc.) and achieve broader societal benefits over the long term. By extension, just as with the transit industry at large, policy and financial commitment will be required from government leaders to achieve the desired benefits. The federal government's contribution to these goals via FTA and Low-No grants is already accounted for, leaving state and local leaders to cover the remaining increase in upfront capital cost.

The zero-emissions bus market is a new and developing space, with rapid advancements in technology. Although this study used the best information available to date to analyze the alternatives and recommend a path forward, it will be important in the coming years for Island Transit to review the assumptions underlying this report to ensure that they have not changed significantly. Major changes in capital costs, fuel costs, labor costs, routes, schedules, or other operating practices may make it prudent for Island Transit to modify vehicle procurement schedules or quantities, tweak operating schedules, or otherwise revise this report's assumed end state.

7. Emissions Impacts

One of the motivations behind Island Transit's transition towards zero-emissions buses is the State of Washington's goals to reduce emissions. While specific targets for public transportation have not been established, the state Clean Fuel Standard's goal to achieve a 20% overall emissions reduction by 2035 was considered as a target by Island Transit.

The anticipated emissions reductions from Island Transit's transition plan were calculated to quantify the plan's contribution toward meeting the state's emissions reduction goals. To provide a complete view of the reduction in emissions offered by the transition plan, the effects were analyzed based on three criteria:

Well-to-tank

- These are emissions associated with fossil fuel production and delivery.

Tank-to-wheel

- These are "tailpipe" emissions produced when the fossil fuel is used.

Energy Generation

- These emissions are associated with production of the electricity/hydrogen needed for vehicle operation. The two utilities that supply power to Island Transit (Puget Sound Energy on Whidbey Island and the Snohomish Public Utility District on Camano Island) each provide information on the emissions associated with their sources of electricity. These data were incorporated into the calculations below, reflecting the total emissions that would result from operation of zero-emissions vehicles if the grid did not change from its current state. However, the Washington State Clean Energy Transformation Act, signed in 2019, requires utilities to provide a fully emissions-neutral electricity mix by 2030. To account for these future grid emissions reduction goals, emissions reductions were also calculated assuming that utilities achieve these goals.

Table 5 below presents the types of emissions that are considered for each case.

Table 5 Types of Emissions

	Diesel	Battery-Electric	Hydrogen Fuel Cell
Well-to-tank	Fuel production, processing, and delivery	Diesel heater fuel production, processing, and delivery	Fuel production, processing, and delivery for hydrogen transport truck (East Wenatchee to Island Transit)
Tank-to-wheel	Use of diesel fuel for propulsion	Use of diesel fuel for cabin heating	Use of diesel fuel for propulsion for hydrogen transport truck (East Wenatchee to Island Transit)
Energy Generation	N/A	Electricity production from non-renewable sources	Grey Hydrogen: Emissions from hydrogen production
			Green Hydrogen: Electricity production from non-renewable sources to power hydrogen production

Table 6 and Figure 9 summarize the results of the emissions calculations. These results demonstrate the critical impact that electricity production technology has on emissions reduction, especially given that FCEBs will be used.

Table 6 Emissions Estimates

Scenario	Well-to-Tank (kg)	Tank-to-Wheel (kg)	Energy Generation (kg)		Total (kg) (Current)	Reduction	
			Current	Future		Current	Future
Baseline	2,000,583	3,443,272	-	-	5,443,855	-	-
Future Fleet (Grey H_2)	55,667	95,811	1,638,500	1,638,500	1,789,978	67%	67%
Future Fleet (Green H_2)	55,667	95,811	2,797,822	-	2,949,301	46%	97%

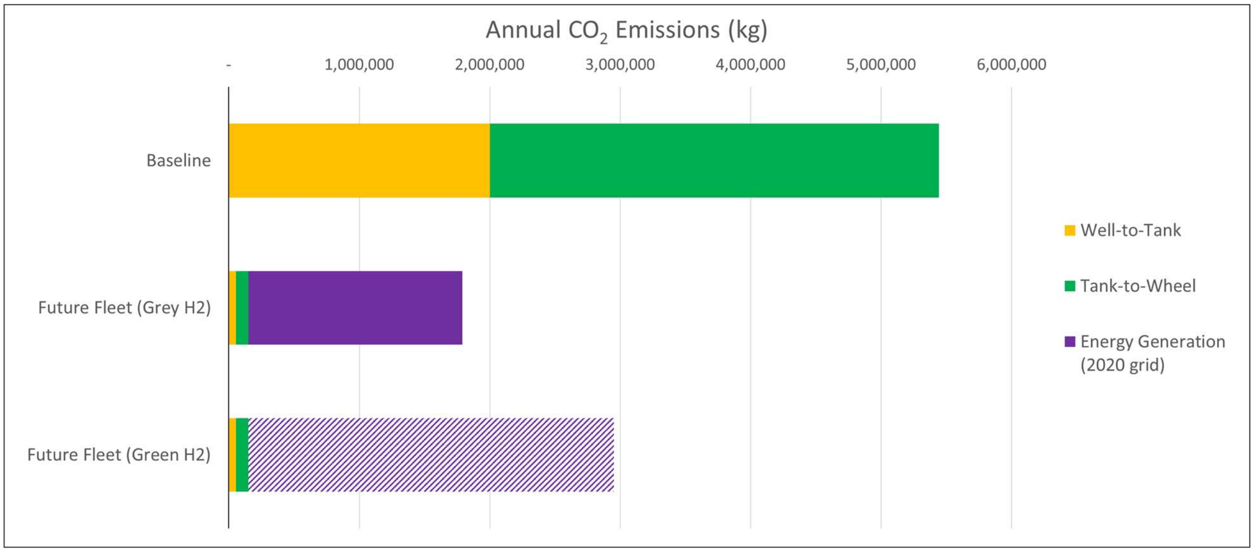

Figure 9 Emissions Estimates

The largest contributor, by far, to the carbon emissions from zero-emissions bus operation is the technology used to generate the electricity and/or hydrogen. For grey hydrogen, this is related to the fossil fuel that is burned during production. Although the large scale of such facilities increases the efficiency of fossil fuel burning compared to the small diesel engines found on buses, there are still inefficiencies related to the steam methane reformation process used to produce grey hydrogen. Hence, fleet operation using grey hydrogen only yields a 67% emissions reduction compared to the diesel baseline. For battery-electric operation and for green hydrogen, this is directly related to the composition of the Washington State grid. For the current grid composition, BEBs are the most climate-friendly technology because they avoid the energy expenditures (and the resulting emissions) associated with producing, transporting, storing, and using hydrogen. Once fully carbon-neutral electricity production is achieved, however, as much as 97% of emitted carbon being eliminated by a transition to the proposed fleet.

