Electric Bus Infrastructure Study – Final

Kitsap Transit

Kitsap County, WA

February 3, 2020

Executive Summary

Zero-emission bus technologies are evolving rapidly. Battery electric buses (BEBs) are the most common zero-emission bus technology. However, battery electric buses operate differently than existing carbon fuel source buses such as diesel and compressed natural gas (CNG). Beyond the differences in propulsion technology there are significant dissimilarities in operation due to the time required to charge the buses and the shorter range compared to diesel or CNG buses. Kitsap Transit is aware of these differences and sought to further understand the impacts to their operation as well as begin to implement a methodical approach to electric bus conversion and deployment.

Kitsap Transit has already been implementing many appropriate steps for a successful transition from carbon fuel buses to electric buses. Several elements should continue to be properly planned during further expansion.

1. **Phased approach**: Kitsap Transit is starting small to better understand of the implications of electric bus conversions. One new electric bus was purchased from Proterra and deployed on a route in Bremerton. Kitsap Transit determined that the length of the bus did not fit the compact roads and had trouble completing a longer route given the steep terrain which limited the range. Kitsap Transit has already used the lessons learned from that deployment to redeploy the bus on a better-suited route as well as look to purchase smaller buses for future conversions.
2. **Technology Assessment**: Through this study, Kitsap Transit has reinforced their decision to continue to deploy battery electric buses over other technologies such as hydrogen fuel buses due to additional costs and challenges over electric buses.
3. **Staff Training**: Kitsap Transit's existing electric bus has helped to understand the difference in operability between the electric bus and traditional diesel buses as well as the limitations of electric buses. Kitsap Transit will continue to refine new driver training to include charging and battery optimization to improve efficiencies of the electric buses.
4. **Stakeholder Collaboration**: Numerous stakeholders are critical to successfully deploying electric buses, including Kitsap Transit staff, bus riders, local and state agencies, and the local utility. This study focuses heavily on coordination with the local utility and provides Kitsap Transit with useful information on electric load projections for the full transition to BEBs. This study also helped introduce Kitsap Transit to the appropriate planning staff at Puget Sound Energy who will be a partner in this transition. Kitsap Transit understands that the electrical grid is adequate to support additional charging load at each of the three existing bus bases for the initial deployment, approximately 10 years depending on the speed of conversion.

As part of Kitsap Transit's goal to continue to wade into the electric bus deployment, this study evaluated how many bus runs can operate electric buses using the existing bus, battery, and charging technology. It was determined that 44 bus runs are short enough to consistently operate a battery electric bus. Due to the fact that many of Kitsap Transit's bus routes operate in the morning and then return to base for several hours before deploying again in the afternoon, several bus runs are capable of operating a single electric bus for both morning and afternoon deployments with a mid-day charge. This mid-day charge will allow Kitsap Transit to purchase fewer electric buses while becoming more comfortable with electric buses, experimenting with the range and operability of these buses, and allowing battery and charging technology to continue to advance before deploying additional electric buses on longer routes in the future.

HDR recommends Kitsap Transit follows a three-step electric bus deployment process. The first step is to continue to expand the electric bus fleet primarily at Charleston Base. Kitsap Transit is in the process of installing a single, 62.5 kW bus charger at North Base to transfer the existing Proterra bus from Charleston to North Base. During the development of this study, Kitsap Transit has applied for a grant to improve the existing electrical utility infrastructure at Charleston Base and install six new 62.5 kW chargers at Charleston Base. The installation of the 6 additional chargers at Charleston Base would allow Kitsap Transit to deploy up to 13 electric buses at Charleston Base and one electric bus at North Base through a near-term deployment (present through 2024).

During the second step, Kitsap Transit will then begin to deploy electric buses at North Base followed by South Base during a mid-term deployment. Kitsap Transit will purchase about four electric buses per year between 2025 and 2029 to deploy 19 total buses at North Base. These 19 buses will be capable of operating on 25 runs by utilizing mid-day charging. In about 2030, Kitsap Transit will deploy four electric buses and chargers at South Base to cover seven bus runs, via mid-day charging.

The third step in electric bus deployment is a long-term step in which Kitsap Transit will evaluate the electric bus, battery and charging technologies prior to moving forward with any additional electric bus deployments. Kitsap Transit will evaluate the performance of electric buses deployed during the first two steps to determine any route modifications as well as on-route charging improvements needed to complete the conversion to zero-emission buses.

It should be understood that in addition to operation, electric bus maintenance is also different in comparison to diesel and natural gas buses. Electric buses require a maintenance facility that allows access to the top of the bus to access batteries and other components. For a fleet the size of Kitsap Transit's, an approximately 25,000 square foot maintenance facility is recommended. It is likely that this facility would be constructed toward the end of the Charleston Base deployment or in the early stages of the second deployment step. While Kitsap Transit is currently evaluating expanding or relocating some of their operations, this study examined a new maintenance facility on a portion of the existing Gateway Center, which is a property currently owned by Kitsap Transit and operated as a Park and Ride.

In the long-term Kitsap Transit will be able to evaluate potential improvements and technology advances to determine how to best complete the electric bus conversion on their route buses. Ten years of technology advancements will likely improve bus range, increase battery storage, decrease battery charge times, and decrease bus and charger costs. These advancements are anticipated to increase the viability of electric buses and allow deployment on more routes.

Kitsap Transit should continue to adjust bus runs to optimize the number of runs that can utilize electric buses. While electric buses on every run might be desirable, the range of these buses must see improvement so that an excessive number of buses do not operate on a large number of short runs with the sole justification of converting the entire fleet to electric buses. The electric bus cost should be balanced with the practical deployment. Depending on the route needs, it may be quite some time before electric bus technology matches the route needs. Further, it may also be some time until electric buses match the range and/or fueling time of the the existing diesel buses.

On-route charging was considered within this study, but complications due to construction, scheduling, and space limitations limit Kitsap Transit's desire to install these at the larger transit centers (Bainbridge, Bremerton, and North Viking). Further, a limited return on investment is projected for the smaller transit centers (Silverdale, Port Orchard, and Wheaton Way) due to relatively few additional buses that benefit from these charger locations. To optimize electric bus run times, Kitsap Transit will eventually need to consider on-route charging.

Table of Contents

Transit Analysis

Introduction

Kitsap Transit contracted HDR Engineering, Inc. (HDR) to assist in planning for electric bus infrastructure improvements regarding how to convert their fixed route buses to battery electric buses by reviewing the electrical charging needs for base and/or transit center's operational bus capacity.

The purpose of this vision and goals paper is to document the electric bus needs at each of the three bus base facilities in order to plan for additional future conversion of the bus fleet. Following completion of the draft Vision and Goals paper on September 18, 2019, HDR met with Kitsap Transit staff on September 23rd and 24th as part of a design charrette to discuss the paper, the conceptual site layouts, and vehicle charging. This version of this Vision and Goals paper summarizes the findings from that meeting as well as advances the concepts and items discussed during the charrette.

Figure 1 illustrates the locations of Kitsap Transit's three bus bases, one main office and seven transit centers.

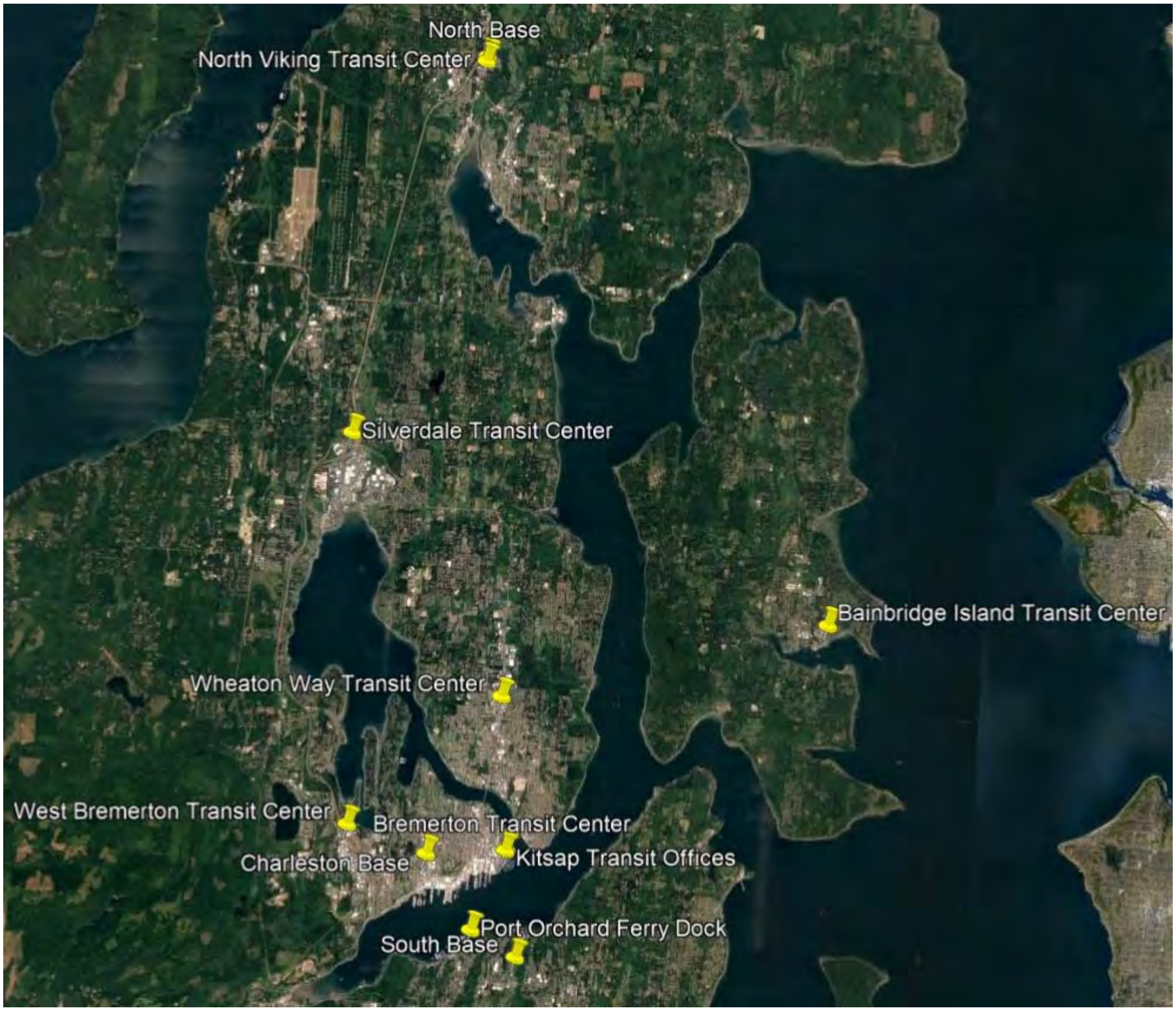

Figure 1: Kitsap Transit Bus Base and Transit Center Locations (Courtesy: Google Earth)

Bus Bases

North Base – Poulsbo, WA

Kitsap Transit operates three bus bases, which also serve to divide the Kitsap Transit service territory into three areas. The northern most bus base is located in Poulsbo and is adjacent to and north of the North Viking Transit Center (217100 Vetter Road NE). An aerial photo of the facility is shown in Figure 2, while a schematic drawing is shown in Figure 3.

Figure 2: North Base (Courtesy: Google Earth)

Figure 3: North Base Schematic

The North Base is a fuel and wash satellite bus base located adjacent to the North Viking Transit Center. Buses are parked, fueled, and washed on site with light maintenance, such as inspection and brake adjustments being performed in the Chassis Wash Bay or bus parking spaces. Currently, diesel and propane are the two fuel types at North Base. The North Base can store approximately 65 to 70 buses on site.

Employee parking is located adjacent to the Drivers Building, separate from the bus storage. This creates a streamlined traffic flow by not combining buses and personnel vehicles.

Currently Kitsap Transit has plans to store and operate eight (8) battery electric buses at North Base. With space for all of the infrastructure including, buses, chargers, and transformers planned at the north portion of the bus storage area.

Kitsap Transit has a master plan with space allocated to build a bus maintenance building adjacent to the Drivers Building. This would allow Kitsap Transit to maintain buses at the north end of the service area and alleviate some pressure at Charleston Bus Base. The future maintenance facility could be utilized for electric buses; however, if all maintenance were to be performed at this location, long deadhead runs would be required to get buses back to the central or southern portion of the service territory.

The following buses utilize this base and need to be able to park at the North Base.

- 35 Routed Buses (12' x 45' and/or 12' x 40' spaces)
- 17 Access Buses (12' x 35' spaces)
- 1 worker/driver bus during the day and 5 buses at night (12' x 45' spaces)

Operational Challenges/Issues

The North Base is a new facility that generally serves the agency well. The following potential challenges may arise with the introduction of the battery electric bus fleet at this base.

- Space for bus storage growth is currently limited by streets on the east and west side of the site. There is open space adjacent to the Driver's Building available for bus storage or a bus maintenance facility.
- The drivers building is located across the street from the bus storage.
- The base has limited maintenance capabilities. The majority of bus maintenance currently occurs at the Charleston Base.

Design Charrette and Electrical Bus Layout

During the design charrette, HDR presented multiple options for this site to accommodate future electrical buses.

Figure 4 depicts the layout that was discussed during and modified following the design charrette. For this layout, 34 total electric buses could be deployed at this location, which nearly meets the 35 route buses currently stationed at this facility.

In an effort to be good neighbors and reduce noise levels, Kitsap Transit does not allow diesel buses to start and warm up in the mornings along the north side of the property. The Kitsap Transit and HDR team felt that this area is a good location to install much of the electrical infrastructure and electric buses. The area along the north side of the facility can house up to 19 buses. Utility transformers and chargers could be installed in this area and in a phased order, if desired. Discussions with PSE will help to determine how to best install utility infrastructure.

In addition to the 19 buses along the north, there is adequate room for 15 additional electric buses to park nose-to-tail and charge east of the fueling building. Electrical supply to these chargers would be somewhat difficult to install due to the thick concrete slabs currently in place; however, it is recommended to cut the concrete slab, install conductor in conduit, and then replace the existing concrete.

Figure 4: North Base Layout to Accommodate Electric Buses

Charleston Bus Base – Bremerton, WA

The central base is located in Bremerton, along Charleston Boulevard (200 Charleston Boulevard). An aerial photo of the facility is shown in Figure 5, while a schematic drawing is shown in Figure 6.

The Charleston Base is Kitsap Transit's oldest and largest operations and maintenance bus base. Charleston Base is centrally located to bus routes served, and all Kitsap Transit buses are maintained at this base. The Charleston Base was built in 1935 and has always been a transit storage and maintenance facility.

Charleston bus base can store approximately 110 to 120 buses. Buses are parked, maintained, fueled, and washed on site. The bus base has four maintenance bays, tool storage, two fuel lanes, drive through wash, and two service bays. Currently, diesel and propane are the two fuel types at Charleston Base.

Employee parking is located adjacent to the operations section of the building separate from the bus storage. This streamlines traffic flow and reduces conflicts by not combining buses and personnel vehicles within the yard.

Kitsap Transit is currently testing one battery electric bus at Charleston Base. This bus is a Proterra battery electric bus with plug-in charging unit. The bus and charging infrastructure are undersized on site, and Kitsap Transit reports that the electrical load required exceeds the electrical load available on site due to the charger being connected to the bus wash transformer. Upon review of the existing PSE transformers at the site, it is likely that the charger has a larger capacity than the existing transformers, thus the reason for exceeding the transformer size.

The following buses spend time and need to be able to park at the Charleston Bus Base.

- 25 routed buses parked in the yard and 16 in the shop (12' x 45' and/or 12' x 40' spaces)
- 45 Access Buses (12' x 35' spaces)
- 38 worker/driver buses during the day and 8 at night (12' x 45' spaces)

Operational Challenges/Issues

The Charleston Base is the oldest facility, but it is also the largest and well located. The following may be challenges that may arise with the introduction of the electric bus fleet.

- The Charleston Base has limited growth opportunities due to the Naval Shipyard to the east and south and Route 304 to the west.
- The maintenance portion of the building has limited vertical clearance to be able to perform maintenance or replace components on the roof of the buses. This also limits the ability to lift the buses up to perform maintenance underneath.
- Maintenance is limited by the number of repair bays. Industry standards show more bays are required to adequately maintain Kitsap Transit's bus fleet, but currently Kitsap Transit is able to maintain the existing fleet due to procedures and operational practices. If the maintenance processes and procedures change, more maintenance bays would be required. Alternatively, the number of bays required may be reduced with implementation of best engineering practices.

Buses are stored on site by backing into diagonal parking spaces. The space between the two main bus parking lanes is limited. Finding locations for adding or changing infrastructure will be challenging and will have to be evaluated further prior to implementation.