8. Asset Selection, Fleet Management, and Transition Timeline

A key decision for Island Transit relates to the procurement timelines for vehicles and supporting infrastructure. Island Transit, like almost all transit agencies, currently acquires buses on a rolling schedule. This helps lower average fleet age, maintain stakeholder competency with procurements and new vehicles, and minimize scheduling risks. However, this also yields a high number of small orders. For any bus procurement – and especially for a newer technology like BEB or FCEBs – there are advantages to larger orders, such as lower cost and more efficient vendor support. Because of this potential for economies of scale, as well as the large number of vehicles past due for replacement, Island Transit should consolidate the procurement timeline as outlined below.

Consolidation of vehicle procurements will also simplify the infrastructure installation timeline. FCEB operations are very capital-intensive because they require hydrogen pumping, storage, and potentially generation equipment at each fueling location. This makes deployment of only one or two FCEB at a given depot uneconomical. On the other hand, once the required infrastructure is installed, it is most efficient to convert the depot's entire fleet to FCEBs, maximizing the benefit of the installed equipment. Even for BEBs, the required retrofit of the depot for charger installation will be most economical for larger fleet sizes. For small depots, such as on Camano Island, an all-at-once conversion will have the benefit of keeping the facility consolidated; given the small size of that facility, minimizing the number of fuel types used there is beneficial.

To fulfill Island Transit's fixed-route operational requirements, the agency will need peak fleet sizes of 18 buses on Whidbey and eight buses on Camano Island. Given the agency's comparatively small fleet size, the long distance between the two depots, and the lack of any nearby fueling or maintenance facilities for hydrogen or heavy-duty battery-electric vehicles, a vehicle spare ratio of 30% is assumed on each island to ensure operational robustness. Although this exceeds the FTA guideline maximum spare ratio of 20%, that guideline only applies to agencies operating 50 or more revenue vehicles and is not applicable to Island Transit's fixed-route operation. In total, to fully convert its fixed-route operations to zero emission buses, Island Transit should procure 24 for Whidbey Island buses and 10 buses for Camano Island.

For charging stations and especially hydrogen fueling facilities, the agency will need to do significant permitting, grant-seeking, engineering, and construction work. In addition, as mentioned previously, many of Island Transit's existing vehicles are past due for replacement. For these reasons, Island Transit should plan to replace its entire Whidbey Island fixed-route fleet with zero-emissions vehicles as quickly as possible starting in 2026. This will allow sufficient time for the agency to design, fund, procure, install, and commission the required infrastructure ahead of the arrival of the first vehicles, and would avoid incurring the high cost of installing the infrastructure to serve only a few vehicles. On Camano Island, Island Transit should convert the facility (or construct a new one, if necessary) for zero-emissions operation by early 2028 and start procuring the battery electric fleet for entry into service in the same year. This would allow the transition on both Islands to begin almost simultaneously. At the same time, having two years gap between the two projects will allow Island Transit to more efficiently manage both projects internally with current resources.

Island Transit should consider several factors as it begins its transition to a zero-emissions fleet. First, FCEBs, and use of hydrogen for transportation in general, are largely unexplored in Washington State, posing significant uncertainty to the agency. Agency leaders should talk closely with other agencies in the state (such as Twin Transit) that will be operating FCEBs, as their experiences and incurred costs will likely be similar to Island Transit's. Second, because there are operational implications to owning a mixed fleet of both FCEBs and BEBs, the agency should consider these challenges and develop operational contingency plans before purchasing vehicles. Finally, the total cost of ownership of each technology is also a concern. Although federal grants mitigate much of the upfront cost of zero-emissions vehicles and infrastructure, the agency will need to identify funding sources for the recurring costs – ranging from charger maintenance to hydrogen fuel – that are less likely to qualify for grants.

Table 7 and Table 8 below show the preferred timeline for asset replacement over the transition period, taking into account limitations on vehicle order size related to availability of local matching funds.

Table 7 shows the start date for the process of facility upgrade development or vehicle procurement as well as the date when the facility or vehicle enters service for fixed route operation. For the infrastructure expansions, the estimated timeline for funding application and approval, detailed engineering, and construction for such projects can be up to three years. Hence, it is recommended that Island Transit begin the funding application and detailed design development for Whidbey Island immediately. For the vehicles, the agency will need to secure the funding and place order for the vehicle approximately two years before entry into service. The lead times for zero emission vehicles – approximately 18 to 24 months – are longer than diesel vehicles due to the developing supply chains and limited availability of the raw materials for battery and fuel cell production.

Table 7 Asset Procurement Timeline for Fixed Route Operation

Year (Start of Process)	Year (Entry into Service)	Asset	Replacing
2023	2026	Hydrogen storage / fueling station (Whidbey Depot)	N/A
2024	2026	Three 40’ hydrogen fuel cell buses Two 35’ hydrogen fuel cell buses	118-120, 1 cutaway, 1 new
2025	2027	Three 40’ hydrogen fuel cell buses Two 35’ hydrogen fuel cell buses	122-124, 1 cutaway, 1 new
2025	2028	Three centralized 150 kW chargers (Camano Depot)	N/A
2026	2028	Two 40’ hydrogen fuel cell buses Three 35’ battery-electric buses (492 kWh)	125-127, 2 cutaways
2027	2029	Four 35’ hydrogen fuel cell buses Two 40’ battery-electric buses (492 kWh)	128-129, 4 cutaways
2028	2030	Two 35’ hydrogen fuel cell buses Two 35’ battery-electric buses (492 kWh)	130, 3 cutaways
2029	2031	Two 35’ hydrogen fuel cell buses One 35’ battery-electric buses (492 kWh)	131, 2 cutaways
2031	2033	Four 35’ hydrogen fuel cell buses	132-135
2033	2035	Two 35’ battery-electric buses (492 kWh)	136-137

Figure 10 below shows the fleet composition for fixed route operation by year as new zero emissions vehicles enter service.

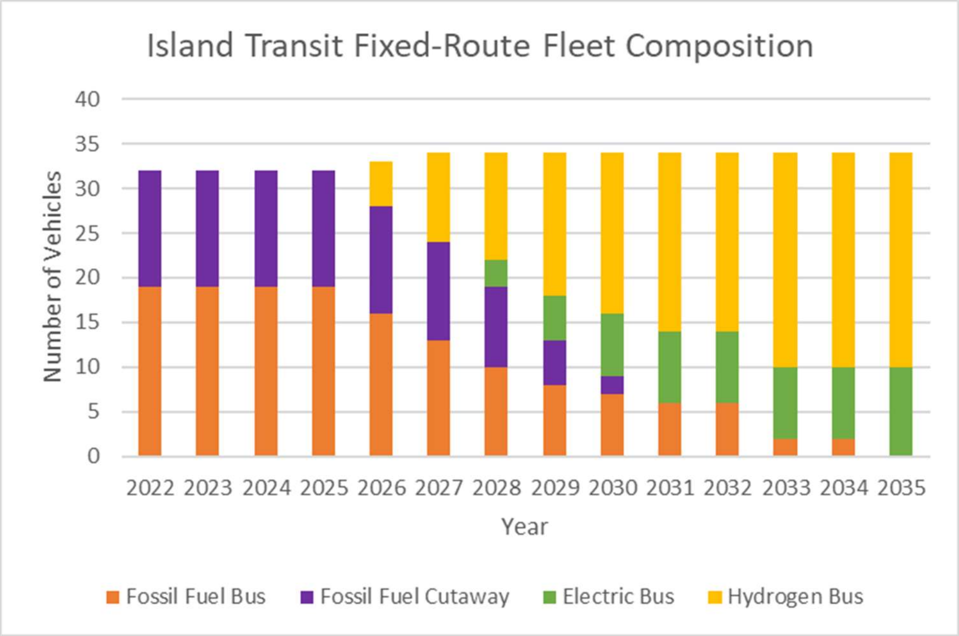

Figure 10 Fixed-Route Fleet Composition

Table 8 shows the start date for the process of charger installation or vehicle procurement as well as the date when the charger or vehicle enters service for paratransit and rideshare operation.

Table 8 Asset Procurement Timeline for Paratransit/Rideshare Route Operation

Year (Start of Process)	Year (Entry into Service)	Asset	Replacing
2022	2023	Five DC Fast Chargers (Whidbey Depot)	N/A
2022	2023	Five Electric SUVs	Five Fossil Fuel Light Vehicles
2023	2024	Five Electric Vans	Five Fossil Fuel Light Vehicles
2023	2025	New Chargers (Whidbey Depot)	N/A
2024	2025	Five Electric Vans	Five Fossil Fuel Light Vehicles
2025	2026	Five Electric Vans	Five Fossil Fuel Light Vehicles
2025	2027	New Chargers (Camano Depot)	N/A
2026	2027	Four Electric Vans	Six Fossil Fuel Light Vehicles
2026	2028	New Chargers (Whidbey Depot)	N/A
2027	2028	Six Electric Vans	Six Fossil Fuel Light Vehicles
2028	2029	Nine Electric Vans	Nine Fossil Fuel Light Vehicles
2028	2030	New Chargers (Whidbey Depot)	N/A
2029	2030	Nine Electric Vans	Nine Fossil Fuel Light Vehicles
2030	2031	Nine Electric Vans	Nine Fossil Fuel Light Vehicles
2030	2032	New Chargers (Camano Depot)	N/A
2031	2032	Nine Electric Vans	Nine Fossil Fuel Light Vehicles

2031	**2033**	New Chargers (Whidbey Depot)	N/A
2032	**2033**	Nine Electric Vans	Nine Fossil Fuel Light Vehicles
2033	**2034**	Nine Electric Vans	Nine Fossil Fuel Light Vehicles
2033	**2035**	New Chargers (Whidbey Depot)	N/A
2034	**2035**	Nine Electric Vans	Nine Fossil Fuel Light Vehicles
2035	**2036**	Eight Electric Vans	Eight Fossil Fuel Light Vehicles
2036	**2037**	Five Electric Vans	Five Fossil Fuel Light Vehicles
2036	**2038**	New Chargers (Whidbey Depot)	N/A
2037	**2038**	Three Electric Vans	Three Fossil Fuel Light Vehicles
2038	**2039**	Three Electric Vans	Three Fossil Fuel Light Vehicles

Figure 11 below shows the fleet composition for Paratransit and Rideshare operations by year as new zero emissions vehicles enter service.