Figure 5: Charleston Base (Courtesy: Google Earth)

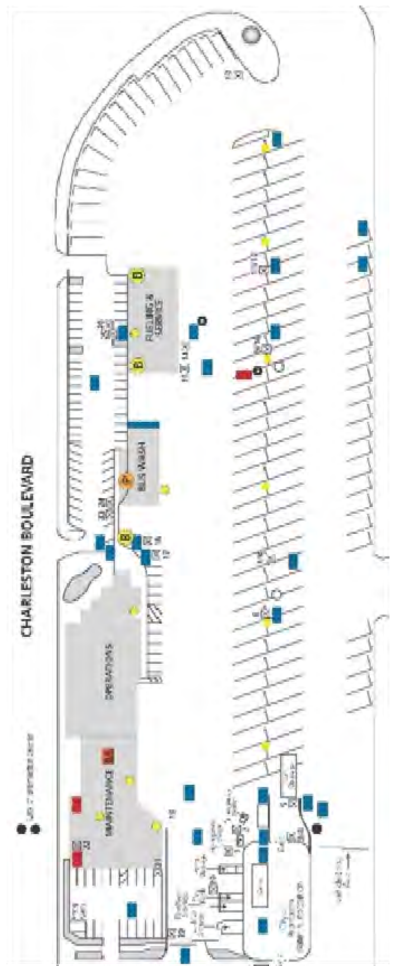

Figure 6: Charleston Base Schematic

Design Charrette and Electrical Bus Layout

Figure 7 depicts the layout that was discussed during and modified following the design charrette. For this layout, 17 buses could be located at the north of the site for a first phase. These buses would back into the parking locations for charging.

Twenty-four additional buses would constitute Phase 2 and would meet the 41 route buses currently located at the facility. This site also has potential for another 16 electric buses in the future, if needed. Buses in the Phase 2 or Phase 3 areas would be backed into the parking spaces.

A grassy area at the north of the site is currently not fenced, but fencing could be extended to encompass electrical infrastructure at that location, if necessary. After discussing this site with PSE, the utility would extend power from the existing transformers at the south of the site to the grassy area at the north of the site. Low voltage power would be routed near the back of the Phase 1 buses between the utility transformer and the charge heads.

Figure 7: Charleston Base Layout to Accommodate Electric Buses

South Bus Base - Port Orchard, WA

The South Base is located in Port Orchard along Retsil Road (1430 Retsil Road SE). An aerial photo of the facility is shown in Figure 8, while a schematic drawing is shown in Figure 9.

Figure 8: South Base (Courtesy: Google Earth)

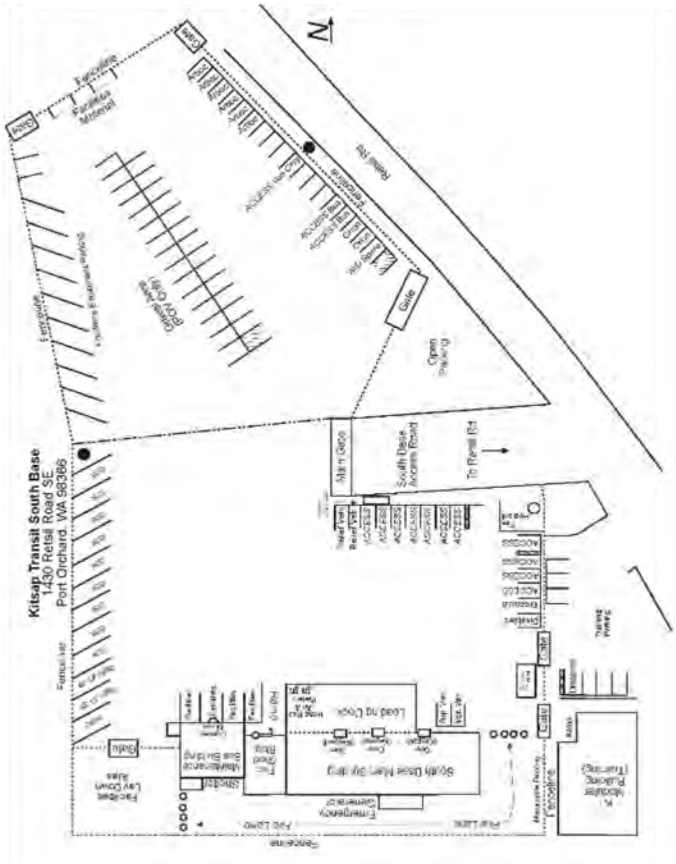

Figure 9: South Base Schematic

South Base is a satellite bus base in Kitsap Transit's south portion service area. Buses are parked and fueled by a portable fueling truck. Facility Maintenance's main shop is headquartered at this base and is utilized for maintaining Kitsap Transit's buildings, offices, real estate properties and infrastructure. A storage area for the facility maintenance is also located at South Base along with Kitsap Transit's Training Center.

There is no dedicated employee parking, and employees' park their personal vehicles in the bus space while out on-route. This is not the preferred method of operation.

The following buses spend time and need to be able to park at the South Base.

- 8 routed buses (12' x 45' and/or 12' x 40' spaces)
- 12 access buses (12' x 35' spaces)
- 9 worker/driver buses during the night (12' x 45' spaces)

Operational Challenges/Issues

The South Base is the smallest facility. The following potential challenges may arise with the introduction of the battery electric bus fleet at this facility.

- No designated employee parking. Personnel vehicles are parked in bus spaces while the buses are out on-route.
- More parking is needed for the Training Center.
- Fuel is delivered by a fuel truck.

- No maintenance is performed on site. Buses are taken to Charleston Base for maintenance.
- South Base is located in a centralized area of the city that is highly visual to the public, near several county parks and the South Kitsap High School.

Design Charrette and Electrical Bus Layout

Figure 10 depicts the layout that was discussed during and modified following the design charrette. For this layout, five buses could be located at the southwest corner of the site and would back into the parking location for charging.

Nine additional electric buses could be deployed at this site in the future. These buses would be parked and charged nose-to-tail. A new traffic flow for this facility would be established to reduce backing into sites as well as increasing the number of buses capable of parking at this location.

The current site layout creates difficulties with training center and employee parking. Kitsap Transit has expressed interest in possibly working with the park across Retsil Road to establish better employee parking at the South Base.

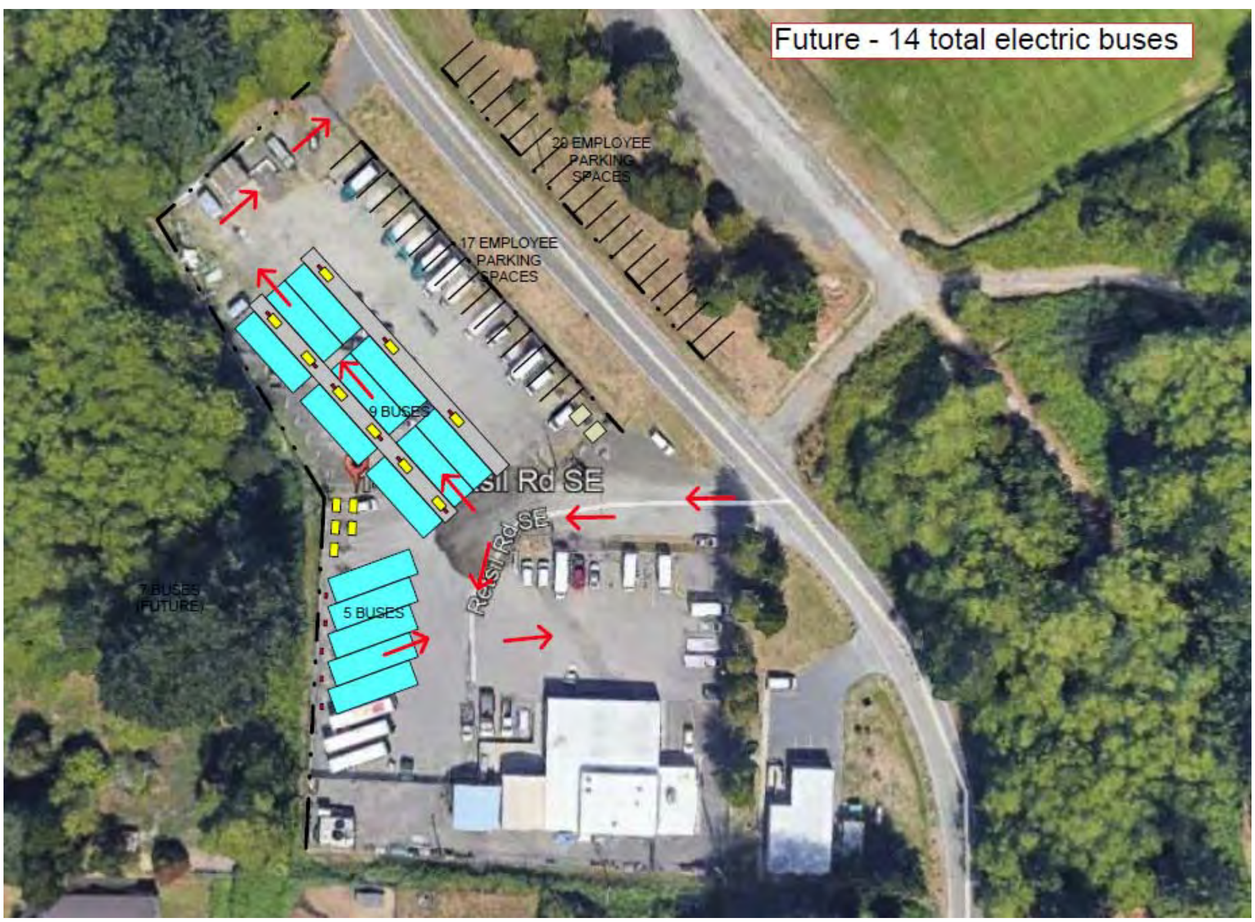

Figure 10: South Base Layout to Accommodate Electric Buses

Maintenance and Operational Considerations for Battery Electric Buses

The following is a list of Maintenance and Operational considerations for battery electric buses at bus bases.

- Access to the roof of the buses for service and inspection is necessary.
- Storage of replacement batteries will need to be evaluated, an approach or policy developed, and quantity determined.
- Parts storage will need to be evaluated and changes and/or modifications addressed.
- Operators will need to be trained to drive battery electric buses to optimize the bus travel distance and capacity.
- Number of battery electric buses required will need to be evaluated based on bus routes, distance of travel, and when charging can take place.
- Battery electric buses will still need to be washed on a scheduled basis.
- Servicing of battery electric buses, such as interior cleaning, inspection, and fare collection will still be required.

Transit Centers

North Viking Transit Center

The North Viking Transit Center has five transit berths with approximately 220 Park and Ride parking spaces. The North Viking Transit Center was constructed in 2016. An aerial photo of the North Viking Transit Center is shown in Figure 11.

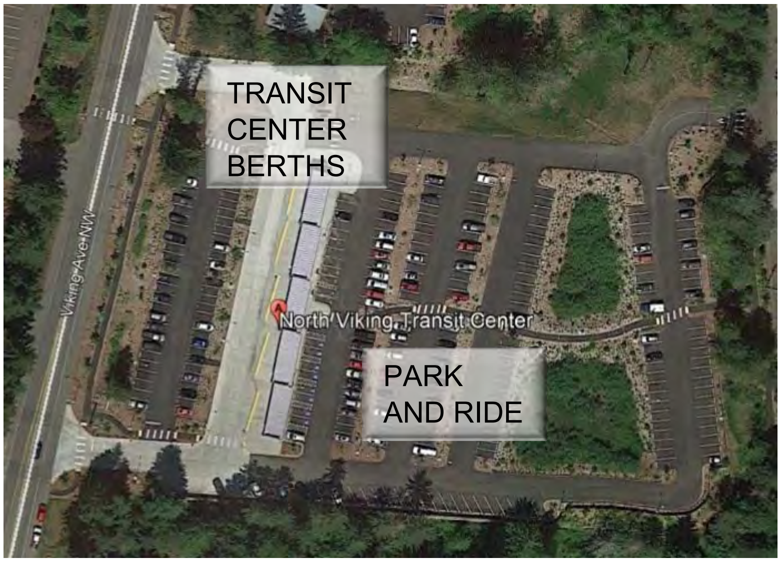

Figure 11: North Viking Transit Center (Courtesy: Google Earth)

Buses will layover at the transit center for about 10 to 15 minutes. Five Kitsap Transit, one Jefferson Transit, and one Clallam Transit bus route operate out of the North Viking Transit Center. At this time, Jefferson and Clallam Transit have not been contacted to determine plans for electric charging of their fleets and whether they may need electric charging berths at the North Viking Transit Center. These issues will need to be discussed during station design.

The five Kitsap Transit routes serviced out of the North Viking Transit Center include:

- Route 332 – Poulsbo/Silverdale
- Route 301 North Kitsap Fast Ferry Express
- Route 307 Kingston
    - Jefferson Transit offers a connecting line that extends service from Kingston to Port Townsend, via stop at North Viking Transit Center
- Route 344 Poulsbo Central
- Route 390 Poulsbo/Bainbridge

While these five routes operate through the North Viking Transit Center, Kitsap Transit does not always dedicate a one bus to a dedicated route. Kitsap Transit operates their buses based on interlining routes to maximize efficiency and limit deadheading and down time. A bus following a particular interlining run card may operate on portions of multiple routes. For example, the BNG run card instructs bus drivers to alternate between Route 334 and Route 237. While eliminating long stops at a transit center increases driver and bus efficiency, it also decreases the amount of time available for a bus to charge at these stops during the middle of the day.

Based on the current run cards, 20 run cards currently have stops at the North Viking Transit Center throughout the day. Depending on the stop duration, charging at this facility could possibly extend the mileage for these buses. At this time, Kitsap Transit has asked that this facility not be considered for on-route charging.

Operational Challenges/Issues

- North Viking Transit Center is located at the far north end of Kitsap Transits service area.
- North Viking Transit Center is a new facility and is heavily utilized, so construction at this site could create difficult rerouting and delays.

Bainbridge Island Ferry Terminal - Bainbridge, WA

The Bainbridge Island Ferry Terminal is a multi-purpose transit center for the ferry terminal and bus facility. The bus transit center has five bus transit berths and approximately nine bus parking spaces. An aerial photo of the Bainbridge Island Transit Center is shown in Figure 12.

Figure 12: Bainbridge Island Transit Center (Courtesy: Google Earth)

Buses will layover at the terminal for about 10 to 15 minutes. Thirteen Kitsap Transit routes, access vans, Clallam Transit, and one private operator operate out of the Bainbridge Island Ferry Terminal. At this time, Clallam Transit has not been contacted to determine plans for electric charging of their fleets and whether they may need electric charging berths at the Bainbridge Transit Center. These issues, as well as the presence of the access vans, will need to be discussed during station design.

The 13 Kitsap Transit routes serviced out of the Bainbridge Island Transit Center include:

- Route 91 – Kingston/Bainbridge
- Route 93 – Manzanita
- Route 94 – Agate Point
- Route 95 – Battle Point
- Route 96 – Sunrise
- Route 97 – Crystal Springs
- Route 98 – Fort Ward
- Route 99 –Bill Point
- Route 106 – Fletcher Bay
- Route 333 – Silverdale/Bainbridge
- Route 338 – Gateway/Bainbridge Express
- Route 390 – Poulsbo/Bainbridge
- BI Ride

The BI Ride route is not a scheduled route but a shared-ride option on Bainbridge Island that is available on an as-request basis only.

The Bainbridge Island Transit Center is heavily utilized. Based on the current run cards, 30 run cards currently have stops at the Bainbridge Island Transit Center throughout the day. Several of the stops at this facility are quite lengthy and provide a good opportunity for on-route charging. At this time, Kitsap Transit has asked that this facility not be considered for on-route charging though this option may be considered in the future.

Operational Challenges/Issues

- Busy terminal with heavy traffic.
- Limited room for growth unless expansion is into the parking to the north.
- Construction at this site could create difficult rerouting and delays.

Wheaton Way Transit Center – East Bremerton, WA

Wheaton Way Transit Center is currently under construction and to be completed by the end of 2019. Wheaton Way Transit Center will have eight transit berths with approximately 160 park and ride parking spaces. An aerial photo of the current Wheaton Way Transit Center area is shown in Figure 13.

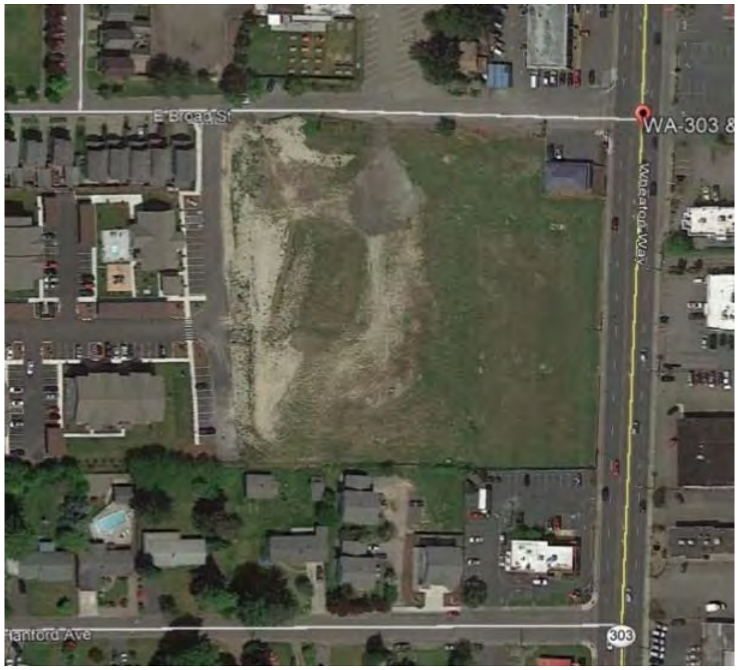

Figure 13: Wheaton Way Transit Center (Courtesy: Google Earth)

Buses will layover at the transit center for about 10 to 15 minutes. Seven Kitsap Transit bus routes will operate out of the Wheaton Way Transit Center. The seven Kitsap Transit routes serviced out of the Wheaton Way Transit Center include:

- Route 215 – McWilliams Shuttle
- Route 219 – Crossroads Shuttle
- Route 221 – Perry Avenue
- Route 223 – Kariotis
- Route 217 – Silverdale East
- Route 225 – Sheridan Park
- Route 301 – North Kitsap Fast Ferry Express

Based on the current run cards, seven run cards currently have stops at the Wheaton Way Transit Center throughout the day. Stops at this facility are currently short in duration. Kitsap Transit has expressed interest in modifying this facility for on-route charging; however, due to the short stop duration, only one additional run card could be charged at this location and even then only with additional charging from the Silverdale Transit Center.