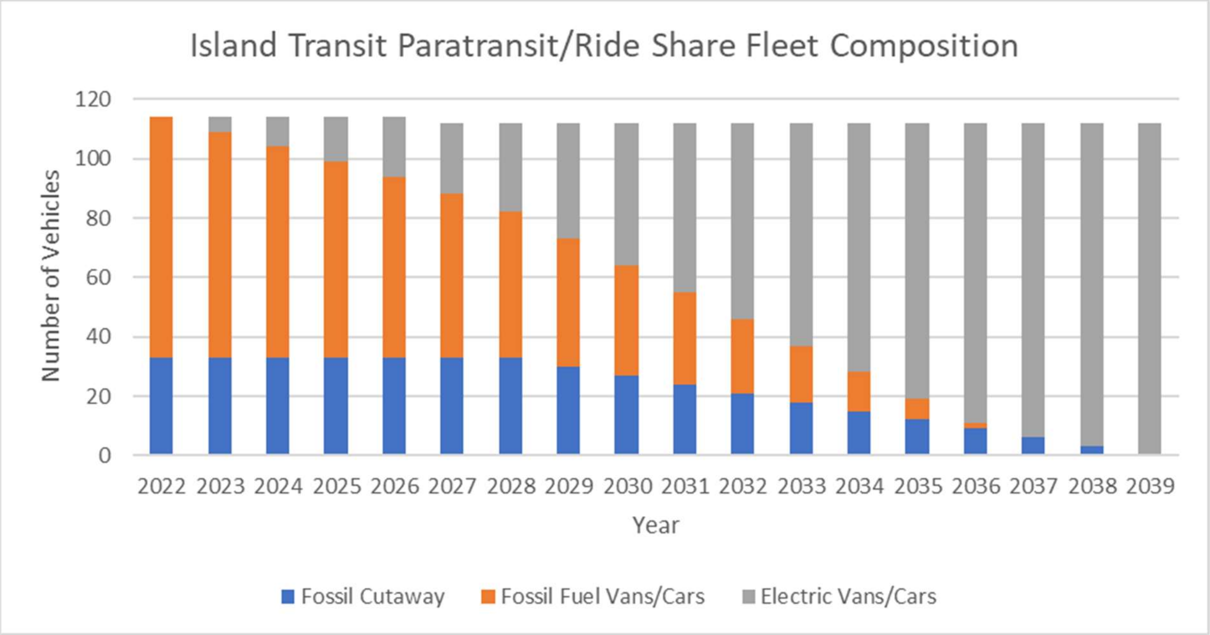

Figure 11 Paratransit/Rideshare Fleet Composition

9. Conceptual Infrastructure Design

As discussed above, the infrastructure required to support zero-emissions vehicles (fast chargers and battery maintenance areas, or hydrogen storage, pumping, and fuel-cell repair areas) has many bespoke requirements restricting how it can be installed in an existing (or even in a new) facility. Although a detailed engineering study of each location would be required to create a full design, this section presents conceptual layouts to help Island Transit leaders understand the impact the new infrastructure will have on each location.

The agency's Whidbey Depot in Coupeville is its largest and most versatile facility. It has the space to accommodate the minimum setbacks between hydrogen tanks and adjacent buildings, property lines, and other fueling systems that are required by NFPA code. Even on such a large site, however, these safety regulations, and the large footprint of a hydrogen fueling station, restrict the placement of such a station to only a few locations on the property. Figure 12 below shows a conceptual layout for one such location, near the existing bus wash and fueling building. Given the hydrogen storage tank size of approximately 10,000 gallons, a hydrogen station footprint of approximately 30' by 85' was assumed; this would provide sufficient space for the tank itself, the pumps, chillers, vaporizers, and other equipment to handle the hydrogen, and the electrical equipment to power each of these items. Two hydrogen pumps were assumed to be installed in the nearby fueling lane, and a protective wall was proposed east of the hydrogen station because of the inadequate setback distance between the station and the nearby property line.

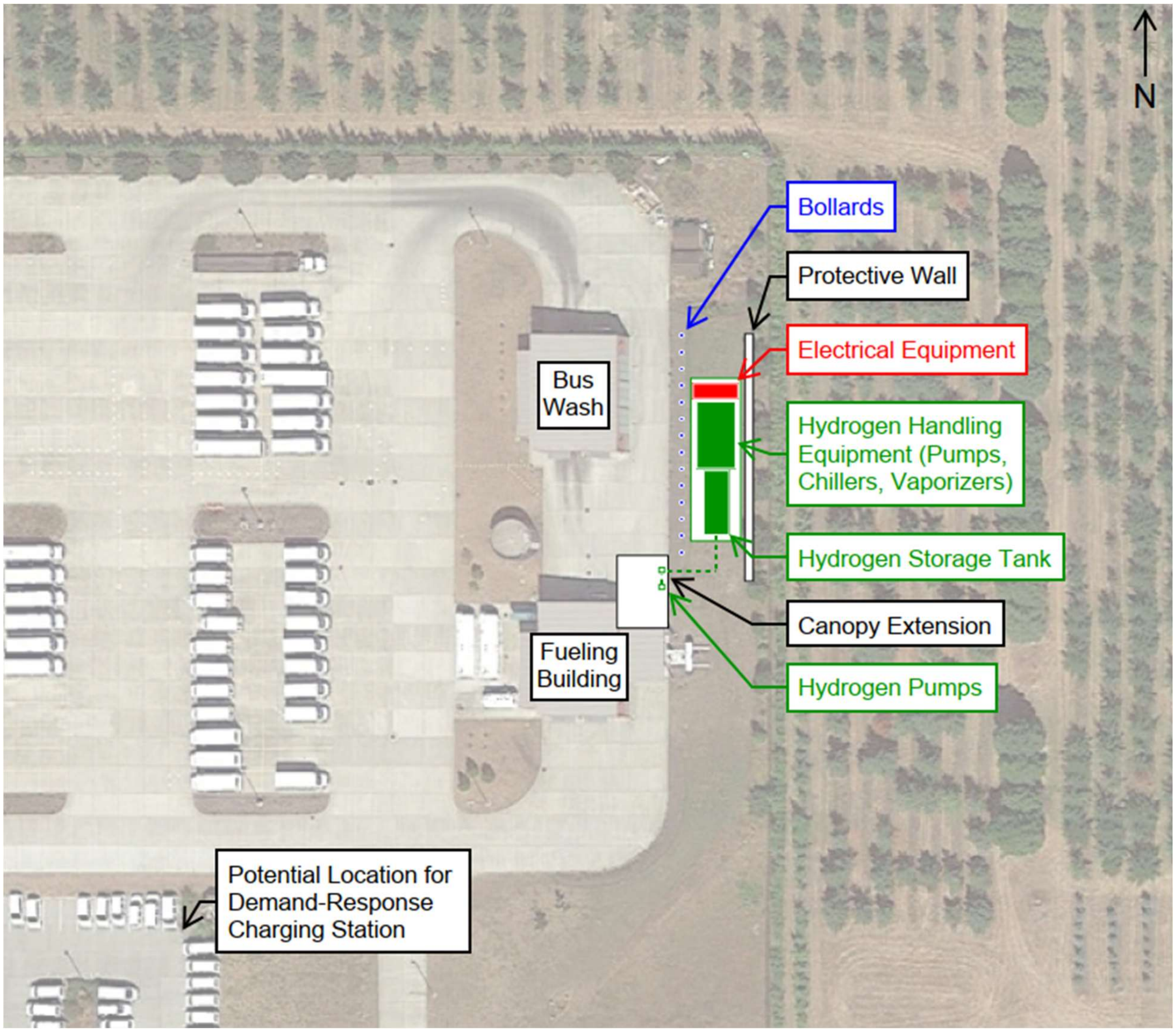

Figure 12 Whidbey Depot Hydrogen Station Conceptual Layout

The Camano Depot is much more space constrained. However, a curb could be installed between the two rows of existing parking spaces to accommodate the charging dispensers as shown in Figure 13, and a trench constructed to house charging cabinets and ancillary equipment placed on the northwest corner of the property.

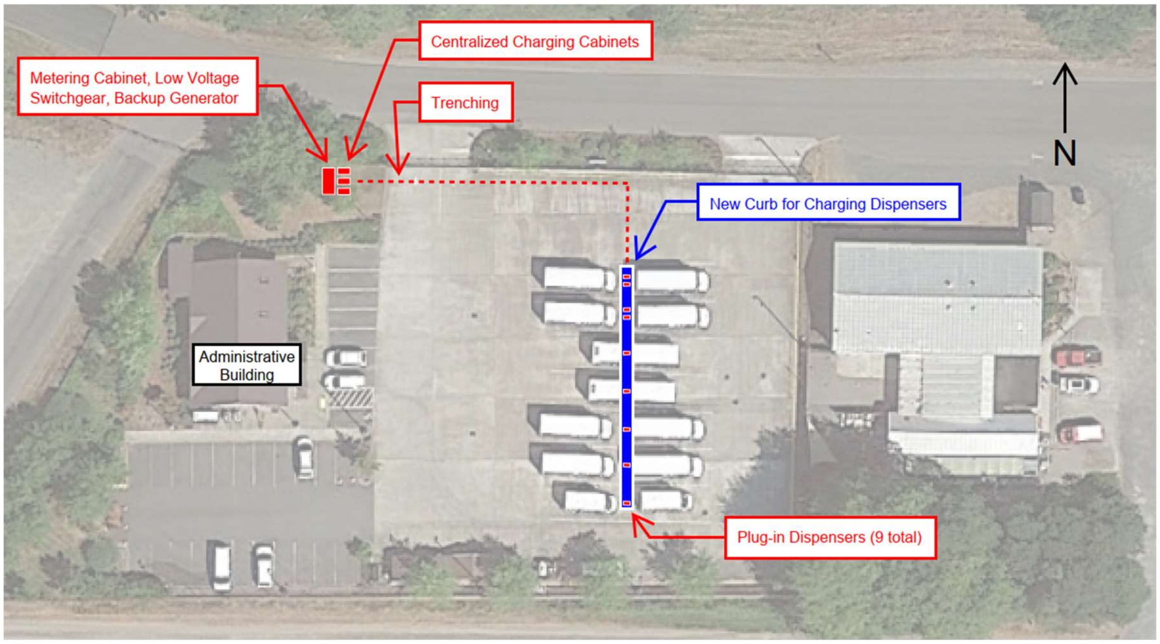

Figure 13 Camano Depot Charging Station Conceptual Layout

10. Current and Future Resource Availability

10a. Battery Electric

The electrical grid in Washington State is well developed and, aside from reliability challenges in the Island Transit service area, is well suited to supply electricity to meet the agency's BEB operation needs. The primary resource constraint on use of BEBs is likely to be the supply of components, especially batteries.

Although batteries have existed for centuries, the recent rapid growth in the electric vehicle market has strained the battery supply chain. Most battery types available today are produced with several key rare materials, most notably lithium. Other electric vehicle components are also produced using rare earth minerals: neodymium is a vital component of motor magnets, and terbium and dysprosium are added to improve magnetism at high temperatures. Although the mining industry is currently able to meet EV manufacturers' demand, the need for these rare-earth elements may become a constraint as EV demand continues to grow. Island Transit is encouraged to monitor the state of the EV industry, for example by attending conferences, to stay up to date on the EV and battery market's supply chain and the development of any new battery chemistries that may require fewer, or different, rare-earth elements.

10b. Hydrogen Fuel Cell

Unlike electricity, the availability of hydrogen is comparatively limited. Currently, hydrogen has a small number of commercial applications, such as fertilizer production, fossil fuel processing, and food refinement. These applications generally draw their hydrogen from dedicated sources that are located close to the point of use. Although hydrogen production in Washington State is scarce, there are several companies in the market:

- BP West Coast Products LLC in Ferndale, WA has a production capacity of 439,000 kg/day. Its hydrogen is used for oil refineries.
- Air Liquide in Kalama, WA has a production capacity of 686 kg/day; the hydrogen produced is for general sale.

In addition, public utilities are entering the hydrogen market. The Douglas County Public Utility District is planning a hydrogen production plant in East Wenatchee, which is expected to be ready in late 2022 or early 2023. This plant's electrolyzers will be powered by dams on the Columbia River, thereby producing green hydrogen, and are expected to produce up to two tons of hydrogen a day. This hydrogen is expected to fuel two planned hydrogen-vehicle refueling stations: in Chehalis, for Twin Transit buses, and in East Wenatchee.

Another proposal, by Fortescue Future Industries, seeks to establish a green hydrogen production facility on a retired coal mining site in Centralia.

At present, hydrogen is not used at scale for ground transportation. Even after the proposed fueling stations are commissioned, hydrogen generation and distribution facilities are likely to remain scarce, posing financial obstacles to widespread adoption of fuel cell vehicles. Identification of a reliable, nearby source of hydrogen – such as the plant in East Wenatchee – will be important to successful operation of FCEB because of the high costs associated with transporting hydrogen over long distances.