A preliminary site layout (Figure 14) was generated to depict possible charging locations at the Wheaton Way Transit Center. This transit center could service up to five electric buses at a single time as well as maintain stops for up to seven diesel buses.

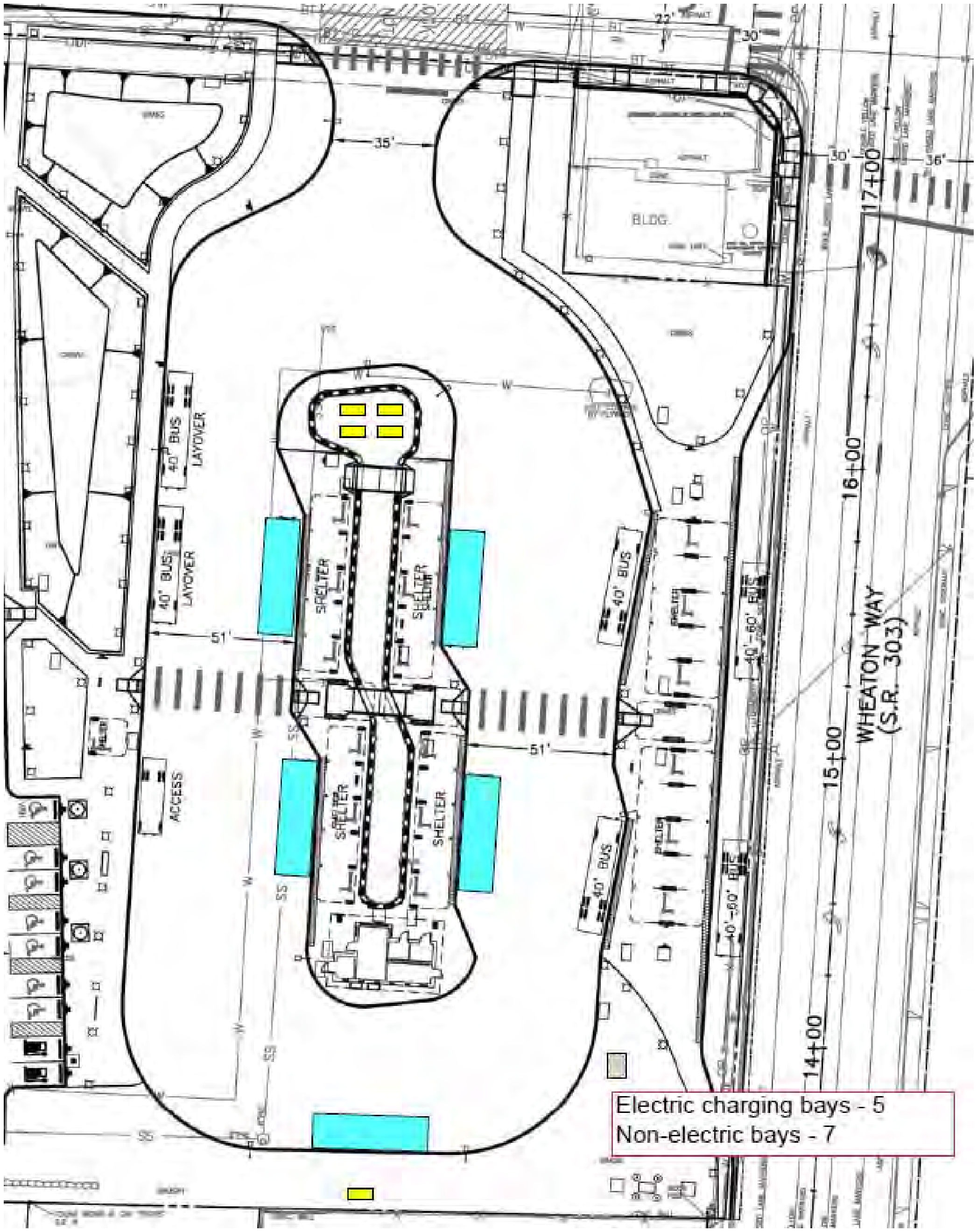

Figure 14: Wheaton Way Transit Center Layout to Accommodate Electric Buses

Operational Challenges/Issues

- On-route chargers would have high electrical demand.

Bremerton Transportation Center/Ferry Terminal - Bremerton, WA

The Bremerton Ferry Terminal is a multi-purpose transit center for the ferry terminal and bus facility. The bus transit center has 15 to 16 bus transit berths, with only 10 currently being used, and a few bus parking spaces. An aerial photo of the Bremerton Transit Center area is shown in Figure 15.

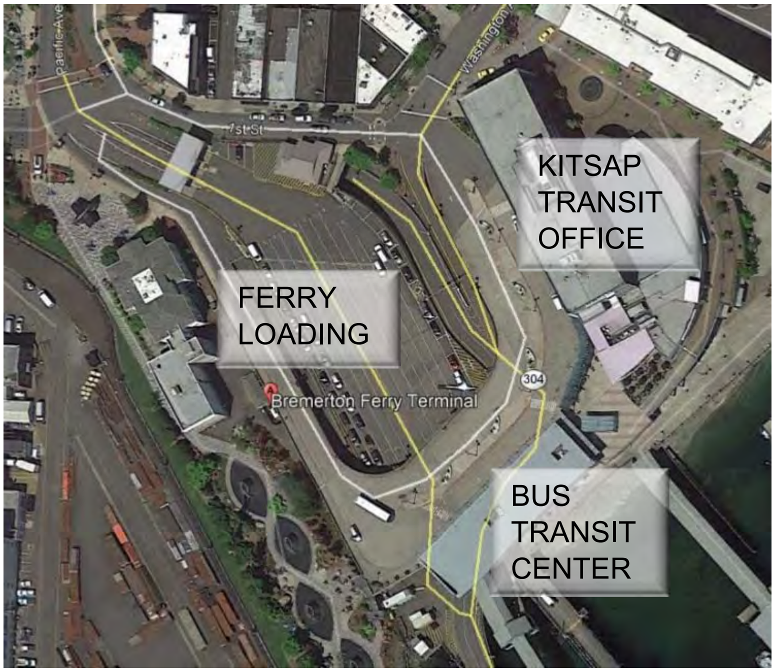

Figure 15: Bremerton Transit Center (Courtesy: Google Earth)

Buses will layover at the terminal for about 10 to 15 minutes. There are 11 Kitsap Transit routes and one Mason Transit route operating out of the Bremerton Ferry Terminal. At this time, Mason Transit has not been contacted to determine plans for electric charging of their fleets and whether they may need electric charging berths at the Bremerton Transit Center. These issues, as well as the presence of the access vans, will need to be discussed during station design.

Eleven Kitsap Transit bus routes will operate out of the Bremerton Transit Center. These eleven routes include:

- Route 215 – McWilliams Shuttle
- Route 20 – Navy Yard City
- Route 221 – Perry Avenue
- Route 222 – Gateway Express
- Route 24 – Olympic College
- Route 26 – Bay Vista
- Route 202 – Central Kitsap Fast Ferry Express
- Route 212 – Silverdale West
- Route 217 – Silverdale East
- Route 225 – Sheridan Park
- Route 301 – North Kitsap Fast Ferry Express

The Bremerton Transportation Center is heavily utilized. Based on the current run cards, 33 run cards currently have stops at the Bremerton Transit Center throughout the day. Several of the stops at this facility are quite lengthy and provide a good opportunity for on-route charging. At this time, Kitsap Transit has asked that this facility not be considered for on-route charging.

Operational Challenges/Issues

- Busy terminal with heavy traffic.
- Limited room for growth.
- Construction at this site could create difficult rerouting and delays.

West Bremerton Transit Center - Bremerton, WA

The West Bremerton Transit Center has five transit berths. An aerial photo of the West Bremerton Transit Center area is shown in Figure 16.

Figure 16: West Bremerton Transit Center (Courtesy: Google Earth)

Buses will layover at the transit center for about 10 to 15 minutes. There are four Kitsap Transit bus routes operating out of the West Bremerton Transit Center. The four Kitsap Transit routes serviced out of the West Bremerton Transit Center include:

- Route 20 – Navy Yard City
- Route 24 – Olympic College
- Route 26 – Bay Vista
- Route 212 – Silverdale West

The West Bremerton Transit Center is very lightly utilized with few extended stops. Based on the current run cards, six run cards currently have stops at the West Bremerton Transit Center throughout the day. On-route charging at this facility is not recommended due to the few stops and their short duration.

Operational Challenges/Issues

- Small transit center with parking across a street from the transit berths.

Silverdale Transit Center - Silverdale, WA

The Silverdale Transit Center is currently in design and to be completed 2021. Silverdale Transit Center is planned to have eight transit berths and no park and ride. An aerial photo of the Silverdale Transit Center area is shown in Figure 17.

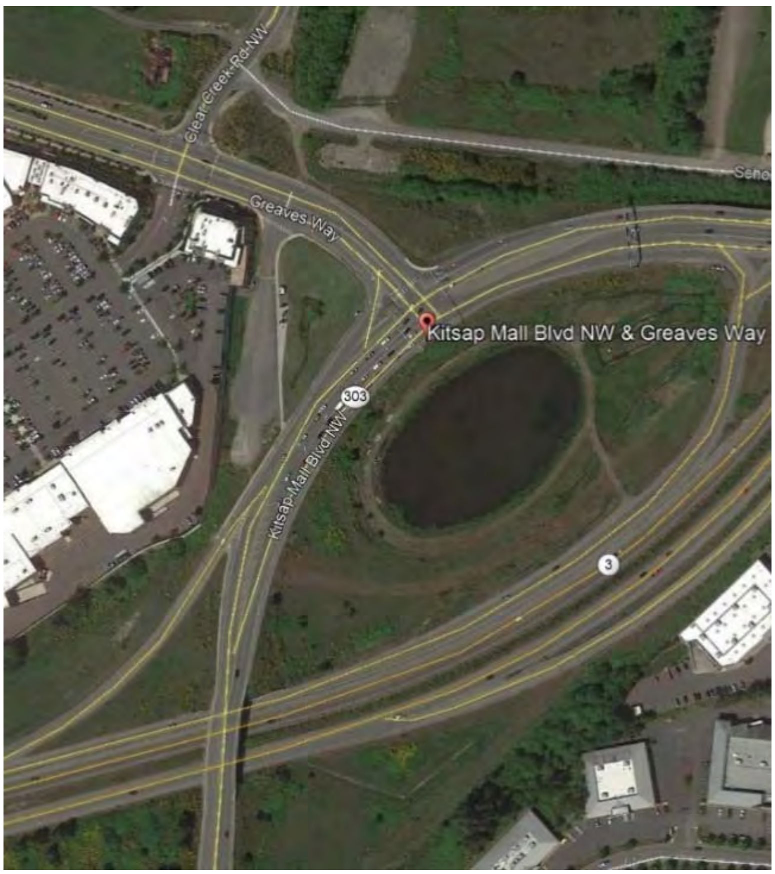

Figure 17: Silverdale Transit Center (Courtesy: Google Earth)

Buses are planned to layover at the transit center for about 10 to 15 minutes. Eleven Kitsap Transit bus routes are planned to operate out of the Silverdale Transit Center.

The 11 Kitsap Transit routes serviced out of the Silverdale Transit Center include:

- Route 223 – Kariotis
- Route 332 – Poulsbo/Silverdale
- Route 234 – Bangor Shuttle

- Route 235 – Old Town Shuttle
- Route 236 – Ridgetop Shuttle
- Route 237 – Fairgrounds Shuttle
- Route 202 – Central Kitsap Fast Ferry Shuttle
- Route 212 – Silverdale West
- Route 217 – Silverdale East
- Route 301 – North Kitsap Fast Ferry Express
- Route 333 – Silverdale/Bainbridge

The current Silverdale Transit Center is moderately utilized. Based on the current run cards, 19 run cards currently have stops at the Silverdale Transit Center throughout the day. Stops at this facility vary in length. Since the proposed transit center is currently in the early design stages, Kitsap Transit has expressed interest in installing provisions for future on-route electric bus charging at this facility.

A preliminary site layout (Figure 18) was generated to depict possible charging locations at the proposed Silverdale Transit Center. This transit center is going to be planned for future provisions to serve up to two electric buses at a single time as well as maintain stops for up to six diesel buses.

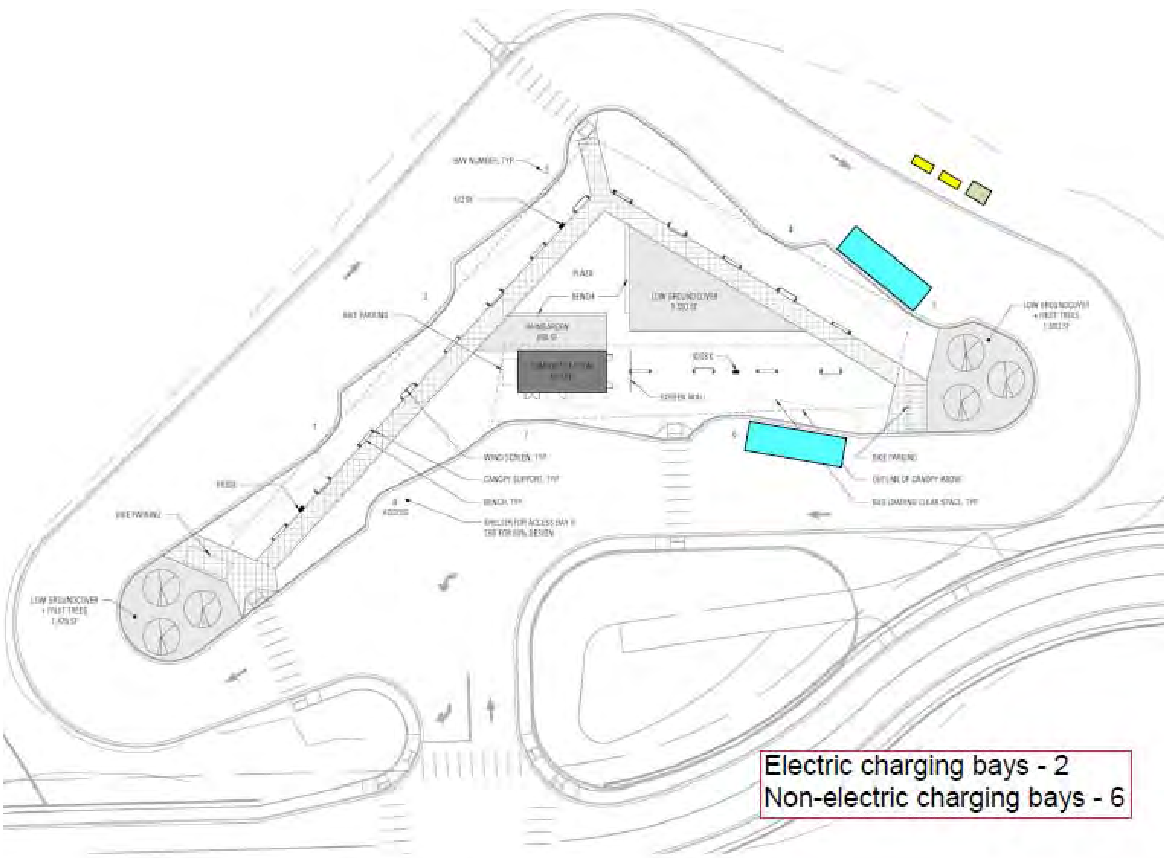

Figure 18: Silverdale Transit Center Layout to Accommodate Electric Buses

Operational Challenges/Issues

- This transit center is currently under preliminary design and operation considerations are not determined at this time.

Port Orchard Foot Ferry Dock - Port Orchard, WA

The Port Orchard Foot Ferry Dock provides a connection from Port Orchard to Bremerton. The Port Orchard Foot Ferry Dock has two bus transit berths. The bus facility is not a complete transit center, but only has on street parking for two buses. An aerial photo of the Port Orchard Foot Ferry Dock area is shown in Figure 19.

Figure 19: Port Orchard Transit Center (Courtesy: Google Earth)

Buses will layover at the foot ferry dock for about 5 to 10 minutes. Currently, six Kitsap Transit routes, including the Purdy Connection, operate out of the Port Orchard Foot Ferry Dock. The six Kitsap Transit routes serviced out of the Port Orchard dock include:

- Purdy Connection
- Route 4 – Tremont
- Route 5 – Sidney
- Route 8 – Bethel
- Route 9 – South Park
- Route 86 – Southworth Shuttle

The Port Orchard facility is not currently a full service transit center. Kitsap Transit has been approached by the City to purchase/transfer property to construct a new transit center at this location. For this reason, Kitsap Transit has asked that this facility be considered for potential on-route charging. Since nearly all of the Port Orchard buses stop at this facility and six spend time laying over, this facility should be considered for future on-route charging. No potential layout is included for this site at this time.