Another possibility for Island Transit is to avoid dependence on hydrogen suppliers altogether and generate hydrogen on-site. For example, the agency could generate hydrogen utilizing an electrolyzer. Although this will eliminate the agency's dependence on external suppliers, it is not recommended due to the high construction and maintenance cost of hydrogen generators.

11. Policy and Legislative Impacts on Technology

Island Transit is not alone in recognizing the immediate need to reduce carbon emissions and pollution to ensure a healthier climate. Leaders at both the state and federal levels recognize the significance of zero-emissions vehicles and have implemented strong plans to achieve these goals. These plans include both timelines to achieve carbon emissions reductions and grant programs to provide the funding necessary for these reductions. Island Transit's decision to convert its fleet to zero-emissions vehicles aligns well with these policies and incentives.

The federal government provides several types of incentives for transit agencies to convert their fleets to zero-emissions vehicles, the most well-known of which is the Low or No Emission Grant Program (49 U.S.C. 5339 (c)), or the "Low-No" program. Through this program, which can allocate up to $1.6 billion annually for five years, the FTA provides matching funds for procurements of zero-emissions vehicles as well as for bus facility upgrades to support these vehicles. The Buses and Bus Facilities Competitive Program (49 U.S.C. 5339 (b)), though not limited to zero-emissions vehicles, can also provide federal funding for vehicle and infrastructure procurements. Other, more general funding options are also available. For example, US DOT's Public Transportation Innovation Program provides funding for research projects analyzing a wide range of new ideas, including zero-emissions vehicle technologies. The FHWA's Congestion Mitigation and Air Quality Improvement Program (CMAQ) provides over $2.5 billion a year for measures, including the adoption of zero-emissions vehicles, that will improve air quality and reduce pollution. Notably, each of these programs are competitive, so Island Transit is not guaranteed to receive funding. As the zero-emissions vehicle landscape expands and a greater number of agencies begin converting their fleets, availability of this funding is expected to become scarcer. Though less common, some formula (i.e. non-competitive) funding is also available, for example through the Formula Grants for Rural Areas (49 U.S.C. 5311). This is generally more appropriate to fund operations rather than capital purchases.

The state government has also made clear the importance of zero-emission vehicle adoption. For light-duty vehicles, the state has announced a plan to ban the sale of gasoline-powered cars by 2035. The state has also reduced by half the sales tax levy on the first 650 hydrogen fuel-cell light/medium-duty vehicles sold. For heavy-duty vehicles the state has made similar commitments. In 2020, the Governor of Washington, Jay Inslee, signed the Multistate Zero Emission Medium- and Heavy-Duty Vehicle Memorandum of Understanding, aiming to increase the percentage of zero-emissions vehicles sold in these classes to 30% by 2030 and 100% by 2050. As mentioned above, the state has also invested four million dollars in building the state's first two hydrogen fueling stations in the cities of Chehalis and East Wenatchee. Furthermore, the state applied to host a regional hydrogen hub, of which four to eight are expected to be placed around the country. This network of hubs, which has been allocated $8 billion in funding by Congress, will lower the barrier to entry for hydrogen fueling station operators, decreasing the cost of owning and operating fuel cell vehicles of all classes.

As Island Transit transitions to zero emissions technology, additional policies and resources will become applicable to Island Transit. Table 9 **Error! Reference source not found.**provides a summary of current policies, resources and legislation that are relevant to Island Transit's fleet electrification transition.

Table 9 Policy and Resources Available to Island Transit

Policy	Details	Relevance to Agency Transition
Electric Vehicle (EV) Charging Station Community Grant Program Authorization	The Washington State Department of Transportation (WSDOT) is approved to establish a grant program to deploy EV charging stations. Preferences will be given to direct current fast charging (DCFC) projects.	Can be used to fund charger purchases.
Volkswagen (VW) Settlement Allocation	The Washington State Department of Ecology together with the Office of the Governor and state agencies will distribute funding to leverage 15% of Washington's portion of the VW Environmental Mitigation Trust for the acquisition, installation, operation, and maintenance of light-duty zero-emission vehicle charging infrastructure.	Can be used to fund costs associated with chargers for demand-response vehicles.
Alternative Fuel Vehicle (AFV) Retail Sales and Use Tax Exemption	Vehicles powered by natural gas, propane, hydrogen, or electricity can be exempt from the state retail sales and use tax if the vehicle is valued below $45000 if it is new, and below $30000 if it is used.	Can minimize the tax associated with buying the demand-response vehicles.
Alternative Fueling Infrastructure Grant Program	The WSDOT offers grants for the deployment of Level 2 and DCFC EV chargers and hydrogen fueling infrastructure along highway corridors in Washington. Eligible project costs include siting, equipment purchases, electrical upgrades, installation, operations and maintenance.	Can be used to fund costs associated with chargers.
Commercial Alternative Fuel Vehicle (AFV) and Fueling Infrastructure Tax Credit	Businesses can receive a tax credit for purchasing new or used medium and heavy duty AFVs and vehicles converted to alternative fuels, and installing the alternative fueling infrastructure.	Can receive a tax credit for purchasing the vehicles and installing fueling stations.
EV and FCEV Infrastructure and Battery Tax Credit	Public land used for installing, maintaining, and operating EV chargers is exempt from leasehold excise taxes.	Can minimize the tax associated with chargers.