Operational Challenges/Issues

- Limited passenger vehicle parking.
- Located in a busy section of the City of Port Orchard.
- No existing transit center.

Kingston-route Stop - Kingston, WA

The Kingston-route Stop is a drop-off and pick-up point only. However, four routes pass through this area, and two of those routes are not serviced through any connecting stations. An aerial photo of the Kingston ferry area is shown in Figure 20.

Figure 20: Kingston-route Stop (Courtesy: Google Earth)

Four Kitsap Transit routes operate out of the Kingston-route stop, including:

- Route 91 – Kingston/Bainbridge
- Route 92 – Kingston/Suquamish
- Route 302 – Kingston Suquamish Fast Ferry
- Route 307 – Kingston

Operational Challenges/Issues

- No current transit center.

Non-Transit Center Routes

In addition to the routes passing through Kitsap Transit's transit centers or route stop, two scheduled routes do not make stops at any of the transit centers. These two Kitsap Transit routes include:

- Route 81 – Annapolis Commuter
- Route 85 – Mullenix Express

Overall Space Needs

Table 1 illustrates the number of buses and staff at each Kitsap Transit bus base.

Table 1: Buses and Vehicles Base Stationing

	North Base	Charleston Base	South Base	Notes
Buses				
Routed Buses	35	41	8	
Access Buses	17	45	12	
Worker/Driver	6	46	9	Numbers differ during the day and at night
Maintenance				
Staff				
Mechanics		13		3 shifts M-F, 12 hrs on Saturday
PM Technicians		4		3 shifts M-F, 8 hrs on Saturday
Service Helpers		10		3 shifts M-F, 12 hrs on Saturday
Service Helpers	2			5AM-3PM M-F
Service Helpers			1	5AM-10PM M-F
Maintenance Bays				
Running Repair Bays	2.89	4.78	1.11	
PM Bays	1.04	1.72	0.40	
Service Bays				
Operations				
Fixed Route Administrative Staff	2	15	2	
Dispatch				
Fixed Route Drivers	40	61	10	
ADA Drivers	17	27	11	
ADA Driver Float		8		

Gateway Center Site Possibilities

Kitsap Transit rents the former Gateway Center. The Gateway Center is a former shopping center and the parking lot is currently utilized for Kitsap Transit's Park and Ride. The existing building on the site is not currently in use and Kitsap Transit is looking at how to best utilize this space. As part of this study, HDR evaluated utilizing the Gateway Center for possible electric bus maintenance.

The Gateway Center site is located in Bremerton, less than half a mile from the Charleston Base and is approximately 2.5 acres (Figure 21).

Figure 21: Gateway Center Park and Ride (Courtesy: Google Earth)

The following sections include possible Kitsap Transit uses for the site. Each section has benefits and drawbacks.

Bus Storage Yard

The Gateway Center site could function as a bus storage yard and accommodate approximately 75 buses.

While this alternative could provide storage space for additional buses, Kitsap Transit has stated that the existing Park and Ride serves at vital role in the current location. Kitsap Transit stated that it would be difficult to abandon the existing Park and Ride site for an alternate purpose.

Expanded Park and Ride

The Gateway Center site could continue to function as a Park and Ride, but the existing building would be demolished and the site would accommodate approximately 200 pedestrian vehicles. This alternative could provide additional Park and Ride space but would not facilitate any additional bus parking or maintenance.

Bus Service Center and Employee Parking

The Gateway Center site could function as a bus service center with fuel and wash facilities, as well as bus and employee parking.

Electric Bus Maintenance Facility

The Gateway Center site could function as an electric bus maintenance facility with bus and employee parking. This alternative does not maintain any Park and Ride spaces at the Gateway Center.

Bus Service Center and Park and Ride

Utilizing a combination of these alternatives and reducing the number of bus spaces while maintaining many of the Park and Ride spaces may be a viable compromise. A potential layout for the site is included in Figure 22; however, further evaluations by Kitsap Transit are required in order to maximize the functionality of this facility, both for the Park and Ride and for potential electric bus maintenance.

Under this potential layout, 10 maintenance staff parking spaces are available, as well as 12 electric bus parking spaces. The 25,000 square foot facility would provide six standard maintenance bays, two preventative maintenance bays, a 5,000 square foot maintenance shop/storage, and provide a 2,600 square feet for support facilities.

Figure 22: Gateway Center Redevelopment for Electric Buses

Transit Bus Fleet Electrification and Zero-Emissions Options

Introduction

Within the past five years, transit agencies have been deploying battery electric buses (BEBs) for demonstration purposes, and some have procured and deployed this evolving technology directly into revenue service, particularly in California where there is a regulation requiring zero-emission buses by 2040. With California leading the way, neighboring states are not far behind. Since the projects were often funded with grants, and in order to meet grant timelines, there has sometimes been inadequate planning or study conducted prior to implementation of these demonstration projects. As BEB technology is still in the state of flux, some agencies had failures in meeting the standard operating profile for diesel buses with BEBs, both in terms of range and the cost per mile. Zero-emission bus technology, contrary to the implementation of clean diesel, compressed natural gas (CNG) and hybrid-electric will need a planned effort from selection of routes to facilities design, managing utility peak demand charges, and the development of robust technical specifications for buses and charging station infrastructure to meet the operational requirements of a transit agency.

The following summarizes the current state of zero-emission bus technology and is based on the current information available through various reports and studies, experience during testing and evaluation of buses, and discussions and feedback from bus manufacturers and transit agencies. As this is a snapshot in time (2019) it is certain the information here will be superseded – costs will change, technology will improve, and more data will become available.

Pros/Cons for Zero-Emission Bus Options

Battery Electric Bus (BEB)

Battery electric buses use a large (currently 300+ kWh lithium-ion though older batteries were smaller with less range) battery pack to power the vehicles. Current designs have battery capacities ranging from 325 kWh to over 600 kWh; providing up to 350 miles of range in ideal circumstances. Proterra and BYD were early entrants to this market, but the traditional bus makers New Flyer, Gillig, and Volvo/Nova are now offering BEBs. Procurement costs generally range from $800,000 to over $1 million per bus. Operating and Maintenance costs can be represented by a specific example, with the understanding that technology and conditions are changing. From June 2017 to May 2018, the National Renewable Energy Lab (NREL) collected data on the BEBs in use at Central Contra Costa Transit Authority (County Connection). A copy of the vehicles and information from the NREL study are shown in Table 2.[1]

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[1] Eudy, Leslie and Matthew Jeffers. 2018. *Zero-Emission Bus Evaluation Results: County Connection Battery Electric Buses*. Golden, CO: National Renewable Energy Laboratory. NREL/TP-5400-72864. Pages 5 and vii. https://www.nrel.gov/docs/fy19osti/72864.pdf.

Table 2: NREL/County Connection Bus Study

Vehicle System	Battery	Diesel	Diesel Trolley
Number of buses in evaluation	4	7	3
Bus manufacturer	Gillig	Gillig	Gillig
Bus year and model	2016	2014 29X102	2002 29X102
Length (ft)	29	29	29
GVWR (lb)	34,500	30,000	30,000
Motor or engine	BAE Systems, HDS200	Diesel engine, Cummins ISL-9	Diesel engine, Cummins ISL-280
Rated power	160 kW nominal, 200 kW peak	280 hp @ 2,200 rpm	280 hp @ 2,000 rpm
Energy storage	Xalt, nickel manganese cobalt, 100 kWh	None	None
Accessories	Electric	Mechanical	Mechanical
Bus purchase cost	$1,053,689	$459,935	$345,432

The major findings from the NREL study are shown in Table 3.

Table 3: NREL/County Connection Study Findings

Data Item	Battery	Diesel	Diesel (Trolley Replica)[a]
Number of buses	4	7	3
Total mileage in data period	51,550	189,068	—
Average monthly mileage per bus	1,074	2,251	—
Availability (85% is target)	76.9	85.5	—
Fuel economy (kWh/mile)	2.84	—	—
Fuel economy (mpdge[b])	13.3	5.1	3.5
Average speed, including stops (mph)[c]	6.0	14.8	6.0
Miles between roadcalls (MBRC)—bus[d]	4,686	63,023	—
MBRC—propulsion system only[d]	6,444	189,068	—
Total maintenance cost ($/mile)[e]	0.39	0.44	—
Maintenance cost—propulsion system only ($/mile)	0.10	0.14	—

[a] Diesel trolley-replica buses used for fuel economy comparison only.
[b] Miles per diesel gallon equivalent.
[c] Based on scheduled revenue service.
[d] MBRC data cumulative through May 2018.
[e] Work order maintenance cost.

For BEBs, the overall assessment from the study is as follows:
Pros:

- Currently the most technologically mature and most popular zero-emission choice.
- High energy efficiency
- Multiple recharging options – bus-up or bus-down pantographs, inductive wireless, corded plug

Cons:

- Equipment costs and infrastructure costs compared to diesel
- Range limitations on a single charge; on-route charging may be required increasing charging, capital, and maintenance costs
- Heating and AC use reduces range
- Terrain/Hills can reduce range
- Safety of large lithium-ion batteries; currently insufficient training in fire suppression and accident recovery
- Cost of electricity must be negotiated with local utility; demand charges can greatly increase costs
- Facility modifications and electric charging infrastructure is required increasing capital costs for the charger and often for additional utility infrastructure to meet the large load demands

Electric Bus Charging

There are three fundamental technologies for recharging electric buses – plug-in, conductive, and wireless inductive charging. Each can be implemented at varying power levels and locations, depending upon how the bus fleet is managed, the size of facilities, the routes and timing, and other operational factors.

Plug-in Charging (Figure 23) is similar to the charging technology currently available for light-duty cars, with a charging unit that has a cord of varying length and a standardized connector on the end that matches a socket on the bus. The charging unit can be small if the related electrical equipment is located in cabinets some distance away. Typically, buses will use Direct Current Fast Chargers (DCFC or Level 3) which vary from 50 kW to 350 kW of capacity. Costs for higher power units are proportionally higher, from about $30,000 for a 50 kW unit to over $125,000 for a 350 kW device, plus installation. The overall cost of equipment and installation of 150 kW plug in chargers is approximately $110,000 per charger, depending on the installation.

Figure 23: 150 kW Plug-In Bus Charger (Courtesy: Siemens)

Conductive is typically called “Bus-Up” (Figure 24) or “Bus-Down” (Figure 25) and uses a pantograph such as seen on light rail trolley cars, either mounted on the bus itself (Bus-Up) or on a structure above the bus (Bus-Down). These systems are not as standardized between bus manufacturers and costs vary widely depending on the installations and suppliers, as well as the power levels provided. Because of this, conductive charging is typically high-power, very fast charging at on-route bus stops, such as an Asea Brown Boveri (ABB) system that delivers 600 kW for 20 seconds. In some cases where bus depots have space constraints, conductive charging is not feasible due to the required infrastructure.

Figure 24: Bus-Down Charger (Courtesy: Siemens)

Figure 25: Bus-Up Charger (Courtesy: Siemens)

Wireless Inductive is an approach were magnetic resonance (typically) is used to transmit power across the gap between the ground and the vehicle. A pad is mounted on the ground and a receiver on the bus, and the bus is parked very precisely (within 2 cm) over the pad, utilizing the buses automated parking. The clearances and parking methods are similar to conductive charging. Currently deployed systems are 50 kW typically, but demonstration systems are being tested at 500 kW and 1 MW. The 50 kW system in the demonstration photos delivered 6.6 kWh in a typical charging event at the bus stop where it was installed, where the bus stayed for 6.9 minutes (approximately 1 kWh per minute)[2]. Due to the few actual installations so far, costs are not readily quantified, and while coming down, costs are still higher than other systems for equivalent power delivery. The convenience factor for this technology is significant due to the lack of necessary overhead structures and mating the charger to the bus, however there is still significant subsurface infrastructure required, along with adjacent electrical equipment.

Ongoing research is showing that the wireless inductive system charging efficiency is within one or two percent of plug-in systems, above 90 percent in most cases. For example, a charger may deliver 350 kW during a charge, but the charger will draw 390 kW from the electric grid. Inductive chargers are not disturbed by rain or snow, as the systems use magnetism, not direct transfer of electricity. They also include Foreign Object Detection (FOD) and Live Object Detection (LOD) for monitoring the charging environment for both metallic objects (FOD) and humans or animals (LOD). Safety is an area of extensive testing for this technology to make certain the electro-magnetic field is not reaching people in or around the vehicle at unsafe levels.

The wireless inductive system photos in Figure 26 and Figure 27 are from a demonstration project in northern California, from one of the three major inductive charging suppliers, WAVE[3].

Figure 26: Inductive Charging Infrastructure (Courtesy: WAVE)

[2] Eudy, Leslie and Matthew Jeffers. 2018. *Zero-Emission Bus Evaluation Results: County Connection Battery Electric Buses*. Golden, CO: National Renewable Energy Laboratory. NREL/TP-5400-72864. Page 7 https://www.nrel.gov/docs/fy19osti/72864.pdf.

[3] Eudy, Leslie and Matthew Jeffers. 2018. *Zero-Emission Bus Evaluation Results: County Connection Battery Electric Buses*. Golden, CO: National Renewable Energy Laboratory. NREL/TP-5400-72864. Page 8 https://www.nrel.gov/docs/fy19osti/72864.pdf.

Figure 27: Bus Charging Over Inductive Charger (Courtesy: Wave)

Additional considerations associated with the BEBs include the following from a 2017 study in Massachusetts[4].

- *Charging* considerations such as number of chargers required, charger capacity and location, in combination with route assignment and scheduling require close review and analysis to determine bus range is adequate. In addition, electricity demand charges need to be taken into consideration when deciding the type and rate of charging, so that the lowest overall costs for operation/charging can be obtained.
- *Costs* related to the purchase of electricity and the need to establish an active partnership with electrical companies has been reported. In addition, obtaining enough capital funding from the beginning of the project is essential. Finally, incorporation of monitoring systems to maintain batteries and reduce maintenance costs is a capital cost that should not be overlooked.

Charging Software

Charging costs can greatly affect the economics of battery electric buses. Large chargers with a large electrical demand or multiple smaller chargers all charging simultaneously can lead to high electrical demand charges and quickly reduce the benefits of electric vehicles.

One way to reduce demand charges is to prioritize bus charging. Prioritization can be based on most depleted battery, next bus to leave the base, etc. The use of software and smart technology to stagger charging can also reduce human inefficiencies of manually switching which bus is actively charging.

Proterra recently announced a multi-dispenser charging solution that allows their charging system to have multiple low-profile dispensers paired with a single Power Control System (PCS). This eliminates the need to install a PCS for each bus, since one PCS can now charge up to four dispensers. The charger automates and allows for sequential charging so multiple vehicles can charge once the previous vehicle has been fully charged. Proterra offers this

[4] Zero-Emission Transit Bus and Refueling Technologies and Deployment Status. Eleni Christofa, PhD; Krystal Pollitt, PhD, P.Eng. Dany Chhan; Aikaterini Deliali, BS; Jennifer Gaudreau, BS Rassil El Sayess, PhD. December 2017 page xii

technology for their 62.5 and 125 kW chargers and two types of buses. The multiple-dispenser chargers can be retrofited to existing PCS units, if required.

While Proterra currently leads in the development of this multiple-dispenser approach, other companies are also beginning to employ similar technologies. Aftermarket methods may also be developed, though this may take additional programming efforts and may impact system warranties for the chargers and/or the buses.

This multiple-dispenser approach provides multiple cost saving opportunities. First, the number of chargers and the space they require is reduced by up to 75 percent. While the cost savings would not be 75 percent less than four, 62.5 kW chargers due to the fact that four dispensers would still be required, this could reduce costs by approximately $90,000 for four chargers (one, 250 kW vs. four, 62.5 kW).

Additionally, operations cost savings can be provided by charging the buses in a staggered approach. With the 62.5 kW chargers currently installed by Kitsap Transit and the 440 kWh batteries on their buses, a full charge would take over 7 hours which may limit the ability to stagger charge if a bus begins charging late in the evening and is required to operate again in the early morning. However, many buses may not utilize a full battery during daily operations and may not require a full charge. In those instances, these buses could be stagger charged rather than simultaneously charged. The current bus chargers (62.5 kW) employed by Kitsap Transit may only allow two buses to be charged using the same charger in order to completely charge these buses. Kitsap Transit may consider installing larger chargers (150 kW) in the future, depending on the charge requirements and the number of buses needed at the next shift.

Hydrogen Fuel Cell Electric Bus (FCEB)

Hydrogen fuel cell electric buses use a fuel cell system and onboard hydrogen storage tank to generate electricity to run the electric traction motor and accessories. There is usually a lithium ion battery (less than 200 kWh) to capture brake regeneration energy and to operate the vehicle while the fuel cell starts up and shuts down. Bus makers include Volvo/VanHool, New Flyer, and El Dorado. Fuel cell power units are generally provided by Ballard or Hydrogenics. FCEBs have a range of between 200 and 325 miles and typically only need to be refueled once per day. Procurement costs are $1.2 to $1.8 Million. One of the demonstration programs, at Orange County Transportation Authority (OCTA) has provided performance data on their ten New Flyer and one El-Dorado FCEBs:

- Bus availability: 77% (compared to CNG: 87% and diesel-hybrid: 86%)
- Miles per diesel gallon equivalent: 7.1 (compared to a normal diesel bus: 3.2 mpg; CNG: 3.92 mpg; diesel-hybrid: 4.71 mpg)
- Cost per mile (maintenance): $0.48 (compared to CNG: $0.28 & diesel-hybrid: $0.36)
- Bus Road Call (MBRC): 4,200 miles (compared to a diesel bus: 6,700 miles; CNG: 10,800 miles; diesel-hybrid: 5,900 miles)
- Fuel Cell system Road Call (MBRC): 24,406 (not applicable to other bus designs)

Pros:

- Performance characteristics in terms of range, speed, hill-climbing and refueling processes that are comparable to traditional buses.
- Energy efficiency equivalent or better than CNG – typically about 7.1 mpg equivalent
- Refuel just once per day

Cons:

- High Capital Cost
- Hydrogen is an unfamiliar fuel, and pricing varies greatly (between $8 and $13 per kg, with a bus using 32-40 kg/day)
- Hydrogen fuel infrastructure is costly and may require onsite generation (Cost range is $1.4 to $5 million)
- New maintenance facilities would be required due to the differing technologies from the existing diesel buses

Battery Dominant Hybrid Fuel Cell Electric Bus

This bus technology is the newest variation, combining a larger battery and a fuel cell, to use both grid-supplied electricity and hydrogen fuel cell supplied electricity. Buses are plugged in like a battery bus and then can operate for a full day by using the combined battery and fuel cell to power the electric traction motor and accessories. Using both simultaneously can maximize energy efficiency. Makers of these buses include Proterra and New Flyer, while the fuel cells themselves are from Ballard Power Systems and Hydrogenics. Because so few buses are in use, procurement costs are not defined, nor are maintenance costs. Efficiency in early trials indicates better mileage than fuel cell buses.

Pros:

- Performance characteristics in terms of range, speed, hill-climbing and refueling processes that are comparable to traditional buses.
- Potentially improved energy efficiency over Fuel Cell Buses
- Refuel just once per day

Cons:

- High Capital Cost
- Infrastructure needed for both electric charging and hydrogen refueling
- Hydrogen is an unfamiliar fuel, and pricing varies greatly

Hydrogen Bus Refueling

Hydrogen fuel can be produced onsite at the bus depot or offsite and then delivered to a hydrogen storage facility at the bus depot. Onsite generation can be done by using CNG and a steam reformer or by using electricity and electrolyzing water. Off-site options include truck delivery, mobile tanks, and rarely an actual pipeline. Hydrogen is delivered in a liquid state which must be stored onsite cryogenically before it is dispensed, or transported in a gaseous state and stored onsite in pressure vessels. The fuel is then dispensed into the bus using a cryogenic pressurized hose similar to those used in LNG systems.

The systems are generally modular and can be scaled up in size to accommodate larger volumes, and this scale is critical to pricing with high volume being the key to cost-effectiveness. Due to the wide range of options, pricing for infrastructure also varies widely. Hydrogen is sold by the kilogram, and prices range from under $5.00/kg to over $12.00/kg. As a rule of thumb, the cost needs to be under $5.00 for the business case to be equivalent or better than a battery electric bus.

Additional considerations associated with the FCEBs include the following[5].

Fuel Cell Buses:

- Route assignment and scheduling considerations due to the more stringent safety regulations that dictate permits to get the bus "road certified."
- High cost infrastructure requirements to accommodate the hydrogen fueling and/or production facilities that often have a large footprint.
- Fueling and hydrogen storage need to be carefully designed to provide enough range for the buses without imposing excess weight (from a bigger battery) that could reduce passenger capacity. In addition, fuel supply should be properly matched with demand.
- Technology of fuel cells needs to be improved to allow for longer lifetimes that are comparable to those of the bus itself.
- Maintenance issues have led to recommendations on developing guidelines on maintenance practices as well as creating inventories and improving the supply chain of fuel cells across the country.

Fuel Cell Hybrid Plug-In Buses

- Technological challenges associated with the battery and fuel cell components have been highlighted as with the other two bus technologies as well as challenges associated with the integration of multiple new technologies.
- Maintenance issues have been common given the fact that this technology is still at its early stages of testing and implementation. Therefore, the development of maintenance manuals has been recommended.
- Costs are still high for this type of bus technology but there are expectations that standardization and manufacturing processes will reduce them. It is also recommended that spare parts are stored for maintenance when fleets of these buses are big enough to justify the financial investment.

Battery Storage and Backup Power Supply

The option exists to install large battery banks at or near the charging stations. In addition to utilizing the batteries for emergency charging in the event of a power outage, these batteries could be utilized to reduce the electrical demand charges during peak charging. The analysis of this option is explained in further detail in the Additional Considerations section.

Additional Documentation

A fairly comprehensive listing of the available zero-emission buses comes from the California HVIP program, an incentive program funded by the state to encourage zero-emission bus adoption is shown in Table 4. There are eight different OEMs represented and 32 vehicles across a range of bus sizes and propulsion technologies. Volvo is the one major player missing, as they do not yet sell in California.

[5] Zero-Emission Transit Bus and Refueling Technologies and Deployment Status. Eleni Christofa, PhD; Krystal Pollitt, PhD, P.Eng. Dany Chhan; Aikaterini Deliali, BS; Jennifer Gaudreau, BS Rassil El Sayess, PhD. December 2017 page xii

Table 4: California HVIP - Vehicles and Eligible Technologies (Zero Emission Transit Buses)

Model	Battery	Model Years	Length
BYD Motors			
BYD K11M 60' Articulated All-Electric Transit Bus	652 kWh	2018-2019	Bus > 40'
BYD K7M 30' All-Electric Transit Bus	196 kWh	2017-2018	Bus 30' - 39'
BYD K9M 40' All-Electric Transit Bus	324 kWh	2018-2019	Bus 30' - 39'
BYD K9S 35' All-Electric Transit Bus	350 kWh	2018-2019	Bus 30' - 39'
Complete Coach Works			
Complete Coach Works Zero Emission Propulsion System	373 kWh	2017	> 26,000, Bus > 40'
ElDorado National			
ElDorado National AXESS 35' Fuel Cell Hybrid Transit Bus		2018-2019	Bus 30' - 39'
ElDorado National AXESS 40' Fuel Cell Hybrid Transit Bus		2018-2019	Bus 30' - 39'
Gillig			
Gillig 29' ePlus Battery Electric Low Floor Bus	296 kWh	2018	Bus < 30'
Gillig 35' ePlus Battery Electric Low Floor Bus	444 kWh	2018	Bus 30' - 39'
Gillig 40' ePlus Battery Electric Low Floor Bus	444 kWh	2018	Bus 30' - 39'
GreenPower Motor Company			
GreenPower EV 350 All-Electric Transit Bus	320 kWh	2018-2019	Bus 30' - 39'
GreenPower EV250 All-Electric Transit Bus	210 kWh	2018-2019	Bus 30' - 39'
GreenPower EV550 45' All-Electric Double Decker Transit Bus	>478 kWh	2018-2019	Bus > 40'
GreenPower SYNAPSE Shuttle Bus	200 kWh	2018-2019	Bus 30' - 39'
Lightning Systems			
Lightning Systems LEV110E Bus Ford E-450 with Lightning Powertrain	129 kWh, 86 kWh	2019	Bus 25' - 29'
New Flyer			
New Flyer Fuel Cell Electric XHE40 Transit Bus		2019	Bus 30' - 39'
New Flyer Fuel Cell Electric XHE60 Transit Bus		2019	Bus > 40'
New Flyer XCELSIOR XE 35' All-Electric Transit Bus		2018-2020	Bus 30' - 39'
New Flyer XCELSIOR XE 40 All-Electric Transit Bus	545 kWh	2018-2020	Bus 30' - 39'
New Flyer XCELSIOR XE 60 Transit Bus	818 kWh	2018-2020	Bus > 40'
Proterra			
Proterra 35' Catalyst E2	440 kWh	2018-2019	Bus 30' - 39'
Proterra 35' Catalyst FC	94 kWh	2018-2019	Bus 30' - 39'
Proterra 35' Catalyst FC+	126 kWh	2018-2019	Bus 30' - 39'
Proterra 35' Catalyst XR	220 kWh	2018-2019	Bus 30' - 39'
Proterra 35' Catalyst XR+	330 kWh	2018-2019	Bus 30' - 39'
Proterra 40' Catalyst E2	440 kWh	2018-2019	Bus > 40'
Proterra 40' Catalyst E2 Max	660 kWh	2018-2019	Bus > 40'
Proterra 40' Catalyst E2+	550 kWh	2018-2019	Bus > 40'
Proterra 40' Catalyst FC	94 kWh	2018-2019	Bus > 40'
Proterra 40' Catalyst FC+	126 kWh	2018-2019	Bus > 40'
Proterra 40' Catalyst XR	220 kWh	2018-2019	Bus > 40'
Proterra 40' Catalyst XR+	330 kWh	2018-2019	Bus > 40'

Downloaded from https://www.californiahvip.org on December 15, 2019

Another good comparison table of zero-emission bus technologies is from a December 2017 study conducted for the Massachusetts Department of Transportation[6]. Table 5 was captured from the Massachusetts DOT report and is available in full within that report.

Table 5: Zero-emission Bus Technology Comparison (Courtesy: Massachusetts DOT)

	Battery Electric	**Fuel Cell**	**Fuel Cell Hybrid PlugIn**	**Diesel**	**CNG**
Capital cost ($)	Depot charging: $733,000– $919,000 On-route charging: $800,000–$1,200,000	FTA target: $1.0 million Active fleets: $1.8–$2.5M	Loan from Proterra: $1.2 million	$445,000	$400,000–$495,000
Fuel economy (mpdge or mpg)	8–29.0	6.06–7.83	7.1–7.94	3.8–5.4	2.79–3.33
Fuel ($/mile)	0.18–0.72	1.30–1.58	1.38	0.18–0.90	0.29–0.61
Electricity cost ($/kW)	0.17	NA	0.0554	NA	NA
Hydrogen cost ($/kg)	NA	4.52–23.46	9.93	NA	NA
Maintenance ($/mile)	0.16–1	0.39–1.31	0.5557	0.25–3	0.22–0.61
Max. speed (mph)	NR	37–55	44.7–58	45–50	NR
Availability (%)	84–98	45–88	35–58	>85	78–94
Miles between road calls (MBRC)	6,000–9,000	3,830–6,335	NR	3,400	10,511
Average monthly miles (miles)	2,500	~2,500	491–547	4,500	3,900
Range (miles)	50–350 Fast Charge: 49–62 Slow Charge: 136–193	210–325	Only-battery: 30–406 Fuel Cell & Battery: 280–300	280–690	217
Charging/ fueling time	Fast charge: 6–15 min Slow charge: 4–6 hrs	6–24 min	Fast fill: 15 min Slow Fill: 2–4 hrs	NR	NR
Fuel cycle GHG emissions (g CO2-eq/mile)	12–428	77–264	NR	535	535
Well-to-tank CO2 emissions (g CO2/MJ)	77	117	NR	19	25.9

[6] Zero-Emission Transit Bus and Refueling Technologies and Deployment Status. Eleni Christofa, PhD; Krystal Pollitt, PhD, P.Eng. Dany Chhan; Aikaterini Deliali, BS; Jennifer Gaudreau, BS Rassil El Sayess, PhD. December 2017 page 39

Zero-Emission Summary

Zero-emission bus technologies are evolving rapidly. BEB's are slightly more mature than FCEB at this point. Range issues with BEB's have to be addressed by bus OEMs, as many deployments are experiencing poor real-world performance relative to tests and claimed performance capabilities. Hydrogen fuel needs to become more economical, a function of scale and demand for the fuel.

These ZEB technologies cannot be deployed in the same way that CNG replaced diesel, because much more up-front planning is required. Procurement specifications must be very thoroughly written, and fueling/charging infrastructure designed in parallel with vehicle planning. To reduce risks, an agency must consult others who have gone before them, work with experts as needed, and proceed cautiously. The Massachusetts DOT report correctly identified some of the critical elements to a successful ZEB deployment[7]:

1) Fleet Size: starting with a few buses rather than with a large fleet
2) Technology Choice: understanding the technologies and properly choosing the one that matches the needs, conditions, and limitations of a transit agency and service area
3) Staff Training: proper training for a suitable amount of time of drivers and maintenance personnel while enabling information exchange between stakeholders for troubleshooting purposes
4) Stakeholder Collaboration: having an effective level of collaboration, cooperation, and support (both monetary and nonmonetary) between stakeholders

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[7] Zero-Emission Transit Bus and Refueling Technologies and Deployment Status. Eleni Christofa, PhD; Krystal Pollitt, PhD, P.Eng. Dany Chhan; Aikaterini Deliali, BS; Jennifer Gaudreau, BS Rassil El Sayess, PhD. December 2017 page xi

Charging Considerations

The existing offering of electric buses do not have the same range as Kitsap Transit's existing diesel buses. Therefore, the buses may not be able to complete a longer run without some charging in the middle of the day. Buses may require charging at on-route transit centers or returning to base to charge.

Battery Size

Battery size and energy consumption ultimately determines the overall electric bus range. Battery sizes range from 126 kWh to 818 kWh, depending on the manufacturer, so battery size is a major consideration before making a determination of which manufacturer to utilize. For the purpose of this evaluation, a 440 kWh battery was utilized since this matches the size of Kitsap Transit's 40-foot Gillig bus currently on order. An estimated 20 percent battery reserve was also applied in order to ensure that the batteries have enough capacity to reach the base at the end of the route. This reserve reduces the 440 kWh battery size to 352 kWh of usable capacity.

Energy Consumption

The estimated electrical consumption was calculated based on the miles traveled. For the purpose of this study, it was assumed that each bus could reach the advertised 1.8 kWh per mile under optimal driving conditions. However, two mileage reductions were implemented for this study to be applicable to real-world performance. The first mileage reduction is for uneven terrain as it has been shown that electric bus range may decrease by 30 percent due to uneven terrain, and this type of terrain is common within Kitsap Transit's service territory.

The second reduction stems from operating heating or cooling systems during transport. In order to keep a comfortable internal temperature, operating the heating or cooling system can reduce overall range by another 30 percent. Many electric buses do not have the ability to open passenger windows.

For the purposes of this study, it is assumed that the modified vehicle efficiency is 3.67 kWh per mile to account for hilly terrain under hot or cold weather conditions. It should be understood that this is a worst-case scenario and not all operations will occur under these conditions, so better range may be achieved and reduced charge times/cost may be realized.

Under the above assumptions and constraints, it is assumed that the maximum electric bus range for a 440 kWh battery is 96 miles. Kitsap Transit provided run card data from the weekday routes based on late-September 2019 runs. The bus range was then compared to each run card to determine which runs could be completed with and without on-route charging.

Bus charging was analyzed at each of the three bases and during the morning and afternoon route runs. The charging is discussed below for each base and for multiple scenarios.

Daily Base Charging

Out of the 95 bus run cards provided by Kitsap Transit, forty-four runs are less than 96 miles in length and would be able to consistently deploy electric buses under the conservative 3.67 kWH per mile analysis. These runs consist of 19 morning runs and 25 afternoon runs ranging in lengths from 21 to 92 miles. Table 6 shows these route numbers and lengths.

Table 6: Route Lengths

Center	Time	Run Number	Actual Route Miles
Charleston Base	AM	A1	26.1
		A3	25.1
		A7	22.5
		A14	53.9
		A15	21.7
	PM	P1	57.6
		P2	26.3
		P3	20.5
		P5	67.8
		P6	67.5
		P7	29.3
		P8	53
		P11	51.2
North Base	AM	94	88.8
		98	69.9
		A21	71.7
		A27	57.9
		NK1	74.8
		NK2 AM	77.1
		NK3 AM	79
		NK4	79.2
		NVS1 AM	49.9
		PGK1	42.6
	PM	93	91.6
		94-93	84.2
		NK2 PM	78.2
		NK3 PM	39.1
		NVS1 PM	63.6
		P21	41.5
		P22	62.9
		P24	71.9
		P25	44.7
		P27	59.6
		P29	39.5
		P31	49
		P32	44.7
		SS	88.1
South Base	AM	A42	34
		A43	29.8
		PO4	36.5
		SW1	52.4
	PM	P40	52.8
		P42	69.5
		P43	33.6

There are five morning and eight afternoon routes (13 total) out of Charleston Base that are less than 96 miles long. These routes range from 20 to 68 miles. Thirteen morning routes and one afternoon route exceed 96 miles long out of the Charleston Base.

Ten morning routes and 14 afternoon routes (24 total) operating out of the North Base are less than 96 miles long. These routes range from 39 to 92 miles. Seventeen morning routes and 14 afternoon routes are longer than 96 miles.

Out of the South Base, four morning and three afternoon routes (7 total) are less than 96 miles long. These routes range from 33 to 70 miles out of the South Base. Only three morning routes and one afternoon route exceed 96 miles out of this base.

Additional Route Considerations

HDR is currently developing a model (ZEPCOT) to calculate an electric buses energy consumption based on data available from public sources such as Google Maps for route stops and terrain models for route elevation. This model was utilized to check the battery consumption of the conservative estimates above. Since the data for this analysis was obtained from third-party sources, the accuracy has not been verified, therefore precaution should be taken when utilizing these results. The model assumes a peak battery capacity of 91 percent full and a minimum of 25 percent remaining for reserve.

The model also takes into consideration the actual terrain for the run as well as a range of battery consumption for heating and cooling during different periods throughout the year. The estimated average battery consumption due to accessories such as lights, heating, fans, etc. is 22 kWh per hour during the coldest period.