Policy	Details	Relevance to Agency Transition
Green Transportation Grant Program	The WSDOT offers grants for projects that reduce the carbon emissions from the Washington transportation system. This includes fleet electrification, modification or replacement of facilities to facilitate fleet electrification and hydrogen fueling, upgrades to electrical transmission and distribution systems, and constructing of charging and fueling infrastructure.	Can be used to provide funding to procure buses and renovate the facility.
The U.S. Department of Transportation's Public Transportation Innovation Program	Financial assistance is available to local, state, and federal government entities; public transportation providers; private and non-profit organizations; and higher education institutions for research, demonstration, and deployment projects involving low or zero emission public transportation vehicles. Eligible vehicles must be designated for public transportation use and significantly reduce energy consumption or harmful emissions compared to a comparable standard or low emission vehicle.	Can be used to fund electric bus deployments and research projects.
The U.S. Department of Transportation's Low or No Emission Grant Program	Financial assistance is available to local and state government entities for the purchase or lease of low-emission or zero-emission transit buses, in addition to the acquisition, construction, or lease of supporting facilities. Eligible vehicles must be designated for public transportation use and significantly reduce energy consumption or harmful emissions compared to a comparable standard or low emission vehicle.	Can be used for the procurement of hybrid or electric buses and infrastructure
The U.S. Department of Transportation's Urbanized Area Formula Grants - 5307	The Urbanized Area Formula Funding program (49 U.S.C. 5307) makes federal resources available to urbanized areas and to governors for transit capital and operating assistance in urbanized areas and for transportation-related planning. An urbanized area is an incorporated area with a population of 50,000 or more that is designated as such by the U.S. Department of Commerce, Bureau of the Census.	This is one of the primary grant sources currently used by transit agencies to procure buses and to build/renovate facilities.

Policy	Details	Relevance to Agency Transition
The U.S. Department of Transportation's Grants for Buses and Bus Facilities Competitive Program (49 U.S.C. 5339(b))	This grant makes federal resources available to states and direct recipients to replace, rehabilitate and purchase buses and related equipment and to construct bus-related facilities, including technological changes or innovations to modify low or no emission vehicles or facilities. Funding is provided through formula allocations and competitive grants.	This is one of the primary grant sources currently used by transit agencies to procure buses and to build/renovate facilities.
The U.S. Department of Energy (DOE) Title Battery Recycling and Second-Life Applications Grant Program	DOE will issue grants for research, development, and demonstration of electric vehicle (EV) battery recycling and second use application projects in the United States. Eligible activities will include second-life applications for EV batteries, and technologies and processes for final recycling and disposal of EV batteries.	Could be used to fund the conversion of electric bus batteries at end of life as on-site energy storage.
Energy Storage System Research, Development, and Deployment Program	The U.S. Department of Energy (DOE) must establish an Energy Storage System Research, Development, and Deployment Program. The initial program focus is to further the research, development, and deployment of short- and long-duration large-scale energy storage systems, including, but not limited to, distributed energy storage technologies and transportation energy storage technologies.	Can be used to fund energy storage systems for the agency.
The U.S. Economic Development Administration's Innovative Workforce Development Grant	The U.S. Economic Development Administration's (EDA) STEM Talent Challenge aims to build science, technology, engineering and mathematics (STEM) talent training systems to strengthen regional innovation economies through projects that use work-based learning models to expand regional STEM-capable workforce capacity and build the workforce of tomorrow. This program offers competitive grants to organizations that create and implement STEM talent development strategies to support opportunities in high-growth potential sectors in the United States.	Can be used to fund EV training programs.

Policy	Details	Relevance to Agency Transition
Congestion Mitigation and Air Quality Improvement (CMAQ) Program	The U.S. Department of Transportation Federal Highway Administration's CMAQ Program provides funding to state departments of transportation, local governments, and transit agencies for projects and programs that help meet the requirements of the Clean Air Act by reducing mobile source emissions and regional congestion on transportation networks. Eligible activities for alternative fuel infrastructure and research include battery technologies for vehicles.	Can be used to fund capital requirements for the transition.

Despite the large number of potential funding opportunities available to Island Transit to transition to zero emissions technologies, these programs are competitive and do not provide Island Transit with guaranteed funding sources. Therefore, this analysis assumes that Island Transit will only receive funding through the largest grant programs that provide the highest likelihood of issuance to the agency. Specifically, this analysis assumed that Island Transit would receive 80% of the capital required to complete the bus, charging system, hydrogen fueling system and supporting infrastructure procurements outlined in this transition plan.

In summary, state and federal leaders share Island Transit's commitment to decarbonizing the transportation industry and shifting vehicle fleets to zero-emissions technologies. A wide range of funding options are available for Island Transit and its government partners to pursue. Given the competitive nature of most of the grant programs and the ever-increasing pool of agencies entering the zero-emissions market, to ensure that funding is made available it will be important for Island Transit to apply for a broad range of funding opportunities.

12. Workforce Impact

Island Transit staff currently operate and maintain a fleet composed entirely of fossil fuel vehicles. As a result, the staff have skill gaps related to the fuel cell, and high-voltage battery, components of the future vehicles. They are similarly inexperienced with the infrastructure – pumping, storage, and associated safety systems for hydrogen, and charging systems for battery-electric – associated with a zero-emissions fleet. Whether these systems are maintained by general in-house staff (as is sometimes done for chargers) or by a contracted third party (as is most common for hydrogen fueling stations), agency staff will still need to understand their principles of operation and interfaces with the vehicles.

To ensure that both existing and future staff members can operate Island Transit's future system a workforce assessment was conducted. Table 10 and Table 11 below provide details regarding the skill gaps for each workforce group within the agency and outlines training requirements to properly prepare the staff for future operations.

Table 10 Workforce Skill Gaps and Required Training: Hydrogen Fuel Cell

Workforce Group	Key Skills and Required Ongoing Training
Agency Safety and Training Officer, and First Responders	Hydrogen handling and safety measures (wayside and on-vehicle storage, outdoor and indoor leak detection and response), high-voltage operations and safety, battery fire safety
Maintenance Staff	All the above, plus fuel cell operation and repair, electric propulsion, vehicle diagnostics, and battery systems
Electricians	High voltage operations and safety, hydrogen-related regulations for depot upkeep and maintenance
Operators/Fuelers	Hydrogen safety measures, electric propulsion operating techniques, fueling procedures
Agency Management and General Staff	Understanding of hydrogen safety measures, fuel cell technology, vehicle operating practices; state of the regional hydrogen marketplace

Table 11 Workforce Skill Gaps and Required Training: Battery-Electric

Workforce Group	Key Skills and Required Ongoing Training
Agency Safety and Training Officer, and First Responders	High-voltage operations and safety, battery fire safety
Maintenance Staff	All the above, plus electric propulsion, vehicle diagnostics, and battery systems
Electricians	High voltage operations and safety, charging system functionality and maintenance
Operators/Fuelers	Electric propulsion operating techniques, plug-in and pantograph charging system usage, bus alignment with on-route chargers
Agency Management and General Staff	Understanding of vehicle and charger technology and operating practices

To address these training requirements, Island Transit should consider the following training strategies:

- Add requirements to vehicle and infrastructure specifications to require contractors to deliver training programs to mitigate the identified skill gaps.
- For both vehicle types, but especially for hydrogen FCEBs, coordinate with other transit agencies operating such vehicles to transfer ‘lessons learned.’ Send staff to transit agency properties that have already deployed zero-emissions buses to learn about the technology.
- Coordinate with local educational institutions, ranging from aerospace universities to vocational schools, to learn about curricula applicable to hydrogen fuel-cell technology and battery-electric propulsion. Consider partnering with a local school to develop a curriculum.

Island Transit should begin training staff and other local stakeholders on these technologies ahead of the delivery of the first vehicles and fueling/charging systems.

The shift to zero-emissions vehicles is expected to have a minor impact on the size of the workforce. Vehicle maintenance requirements are expected to decrease slightly, because zero-emissions vehicles have fewer moving parts and therefore need less lubrication, adjustment, etc. The size of the infrastructure maintenance team is unlikely to change: BEB chargers are almost entirely solid-state devices, requiring few repairs, and hydrogen fueling stations are complex systems requiring specialized training that most agencies hire a third-party contractor to maintain.

The primary change in workforce size is expected on the operations side, particularly in the number of drivers. For all operating modes, buses must frequently deadhead to the depot for charging/fueling to avoid depleting the battery/fuel tank. As buses deadheading to the depot are not making passenger trips, this inefficiency will require additional driver-hours, and likely a larger pool of drivers.

13. Recommendations and Next Steps

The transit industry is currently at the beginning stages of a wholesale transition. As zero-emissions vehicle technology matures, climate concerns become more pressing, and fossil fuels increase in cost, many transit agencies will transition their fleets away from diesel/propane vehicles in favor of either battery-electric or hydrogen fuel cell propulsion. Island Transit is well positioned to be part of this movement.

Island Transit has selected operation of a mixed fleet (with FCEBs on Whidbey Island and BEBs on Camano Island) as the most practical option for its zero-emissions fixed-route fleet. This option would require installation of a hydrogen fueling station at the Whidbey Depot, but will allow the agency to reduce recurring costs, keep its transit fleet size nearly constant, and install all service-critical infrastructure at the two depots. Though the choice of a mixed fleet will introduce operational and maintenance complexity, it is best suited for the unique constraints of the two islands.

In general, hydrogen fuel cell technology becomes more economical as the fleet size gets larger, because (unlike for charging infrastructure for BEBs) fueling infrastructure cost does not linearly increase with fleet size. In other words, fuel-cell operations are more economical for larger fleets because the large upfront infrastructure capital cost is spread among more vehicles. Therefore, Island Transit should seek opportunities to partner with other groups – such as nearby Public Works Departments – to share the cost (as well as the benefit) of building and operating a hydrogen fueling station.

Island Transit should work towards the goal of converting its Whidbey and Camano fixed-route fleets to hydrogen and battery-electric vehicles, respectively. To do so, Island Transit will need to acquire a total of 24 buses for Whidbey Island and 10 buses for Camano Island in the timeline provided in Section 8. In terms of infrastructure, the Whidbey depot will need to be equipped with a hydrogen fueling station with two pumps while the Camano Island facility will require three centralized chargers (each with three dispensers). As the first zero-emissions buses are not expected to enter service until 2026, Island Transit has enough time to lay the groundwork for this transition.

For the remainder of its fleet that serves the paratransit and demand response service, Island Transit should have a one-to-one conversation from its current fossil fuel fleet to battery electric fleet according to the time provided in Section 8. Charging infrastructure will be required at the Whidbey facility to support the electric vehicle fleet. On Camano Island, the charging infrastructure will need to be expanded to support additional electric vehicles.

To prepare for the transition, Island Transit should consider the following steps:

- Vehicles:
    - Develop vehicle specifications.
    - As part of vehicle procurements, purchase 12-year battery warranties, rather than assuming the risk of battery degradation.
    - As part of vehicle procurements, require the zero-emissions bus vendor to have a technician on site or nearby in case of problems. This is most economical when the technician is shared with several nearby agencies.
    - Reach a “mutual aid” agreement with a nearby transit agency that would let Island Transit borrow spare buses in case of difficulties with its fleet.
    - Retain a small fossil fuel reserve fleet to ensure adequate backup for zero-emissions vehicles if any incidents or weather conditions require it.
    - Develop a strategy for completing grant applications to cover vehicle costs.
- Infrastructure:
    - Begin the planning and design process for the hydrogen fueling station at the Whidbey Depot. Coordinate the timing of these stations to be ready for the arrival of the first BEBs in 2026.
    - Develop contingency plans in case the hydrogen fueling station experiences unexpected downtime and service must be maintained using buses already fueled.
    - Conduct a fire safety analysis for both facilities.
    - Develop a strategy for completing grant applications to cover infrastructure costs.
    - Coordinate the installation of demand-response vehicle supporting infrastructure at both locations to save money by doing both projects concurrently
- Other:
    - Begin training staff and other local stakeholders on battery-electric and fuel cell technology as described in Section 12.

Island Transit is encouraged to monitor the state of the market in the zero-emissions vehicle industry, for example by attending conferences, to understand the technology, cost, and supply factors behind each propulsion type and locate any potential partners for shared infrastructure. If the cost or operating parameters of either technology change dramatically, or if a state agency or local partner agrees to share infrastructure with Island Transit, the agency may choose to commit entirely to one or the other drivetrain technology rather than pursuing a mixed fleet.