Since this model takes into account terrain and route time, the kWh per mile is route specific and shows a battery consumption between 2.8 and 4.6 kWH per mile with an average of 3.2 kWh per mile. This equates to a range between 63 and 105 miles with an average of 90 miles.

Since the ZEPCOT model range was similar to the conservative estimate above, there were not a significant amount of additional bus routes that could be operated using daily base charging alone. Five additional runs out of the North Base could be considered for additional electric bus operations (Table 7).

Table 7: North Base Routes for Consideration

Route	Length
97 AM	95.9
106 PM	99.0
99 PM	102.8
106-95 AM	104.4
A22 AM	104.8

Mid-day Base Charging Analysis

Due to the fact that several morning runs are short in length and duration, it is possible that these buses may complete the morning run, charge at the base, and be deployed for an afternoon run as well. Optimizing bus deployment with this strategy can result in the reduction of the number of electric buses purchased or can provide additional reserve buses.

All five of the morning bus runs at the Charleston Base are capable of charging during the day and completing an afternoon route later that same day. Utilizing this deployment method will reduce the total electric buses purchased and operated out of Charleston Base from 13 buses to eight.

Of the ten morning routes suitable for electric buses out of the North Base, six of these buses could be charged and ready to deploy again in the afternoon. These six buses would reduce the electric buses purchased at the North Base from 24 to 18.

All four of the morning bus runs out of the South Base are capable of charging and deploying for the three afternoon runs. Deploying four electric buses, rather than seven, would be able to serve the current South Base needs.

Utilizing mid-day charging can reduce the amount of electric buses purchased and deployed by Kitsap Transit. If a gradual purchase strategy is used, Kitsap Transit can experiment with mid-day charging to determine the effectiveness or whether additional buses should be purchased due to maintenance or other requirements that limit mid-day charging and redeployment.

Table 8 depicts the morning routes that can complete charging prior to redeploying in the afternoon.

Table 8. Mid-day Charging Routes

AM Route	Base
A-1	Charleston
A-3	Charleston
A-7	Charleston
A-14	Charleston
A-15	Charleston
98	North
A-21	North
A-27	North
NK1	North
NVS1	North
PGK1	North
A-42	South
A-43	South
PO4	South
SW1	South

Select On-route Charging Analysis

As requested by Kitsap Transit, HDR evaluated the potential for on-route charging at the Wheaton Way, Silverdale, and Port Orchard transit centers/stops. Twenty morning routes and eight afternoon routes have stops at one or more of these facilities. Of the 28 total routes, three morning routes and five afternoon routes are fully capable of charging at the bases and do not require on-route charging, though these on-route chargers could be utilized to reduce some of the base charging loads, if it is more economical to charge on-route rather than at the base.

It is assumed that a 350 kW charger would be utilized for on-route charging. Table 9 depicts the routes that have stops at any of these transit centers, the time spent at each transit center, and whether the charge time is adequate to complete the particular route.

Table 9: Select On-route Charging

Route Run	Battery Discharge (kWh)	Transit Stop	Total Stop Duration (min)	Note
Morning Routes				
NVS1-AM	183	STC	20	1
PO4AM	134	PO	10	1
SW1AM	192	PO	5	1
BNG-AM	506	STC	95	2
PO1	749	PO	98	2
PO2	894	PO	128	2
PO3	816	PO	145	2
SS-AM	395	STC	60	2
PK-2	666	WW,STC	90	4
NVS2	918	STC	60	3
NVS3	579	STC	15	3
PB-4	651	STC	20	3
PK-1	712	WW,STC	60	3
SB1	1002	STC	72	3
SB2	826	STC	68	3
SB3	918	STC	56	3
SB4	738	STC	59	3
SB5	924	STC	69	3
SHP	704	WW	55	3
Afternoon Routes				
P-3	75	WW	5	1
P-5	249	WW	15	1
P-6	248	WW	10	1
NVS1-PM	234	STC	20	1
SS-PM	324	STC	53	1
BNG-PM	502	STC	90	2
NK-1	474	STC	10	3
SW1PM	574	PO	25	3

Notes: 1) On-route charging not required, but base charging is reduced
2) On-route charging increases range and route can be completed
3) On-route charging not adequate to complete route
4) On-route charging adequate only if charged at both transit centers

As shown in Table 9, six morning routes and one afternoon route would be capable of finishing an entire run through the addition of on-route charging. However, the Wheaton Way transit stop is only successful in completing one bus run, and even that is only through the additional charging at the Silverdale transit center. At this time and given the 350 kW charger cost, it is not recommended to install route charging at Wheaton Way at this time.

Installation of an on-route charger at the Silverdale transit center would allow three additional bus runs to be completed out of the North Base. Installation of on-route charging at the Port Orchard stop would allow three additional bus runs to be completed out of the South Base.

Viable on-route charging is not practical at the three select transit centers at this time. Kitsap Transit may consider piloting on-route charging at the Port Orchard and/or Silverdale Transit Center, but the return on investment would be minimal. These stations could be more viable under the following circumstances:

- Shorter routes/runs
- Increased battery efficiency
- Longer charge duration at the transit center
- Larger bus battery
- Larger charge capacity

Extensive On-route Charging Analysis

In addition to the select on-route charging at the Silverdale, Wheaton Way, and Port Orchard transit centers, HDR also evaluated potential 350 kW on-route charging at the Bainbridge, Bremerton, and North Viking transit centers. It is understood that these sites require extensive planning, design and construction to convert to on-route charging, so this was just an exercise to understand how much additional on-route charging could be performed at these sites. Planning for and installing on-route charging at these transit centers is not recommended at this time.

Since none of the buses based in South Base spend any significant time at the Bainbridge, Bremerton, or North Viking transit centers, no buses out of the South Base benefit from on-route charging at any of these transit centers. As discussed in the previous section, an on-line charger at the Port Orchard Foot Ferry site would not provide a significant charge based on current run length, transit center layover duration, and existing battery/bus technology.

Table 10 depicts the Charleston Base runs that have stops at the Bremerton Transit Center, the time spent at each transit center, and whether the charge time is adequate to complete the particular route. All of the buses based in Charleston spend time at the Bremerton Transit Center, so multiple on-route chargers would be required at this location. No other on-route charging locations were evaluated for Charleston Base under this analysis.

Based on the current run cards, eight morning runs and one afternoon run out of Charleston Base are able to be completed using on-route charging and 13 additional buses would have reduced base charging due to the on-route charging provided.

Table 10: Charleston Base On-route Charging

Route Run	Battery Discharge (kWh)	Transit Stop	Total Stop Duration (min)	Note
Morning Routes				
A-1	96	BTC	5	1
A-3	92	BTC	18	1
A-7	83	BTC	12	1
A-14	198	BTC	10	1
A-15	80	BTC	10	1
CK	449	BTC	69	2
PK-1	712	BTC	75	2
PK-2	666	BTC	58	2
SB2	826	BTC	88	2
SB6	834	BTC	90	2
SHP	704	BTC	90	2
WS2	608	BTC	120	2
WS3	626	BTC	70	2
SB1	1002	BTC	55	3
SB3	918	BTC	55	3
SB4	738	BTC	48	3
SB5	924	BTC	50	3
WS1	665	BTC	53	3
Afternoon Routes				
P-1	212	BTC	33	1
P-2	97	BTC	31	1
P-3	75	BTC	8	1
P-5	249	BTC	23	1
P-6	248	BTC	25	1
P-7	108	BTC	59	1
P-8	195	BTC	38	1
P-11	188	BTC	31	1
NK-1	474	BTC	102	2

Notes: 1) On-route charging not required, but base charging is reduced
2) On-route charging increases range and route can be completed
3) On-route charging not adequate to complete route

Table 11 depicts the North Base morning runs that have stops at any of these transit centers, the time spent at these transit centers, and whether the charge time is adequate to complete the particular route, while Table 12 depicts the afternoon runs out of North Base. The North Base runs have stops at all three of these transit centers. Multiple on-route chargers would likely be required at each location. In many cases, charging would occur at multiple transit centers.

Based on the current run cards, 13 morning and 8 afternoon buses run out of North Base are able to be completed using on-route charging and 18 additional buses would have reduced base charging due to the on-route charging provided. Finally, 15 bus runs out of North Base do not currently stop at Bainbridge, Bremerton, or North Viking Transit Centers.

Table 11: North Base Morning On-route Charging

Route Run	Battery Discharge (kWh)	Transit Stop	Total Stop Duration (min)	Note
94	326	BI	16	1
98	257	BI	27	1
A-21	263	BI		1
PGK1	156	NV	2	1
NK1	275	NV,BTC	26	1
NK2	283	NV,BTC	23	1
NK3	290	NV,BTC	19	1
NK4	291	BTC	5	1
NVS1	183	NV	17	1
93	400	BI	34	2
96	386	BI	57	2
97	352	BI	43	2
106,95	384	BI	50	2
A-22	385	BI	15	2
KIB1	411	BI	15	2
NVS3	579	BI,NV	46	2
PB-1	451	BI,NV	42	2
PB-2	990	BI,NV	241	2
PB-3	624	BI,NV	52	2
PB-4	651	BI,NV	56	2
PGK2	477	BI,NV	26	2
SIK	413	NV	90	2
99-92	623	BI	5	3
NVS2	918	BI,NV	55	3
A-27	213			4
BNG	506			4
SS	395			4

Notes: 1) On-route charging not required, but base charging is reduced
2) On-route charging increases range and route can be completed
3) On-route charging not adequate to complete route
4) On-route charging not available

Table 12: North Base Afternoon On-route Charging

Route Run	Battery Discharge (kWh)	Transit Stop	Total Stop Duration (min)	Note
NVS1	589	NV	28	1
P24	164	BI	15	1
P31	164	BI,NV	19	1
94	309	BI	10	1
94-93	411	BI	38	1
NK2	143	BTC,NV	66	1
NK3	234	BTC	18	1
P21	231	NV	10	1
P22	264	BI	35	1
NVS3	153	BI,NV	25	2
PB-4	412	BI,NV	30	2
92	733	BI	20	2
93	336	BI	10	2
KIB1	438	BI	65	2
KIB2	287	BI	30	2
PB-1	689	BI,NV	58	2
PB-3	528	BI,NV	62	2
95	447			3
96	389			3
97	378			3
99	363			3
106	502			3
BNG	444			3
P25	219			3
P27	145			3
P29	180			3
P32	474			3
SIK	324			3
SS	733			3

Notes: 1) On-route charging not required, but base charging is reduced
2) On-route charging increases range and route can be completed
3) On-route charging not available

In summary, installing on-route charging at the Bainbridge, Bremerton, and North Viking Transit Centers would increase the number of buses that could complete an entire daily bus run by up to 30 additional runs. These on-route chargers would also reduce the need for some overnight base charging. The need to charge at the base versus on-route would need to be examined further to determine whether it was more economical to charge at either location. On-route charging was not analyzed using the ZEPCOT model, but this analysis could be completed in the future.

Charging and Fuel Comparison

Fuel Comparison

The existing diesel fuel usage was compared with the projected electrical bus usage. One primary concern is the fuel cost; however, other concerns are also valid and deserve consideration. This includes the impact to operating the existing routes and continuing to provide excellent passenger service. One additional consideration is that of point source pollutants.

Electric Costs

Understanding electric rates is the first step in comparing electric and diesel costs. The electric utility typically applies two different electric charges to the electric customer. The first charge is for the energy used (kWh) and the second is for electrical demand (kW) charge. These two charges are described in more detail below.

Energy Usage

Electric usage rates are fairly easy to quantify and are provided by each utility. The electric usage rates do vary, depending on the type of service. For example, a secondary low voltage service rate is generally slightly higher but the power utility handles all of the medium voltage conductor, transformer, and even some secondary conductor maintenance to the facilities meter. A medium voltage, primary service is available for larger loads, of which bus charging may be large enough to qualify. Primary metering may have cheaper rates, but the customer is responsible for more maintenance of the medium voltage conductor and any transformers/ devices/switches downstream of the electrical meter, which all work must be performed by qualified workers.

Utilities bill consumers for energy used based on kilowatt hours (kWh). A 1 kW load running for one hour would be billed as 1 kWh, likewise a 1 kW load running for half an hour would be billed as 0.5 kWh.

For the purpose of this study, it is assumed that PSE will provide Kitsap Transit energy through a secondary metered service ($0.05901 per kWh energy charge).

As an example, a 380 kW load running for nine and half hours would incur a cost of $213.03 (380 kW x 9.5 hour x $0.05901 per kWH). Running this same load for every weekday for a month (22 average weekdays) would incur a monthly energy bill of $4,686 (79,420 kWH).

Since the amount of energy used is directly related to the route length and driving conditions, the amount of kWH required is expected to remain fairly consistent. Reducing kWH usage would require further route optimization.

Energy Demand

In addition to energy use charges, large commercial loads may have an energy demand charge. Electrical demand is not easily understood as it is not charged on most residential customers. Electrical demand is the highest rate of electricity usage in kW during the monthly billing period, per metered service, usually averaged over a 15 minute interval. For the purposes of this analysis, the demand charge is assumed equal to the size of the largest bus charger (i.e. 350 kW fast charger is 92 percent efficient, therefore the input power is 380 kW). PSE's demand rate is $12.28 per kW for a secondary metered service during the summer months and $8.31

per kW in the winter. Under these rates, the monthly demand cost to operate one 350 kW (380 kW input) fast charger is $4,666 per month in the summer and $3,158 per month in the winter. These costs are in addition to the energy use costs.

Reducing Demand Charges

Reducing energy demand costs require the optimization of charger utilization. A larger charger has the advantage of requiring less time, but may also incur a larger demand cost. In order for the electrical buses to be economically viable in the long term, the monthly electrical costs must not exceed the existing monthly fuel costs.

A smaller consistent load will have a smaller demand charge but will have longer charging times. These longer charging times may interfere with normal bus operations and maintenance. Kitsap Transit should optimize charger sizes to minimize cost without significantly impacting bus operability. Different charge types and impacts are discussed below.

Further Rate Considerations

Kitsap Transit may be able to negotiate with PSE for reduced rates, however those rates are usually set through the Washington Utilities and Transportation Commission (UTC) and not easily changed. PSE has indicated that they have proposed an aggregated demand charge to the UTC to decrease demand charges to large customers that may be spread throughout multiple sites. Aggregated demand is explained further in Non-Optimized Aggregated Demand section of this report. The UTC is currently evaluating PSE's proposed rates.

Electric consumption in California has led many utilities to structure rates differently than in nearly any other part of the United States. Many California utilities vary rates depending on the time of the day by charging higher rates during the more heavily used parts of the day in order to try to reduce the peak load on the system as a whole. While this trend has not yet hit Washington, it could impact the economic implications of electric bus charging in the future.

Charging cost comparisons are discussed further in the following sections.

Diesel Fuel Cost

The annual diesel fuel consumption per bus was provided from Kitsap Transit and then compared with the annual miles per bus to determine the average fuel usage. It was determined that the 74 routed buses travel 2,178,085 miles while consuming 423,034 gallons of diesel fuel for an average fuel consumption rate of 5.15 miles per gallon. Assuming a diesel cost of $2.13 per gallon, Kitsap Transit's annual diesel fuel cost is approximately $901,000.

Charge Methods and Charger Sizes

The charger size and method (base or on route charging) has a significant impact on charging costs as well as operability. This has the potential to impact both charging costs as well as daily operations and is discussed prior to further understanding the cost implications.

Base Charging with 62.5 kW Charger

Kitsap Transit currently has one 62.5 kW (70 kW input) charger installed at Charleston Base and is currently planning to install additional 62.5 kW chargers at the North Base for future buses. This charging method retains a low, predictable peak load (kW), thus limiting demand charges. However, achieving a full charge requires a long period of time for buses deployed on long routes. For example, if a bus battery is nearly depleted, it would take over 7 hours to fully charge the battery with this charger. In order to charge an entire fleet, nearly all buses would need to be charged simultaneously to be fully charged by the next deployment.

The drawbacks of this charger size include limiting available time for cleaning and maintenance, precluding a single bus from operating during both the morning and afternoon shifts, and potentially long charge times.

Since the buses operate on two separate shifts, nearly half of the buses could charge during the day and then be deployed during the afternoon while the morning route buses are charged. This charging approach would further reduce demand charges at each base.

Base Charging with Larger Charger

Larger chargers, similar to the 62.5 kW charger, are also available. Proterra utilizes a 125 kW charger, which would reduce charging time of the 62.5 kW charger by half. Other manufacturers utilize various sizes as well, with a common industry size being 150 kW. A 125 kW charger would take 3.5 hours to charge a 440 kWh battery bus while a 150 kW charger would take 3 hours. It should be noted that the 62.5 kW, 125 kW and larger chargers utilize software that can reduce the peak charging rate, if desired. For the purpose of this study, nameplate charge ratings were utilized.

As previously discussed, utilizing a 62.5 kW charger would essentially require one charger for each bus; however, Proterra has recently introduced technology that allows a single charger to charge up to four buses. This technology prioritizes which bus needs charged first and charges the buses sequentially but not concurrently. This does not speed up the overall fleet charging, but does speed up the charging of a single bus before beginning to charge a subsequent bus. Likewise, this does not impact the overall demand charges since fewer buses would charge at one time. Other charging manufacturers have begun to follow with competing technologies.

Utilizing a larger charger would reduce the charge time, freeing up the bus for additional daily deployments and increasing availability for maintenance and cleaning. By also utilizing a staggered charging approach, fewer chargers would be required, charging efficiency is increased by reducing human interaction, and demand loads can possibly be reduced.

One of the more common fast charger sizes is a 350 kW charger. This charger would further reduce the charging time at the expense of higher demand costs. A 350 kW charger could be utilized with a plug in charger but could be more practical for use with a conductive pantograph or wireless inductive charger. A 350 kW charger would take a 440 kWh battery approximately 75 minutes to charge from 0 to 100 percent. Chargers greater than 150 kW may require specialized conductors/cords to decrease heating.

On-route Charging

The transit centers are the only location that a bus has the potential to spend any appreciable time since the intermediary stops are utilized to drop and pick up passengers and then resume the route.

HDR reviewed Kitsap Transit's provided run cards to determine transit center stop times for each bus. HDR compared each buses' run card stoppage time and the route miles to determine if supplemental transit center charging would allow route completion. The practicality of on-route charging was previously discussed, and due to the relatively few buses capable of charging on-route or the complications at the larger transit centers, the cost of on-route charging was not analyzed.

Installation costs

Initial installation cost estimates for a single 62.5 kW charger were $130,000 per charger from the Charleston Bus Grant Application. This included site work, subpanels, conduit, conductor, etc. Approximately half of this cost ($60,000) was the cost of the charger itself. A 150 kW charger purchase price is slightly higher at approximately $75,000 with installation costs slightly higher as well. A second charge port on the 150 kW charger will add approximately $25,000 as well. For that reason a single, 150 kW charger, with dual charging heads will have decreased installation costs over two, 62.5 kW chargers while maintaining nearly the same charge time for two connected buses.

Since Kitsap Transit is moving beyond a "pilot stage" phase into a larger fleet deployment, it is recommended to utilize 150 kW chargers with at least two charge heads. While a larger charger may have a higher demand charge, these costs can be mitigated as described in the next section.

Internet (Cloud-Based) Connectivity

Most bus manufactures are installing on-board monitoring devices on the electric buses. This information is used to track such items as state of charge, speed, location, elevation, and maintenance requirements. Bus manufactures collect this information to improve bus performance, understand maintenance requirements, and even have the capability to push operating system updates to the bus for safety and efficiency improvements.

Internet connectivity has the potential to improve bus fleet operations as well. Identifying the state of charge or maintenance requirements through a preemptive email or text is more efficient than receiving a panicked phone call about a drained battery or broken down bus. This technology can also assist the transit agencies to better serve their ridership by allowing them to track buses as well. While these technologies are generally installed and maintained by the bus manufacture, the amount of data available to the transit agency varies depending on the need and the cost of the service. The need for and extent of this service should be discussed with the bus vendor prior to bus purchase as much of this data can be downloaded from the bus at the bus bases.

Cloud-based connectivity is not required for optimized charging. Charging locations (i.e. bus bases) typically utilize data networks, similar to an office building, that send and receive data from the buses. A bus may communicate the state of charge and the network determines when and how fast to charge that particular bus before it is next required for service. This network connection can then improve charging efficiency and possibly reduce demand chargers as well.

Point Source Pollutant Discharge

Kitsap Transit has previously utilized an emission evaluations tool provided by the Puget Sound Resource Council (PSRC) to estimate pollutant reductions when converting from an older diesel transit bus to a newer bus. Pollutant emission factors are based on a gram/mile bases for vehicle models between 1990 and 2020 and are pulled primarily from Argonne National Laboratory's GREET model. Carbon dioxide (CO_2) emission factors were provided by the PSRC. For the purpose of this study, it is assumed that a 2010 diesel bus would be replaced by an electric bus.

Based on the bus routes recommended to be converted to electric buses, the overall route miles were calculated for each base. The pollutant load reduction was calculated based on the route miles for each base and are included in Table 13.

Table 13: Estimated Pollutant Reduction

	North Base	Charleston Base	South Base	**Total**
Daily Miles	1,550	522	309	**2,381**
Annual Pollutant Reduction (lbs/year)				
CO2	968,133	326,042	193,002	**1,487,177**
CO	977	329	195	**1,501**
PM	18	6	4	**28**
NOx	1,164	392	232	**1,788**
VOC	80	27	16	**123**

Charging Cost Comparison

Battery charging costs were analyzed utilizing a 62.5 kW charger, with a 95 percent charger efficiency, under three separate charging scenarios.

Energy Usage Costs

The following sections will compare different methods of charging. A more detailed explanation of electric rates are included in the Electric Costs section. A summer demand rate of $12.28 per kW was used for comparison within this section. Since the energy usage charge will be the same for every charging option (approximately $11,200) only the energy demand costs are included for this comparison.

Non-Optimized Base Charging

The first charging process evaluated the demand cost for each base if all buses were plugged in 30 minutes after returning to the base at the end of a run. Under this scenario, all buses would charge simultaneously and create the highest demand charge on the system. Since all bases would be billed separately on their peak, this method would also lead to the highest electrical costs. Table 14 shows the demand cost break down by base. Figure 28 shows the demand curve at each base does not necessarily peak at the same time.

Table 14: Non-Optimized Base Charging

Base	Number of buses	Estimated kW Demand	Monthly Summer Demand Cost
North Base	12	789	$ 9,700
Charleston Base	5	329	$ 4,050
South Base	4	263	$ 3,250
TOTAL	**21**	**1,381**	**$ 17,000**

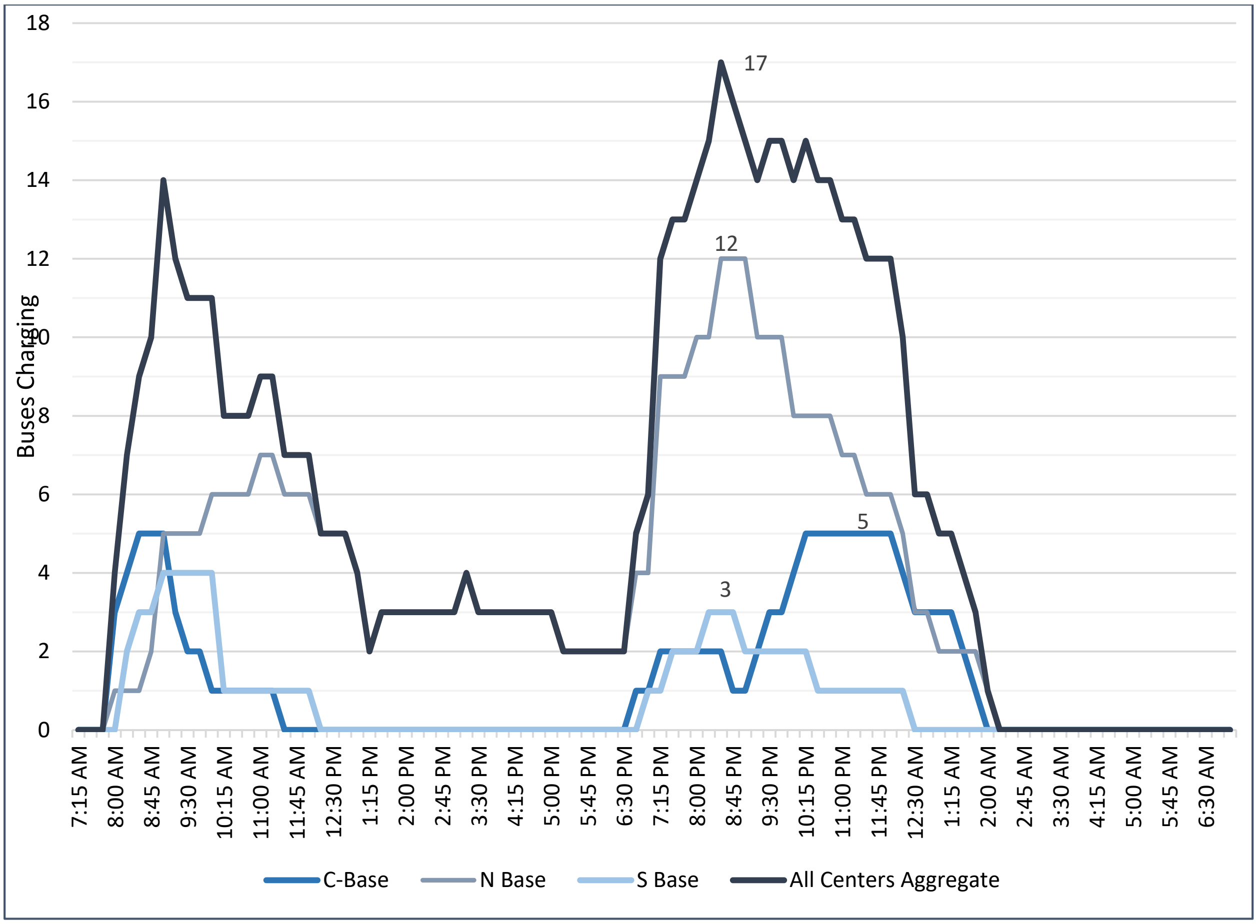

Figure 28: Non-Optimized Base Demand

Non-Optimized Aggregated Demand

The second charging process was very similar to the first process, but evaluates the demand charges as currently proposed by PSE to the UTC. This aggregated demand would reduce the peak demand by combining demand at all three bases to treat them as one entity. This reduces the maximum number of buses to 17 charging concurrently, a kW demand of 1,062 kW, with an associated cost of $13,750 per summer month. The non-optimized base charging demand is shown as the black line in Figure 28.

Optimized Aggregated Demand

Previous base charging costs were based on the assumption that the bus would be placed on the charger one half hour after route completion and remain until charged. By staggering charging times the maximum number of buses charging concurrently can be reduced to eight, a demand of 500 kW, and an associated cost of $6,500 per summer month. The demand curve for optimized aggregated demand can be seen in Figure 29.

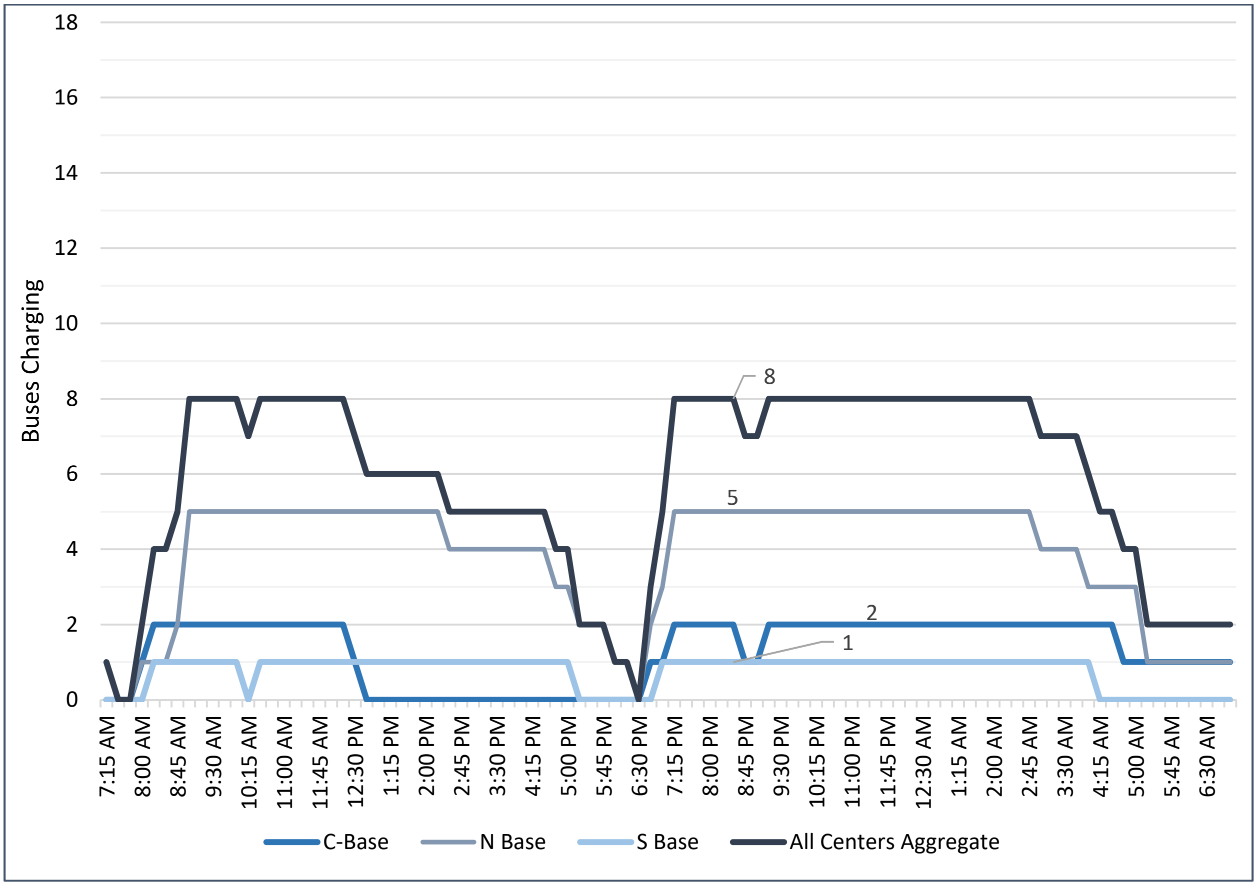

Figure 29: Optimized Aggregated Demand

Electric Cost Comparison

Table 15 shows the combination of the monthly summer and winter demands and the energy costs for each charging scenario above.

Table 15: Annual Electric Charging Cost Comparison

Scenario	Monthly Summer Demand Cost	Monthly Winter Demand Cost	Monthly Energy Cost	Annual Electrical Cost
Non-Optimized Base	$16,700	$11,500	$11,200	$303,600
Non-Optimized Aggregate	$13,750	$9,300	$11,200	$272,700
Optimized Aggregate	$6,500	$4,400	$11,200	$199,800

Comparison to Diesel Fuel

Directly comparing costs between electric buses and diesel buses is not a straightforward process. Certain operational costs exist for one that doesn't exist for the other. Electric buses typically have less maintenance costs; however, diesel buses do not incur an electrical demand cost.

Annual fuel costs were compared for the applicable electric bus routes based on estimated annual costs. Table 16 depicts the annual fuel costs as well as an estimated increase or decrease over the existing diesel buses.

Table 16: Diesel vs. Electric Fuel Comparison

Scenario	Annual Cost	Difference from Diesel
Diesel	$255,900*	NA
Non-Optimized Base	$303,600	$57,700
Non-Optimized Aggregate	$272,700	$16,800
Optimized Aggregate	$199,800	$(56,100)

* Diesel cost is compared only to those runs that would be converted to electric buses

In addition to fuel costs alone, converting existing diesel buses to electrical buses has the potential to reduce tailpipe pollutants such as particulates, carbon dioxide and several others.

Additional Considerations

As proven technologies are left behind and new technologies are adopted, potential limitations, questions and concerns arise. Diesel bus operation has been largely unchanged for decades and operators know how to handle minor emergencies such as running out of fuel, sitting in traffic and even more substantial issues such as breakdowns and weather emergencies.

Through discussions with Kitsap Transit during this study, several concerns regarding electric bus conversion have consistently arisen. The discussion within this section will not entirely solve all of these issues, but provides some methods to overcome obstacles or ease these concerns.

Extended Run Time

While Kitsap Transit maintains up to date run cards that outline stop times for each run, there are times when some of these runs do not go according to the planned schedule. Weather, accidents, and other traffic issues can extend time on the road and away from the base. Since electric buses do not have the same range as a diesel bus, not returning to the base or on-route charger could leave passengers stranded.

To avoid stranding passengers, conservative calculations have been used in this study. Assumptions such as the heating and terrain range reductions give some flexibility. Additionally, the 20 percent reserve battery capacity (88 kWH) is another effective way to reduce potentially stranding passengers.

The ZEPCOT model used for run comparison also took into account a reserve battery capacity (25%). In addition to the battery reserve, this model also factored the heating, cooling, and other accessory loads separately from battery discharge during routed operations. The ZEPCOT method estimated accessory usage at 22.3 kWH per hour under the coldest period of the year. These accessory loads would be running nearly constantly during a traffic delay even if the drive motors are not engaged. Accessory loads could operate for almost four hours at 22.3 kWH per hour before the 88 kWH reserve capacity is consumed.

By maintaining a reserve battery capacity throughout daily operations, the likelihood of stranding passengers due to extended run times is greatly reduced.

Backup Power Supply

If the existing diesel tanks at a base were ever to run dry, the bus could obtain fuel from a commercial dispenser without significant interruption to normal operations. However, if a power outage occurs at a bus charger, an electric bus may not have the capability to operate for a full run during the next shift.

During the initial stages of the diesel to electric conversion, an electric bus may be able to be replaced by a diesel bus for a period until the outage is resolved. However, once an entire fleet is converted to electric buses, reserve buses may be few and the chance that all of the buses were not affected by the outage might be minimal. Kitsap Transit has some concerns about what to do in the event of a power outage.

Several methods that may reduce the impact of an outage to the grid are described below.

Redundant Grid Source

The first option is to work with the utility to have a backup grid source. For instance, the distribution system feeding Charleston Base is a loop system that feeds from two different feeders out of the Rocky Point Substation. In the event that the main north feed experienced an outage, PSE has some ability to isolate that outage while feeding from the south side of the system. The degree of reliability depends on other factors such as the substation and transmission sources as well that may or may not have redundant capabilities. PSE's ability and response to switch sources may limit outage times, but the outage may still impact the full battery charge. Redundant grid sources at the other charging sites was not determined within this study.

Backup Generation

A second source of redundant electric supply is through backup generation. This can be fueled from natural gas or diesel. Due to Kitsap Transit's existing diesel storage capacity, diesel generators may be the preferred alternative, though nearby gas may also be available. A relatively small, transportable generator may be capable of charging a single bus; however, charging multiple buses at the same time will require a larger, stationary generator. The large diesel storage capacity at Kitsap Transit's bases would provide enough capacity for multiple days of charging. In the event of a larger disaster, the diesel tanks could be resupplied indefinitely, providing an even longer ability to charge the bus batteries.

Battery Storage

A third potential source of backup power is through battery storage. Battery storage is gaining popularity as battery technology improves and society relies more heavily on reliable power. At this time, large quantities of battery storage are very expensive and still do not have the ability to sustain long outages. Due to the substantial costs, backup batteries are currently used at electric fleets to reduce peak energy demands but not for extended redundant power purposes. Peak shaving is discussed some in the next section.

For the purpose of consideration, three different battery cases are presented in Table 17 for the loads at the Charleston Base. As shown in the table, smaller batteries could only charge 1 to 3 buses before the battery storage is depleted. The large battery may be capable of nearly charging all 13 electric buses for two days depending on the bus battery consumption. The large battery storage cost are not justifiable to maintain these batteries for long-duration outages that occur very infrequently.

Table 17: Charleston Base Battery Storage

Battery Size (kWH)	Capital Cost	Number of Buses Charged at 80% Charge
500	$325,000	1.42
1000	$600,000	2.84
8000	$5,600,000	22.7

Reduced Energy Demand Costs

Energy demand costs can be significant depending on the charger size, quantity, and speed of charging. Several methods of reducing this demand have been discussed within this report, including staggered charging through the use of smart chargers and aggregated demand rate structure from the utility. One additional method to reduce demand costs is to reduce the peak through battery storage. While large batteries may be cost prohibitive, smaller batteries may provide minimal storage capacity while also reducing energy demand.

Onsite Battery Storage

Several storage scenarios were evaluated for peak demand reduction at the North Base. Similar outcomes would occur at the other bases, but North Base was utilized because it has the largest load and has the most pronounced peak reduction in comparison to the other bases. A battery storage scenario was evaluated for the Non-Optimized and Optimized charging conditions discussed within the Charging Cost Comparison section above.

North Base – Non-Optimized Base Charging

This charging scenario assumes that each bus begins charging 30 minutes after it returns to the base and charges until the battery is fully charged. This scenario leads to the peak load of all other charging conditions. The peak demand without battery storage for this condition is 789 kW.

Under these conditions, the battery size was optimized to utilize a 275 kW/500 kWH battery storage device at the North Base. This battery provides an overall peak demand reduction of 275 kW. PSE's rates as well as the operations and maintenance costs were also considered to determine a 25-year present worth with and without the battery storage. The following is a summary of this analysis:

Capital Cost: ~ $325,000
O&M: ~ $7,000/year
Annual Utility Bill Savings: $23,163.96
Net Present Costs (25 years) – Without Battery Storage: $2.69M
Net Present Costs (25 years) – With Battery Storage: $2.89M
Total Savings: -$203,610
ROI: -1.1%

The analysis indicates that the capital expenditure required would never be recovered by the potential monthly savings.

North Base – Optimized Base Charging

This scenario assumes that the buses are charged sequentially to reduce the draw on the utility while still completely charging the bus prior to the next shift. The peak demand without battery storage for this condition is 329 kW.

Under these conditions, the battery size was optimized to utilize a 250 kW/800 kWH battery storage device at the North Base. This battery provides an overall peak demand reduction of only 73 kW. The 25-year present worth was calculated with and without the battery storage:

Capital Cost: ~ $500,000
O&M: ~ $10,000/year
Annual Utility Bill Savings: $5,527.23
Net Present Costs (25 years) – Without Battery Storage: $2.09M
Net Present Costs (25 years) – With Battery Storage: $2.80M
Total Savings: -$713,468

ROI: -5.4%

These two scenarios show that the larger the demand reduction, the more attractive the battery storage becomes. Since the optimized charging was already reducing the peak demand, the battery storage results in reduced savings and a longer return on investment over the non-optimized scenario. Battery storage has even higher returns and may become economically viable as the peak increases.

In Kitsap Transit's case, the easiest way to drive up the demand costs would be to charge all buses simultaneously. This scenario is not recommended for several reasons including the fact that Kitsap Transit prefers to purchase fewer electric buses and charge morning buses during the day and redeploy the same buses in the afternoon. Further, simultaneous charging would require additional capital costs for additional charge units that could be avoided due to the bi-daily charging and optimized charging.

Emergency Operations

Kitsap Transit operations have the potential to be critical in the event of a natural disaster or wartime acts. Bremerton is home to a large naval base with several other military installations within Kitsap Transit's service territory. Kitsap Transit buses serve the military staff on a daily basis and would serve a significant role in mobilizing that staff in the event of an emergency.

Further, the Kitsap Transit service territory is located within the Ring of Fire and prone to volcanic and seismic activity. An earthquake, eruption or other natural disaster has the potential to limit transportation, as well as utility services such as electric and natural gas. Kitsap Transit would be called upon to utilize the buses for emergency services, transporting the public work force to restore services, or even transporting military service members for homeland protection.

Kitsap Transit staff and facilities must remain prepared for such disasters no matter the bus propulsion. As stated previously, electric buses have some potential complications in the event of a major disruption to the electric grid. It has also been shown that battery storage facilities large enough to sustain services through extended periods are very costly and offer little financial return.

In lieu of the battery storage solution, Kitsap Transit can maintain extended disaster relief both in the short- and long-term electric bus conversion.

Interim Bus Conversion

Kitsap Transit is currently only purchasing electric buses for their route bus fleet at a rate of no more than five buses per year. At this rate, it will take nearly 15 years to completely convert to electric route buses, if all routes could be converted to electric. Over the conversion period, numerous diesel route buses will remain in service due to the time to conversion time and/or the inability for electric buses to complete the longer routes. These holdover diesel buses would be utilized in case of extended service outages and emergencies.

By the time the full route fleet is converted to electric buses, the battery and charging technology will change drastically and likely have shorter charge times and longer deployment durations. These improvements will likely cause the electric buses to operate very similar to the existing diesel buses, but with much fewer emissions.

In addition to Kitsap Transit's route buses, Kitsap Transit also maintains a large fleet of worker/driver buses and access service buses. Kitsap Transit typically purchases used buses for the worker/driver fleet, and it will be some time before used electric buses are available in the resale market. Kitsap Transit is not currently planning to purchase electric buses for these other services. If more buses are required for emergency services than what can be supplied by the diesel route buses, diesel worker/driver buses can reliably supplement service to the area.

Further, Kitsap Transit also plans to maintain several natural gas powered buses for their access fleet. These buses can also continue to serve the fleet during emergency conditions with a fuel source that is not dependent on electricity or diesel fuel.

Long-Term Conversion

Even if the worker/driver and access service fleets never convert to electric buses, Kitsap Transit will likely still want to have a long-term solution to extended power outages and possible emergency services. It is highly likely that the bus, battery and charging technologies will continue to improve to extend battery life, provide more efficient vehicles, and reduce charging time. However, the timing and extent of these improvements cannot be fully predicted.

In order to reliably provide long-term redundant power, Kitsap Transit will likely require purchasing an engine generator. As previously discussed, the generator would utilize a fuel source independent of the electrical grid. Natural gas is available in the Kitsap area and is reliable, clean and economical. One downfall to natural gas is that the underground supply network could become severed in the event of a large natural disaster.

Diesel is another fuel source for engine generators. Kitsap Transit currently has diesel storage tanks at the Charleston and North Bases as well as transport trucks for the South Base. Diesel fuel delivery is dependent on the trucking industry, which could also be interrupted by large disasters. However, keeping Kitsap Transit's existing diesel tanks near full capacity could provide adequate storage to charge electric buses through an extended outage.

Mobile diesel generators are one option to serve multiple bus bases, but this is not likely viable due to the large number of buses at each charging location. Instead, it would be better to install a generator at each of the three bases. The generators should be sized in order to fully charge the buses daily. Due to the uncertainties in the deployment and operation of these buses, it is difficult to size these generators at this time, and they should be sized, purchased and installed after Kitsap Transit has additional experience operating the electric buses.

Utility Coordination

As previously discussed and indicated by other BEB studies, it is crucial to begin conversations early with the utility serving the electric chargers. The utility infrastructure costs can sometimes be neglected until late in the project and cause issues for transit agency budgets. Another item that is not always understood is charging rates as these are not always just a simple, per kilowatt-hour energy cost.

Utility Power Supply – Bus Bases

On behalf of Kitsap Transit, HDR began having discussions early in the study process with Puget Sound Energy (PSE) to understand how potential electric bus infrastructure may impact the PSE electrical grid. HDR met with PSE staff on October 24th to begin discussing Kitsap Transit's electric bus impacts. A follow up conference call between Kitsap Transit, PSE, and HDR occurred on November 12th.

The primary purpose of the November 12th call was to discuss PSE infrastructure supplying power to the Charleston Base as the Charleston Base was being submitted for a grant to upgrade existing infrastructure for electric bus charging. PSE provided information regarding the substation capacity, overhead and underground distribution conductor utilization, and the capacity of any existing distribution transformers at the base.

Following the submittal of the grant, HDR reached out to PSE to understand the substation, distribution conductor, and existing distribution transformer limitations at the North and South Base as well. Information from PSE is discussed within this section below.

PSE stated that the capacity of the existing substation and distribution lines are only relevant at this period in time and that the capacity may not be available in the future. PSE stated that the only way to guarantee the available capacity to any particular customer/meter is to complete an application for service, which includes the requested kWH and kW demand loading. Kitsap Transit is looking into completing the service applications at the three bases to ensure capacity is available until the load develops.

Charleston Base

During the grant application process for Charleston, it was determined that even if the base currently has only 13 routes capable of utilizing electric buses, Kitsap Transit would like to ensure enough capability to power at least 17 electric buses due to space availability at the site. The 17 electric buses were utilized for the grant application and are also carried over to this report.

The Charleston Base is served electricity out of PSE's Rocky Point substation near the corner of 9th Street and North Charleston Avenue, approximately 0.7 miles northwest of the Charleston Base. The Rocky Point Substation supplies power to the area via two, 25 MVA power transformers. PSE has stated that the substation has ample capacity to supply power the first 17 electrical buses at Charleston Base (~1.5 MVA) out of this substation.

Approximately 1.1 miles of overhead distribution conductor supplies power to the Charleston Base. According to PSE, the overhead conductor is rated for 600 amps (A) and is only currently loaded to about 30 percent during peak conditions. Adding charging for up to 17 electric buses at this location will increase the overhead conductor loading to approximately 39 percent. Most utilities generally prefer to load lines at less than 75 percent with large feeder ties often loaded to 50 percent or less. PSE stated that the existing overhead conductor is adequate to handle the additional load from up to 17 electric buses at Charleston Base.

A short portion (400 feet) of underground conductor is located under Charleston Boulevard, and supplies the last length of power to the Charleston Base. This conductor is currently loaded at 13 percent and will increase to 48 percent with the addition of 17 electric buses at Charleston. While this underground segment is not overstressed and has some additional capacity beyond the 17 bus load, this segment may need replaced by PSE if additional electric buses are operated out of this base.

The existing distribution transformers at this location are currently undersized to serve the existing loads. During the grant application process, it was determined that approximately 1,300 feet of new underground distribution conductor would be installed along Callow Avenue to feed a new distribution transformer at the north end of the base. The distribution transformer capacity would likely be 1.5 MVA.

North Base

Kitsap Transit had already began to engage PSE in the process of installing charging stations at the North Base prior to beginning this electrification study. In May 2019, PSE provided a design to install a new underground riser to a padmounted 750 kVA distribution transformer near the northwest corner of the base. The transformer was sized to serve up to eight, 62.5 kW charge stations at the base. One charger was scheduled for complete installation by the end of 2019 or early 2020.

The North Base currently has 24 runs capable of converting to electric buses. This is the most runs out of Kitsap Transit's three bases. The North Base also has the largest potential for future on-route charging and is the only base with capacity for any additional runs predicted by the ZEPCOT model as well. Additional chargers will need to be installed at this base in order to support the additional electric bus conversion at this location.

The North Base is served electricity out of PSE's Poulsbo substation near the corner of Viking Way Northwest and NW Liberty Road, approximately 1.5 miles south of the North Base. The Poulsbo Substation supplies power to the area via one, 25 MVA power transformer. No substation upgrades were required by PSE to serve the initial eight buses at this base. PSE has stated that the substation is currently 39 percent loaded and has ample capacity to supply power 24 electrical buses at North Base (~2 MVA).

Approximately 1.1 miles of overhead distribution conductor supplies power out of the Poulsbo Substation before a 0.1 mile section of underground conductor as the line crosses Highway 305. After crossing the highway, the line returns to overhead for approximately 0.3 miles before reaching the North Base. According to PSE, the overhead conductor is rated for 600 amps (A) and is currently loaded to about 87 percent during peak conditions. Adding charging for up to 24 electric buses at this location will increase the overhead conductor loading to approximately 100 percent. Most utilities generally prefer to load lines at less than 75 percent with large feeder ties often loaded to 50 percent or less. PSE stated that they are currently looking into reducing the existing loads on this conductor and that the overhead line is adequate for the projected loading.

The planned distribution transformer is adequate to serve up to eight chargers. Up to 29 runs could be served out of this bus base. The additional electrical load from these chargers would require additional distribution transformer capacity to serve these loads. This additional load should be coordinated with PSE prior to purchasing more than eight electric buses at this base.

With the North Base proximity to the North Viking Transit Center, it may be possible to utilize on-route charging at the transit center to charge buses prior to or after completion of their daily runs. Electric loads at the transit center would impact the same utility line as the North Base.

South Base

South Base is currently the smallest base, has the fewest buses, and has the least amount of routes capable of operating electric buses. However, Kitsap Transit is committed to converting to electric buses at this location in the future as well. PSE has been engaged to help Kitsap Transit understand the current electrical capacity at South Base. South Base currently has seven runs capable of converting to electric buses.

The South Base is served electricity out of PSE's East Port Orchard substation near the corner of Mitchell Avenue SE and Jefferson Avenue SE, approximately 0.7 miles southwest of the South Base. The substation supplies power to the area via one, 25 MVA power transformer. PSE has stated that while the substation has peaked at 22.2 MVA, it has ample capacity to supply power the first seven electrical buses at South Base (~500 kVA) out of this substation.

Approximately 0.7 miles of overhead distribution conductor supplies power out of the East Port Orchard Substation along Mitchell Avenue and then Mile Hill Drive. At Retsil Road SE, the line taps off the main line for 0.2 miles to Kitsap Transit's South Base. PSE did not provide the capacity of the existing main line out of the substation, but rather only provided the line capacity and loading at the Retsil Road tap. The line is currently loaded at approximately 24A, which equates to 16 percent loaded on a line rated for 150A. By adding the 500 kVA transformer to feed to seven planned chargers, the load increases to 47A, or 31 percent of line capacity.

The existing distribution transformers at this location are currently very small so a new three-phase transformer would be required. The existing electrical load at the South Base is very small, so no additional overhead conductor improvements would be required. PSE and Kitsap Transit may decide to install a padmounted, 500 kVA transformer, so installation of a minimal amount of underground conductor may be required. The existing 40T overhead fuses would be replaced with 65T fuses to serve the increased load.

A 500 kVA transformer would be capable of serving seven electric buses stationed at South Base. However, installing a 750 kVA transformer at this location would be a relatively small additional cost and could serve up to 11 electric buses, giving room for future growth at this location.

Utility Power Supply – Transit Centers

The existing distribution utility route and substation was investigated to serve each transit center. This was completed by windshield surveys, aerial photography, and limited knowledge of PSE's system. The actual route is not always known, especially for those areas served by underground facilities. Substation locations serving these loads were determined by following the existing distribution feeders.

Due to the fact that on-route charging at the transit centers is currently of minimal value at the three select locations or would be difficult to install at the three heavily used centers, PSE was not requested to supply the grid capability to serve these transit centers at this time.

Wheaton Way Transit Center (East Bremerton)

The Wheaton Way Transit Center was completed in late-2019. An overhead conductor is located along the east side of the transit center, and the substation is located approximately 0.4 miles southeast of the transit center near the corner of Sylvan Way and Spruce Avenue.

The Wheaton Way Transit Center currently has only one run that would benefit from on-route charging at this location. Future route changes may include more stops for longer durations at this center and could lead to additional runs benefiting from on-route charging.

Silverdale Transit Center

The substation serving the existing Silverdale Transit Center is located approximately 1.1 miles south of the transit center, near Bucklin Hill Road and Randall Way. The distribution feeders from the substation to the transit center are entirely underground, so the existing conductor size and actual route are not known.

Preliminary design has begun for a new transit center to support the Silverdale area. The new facility would be located near Ridgetop Boulevard NW and NW Sid Uhnick Drive. The substation for this facility is located approximately 1 mile southeast of the transit center near the intersection of Central Valley Road and Highway 303. An existing overhead distribution circuit is located along NW Bucklin Hill Road. An underground feed continues near NW Myhre Road to the proposed transit center site.

Five North Base runs would benefit from on-route charging at the Silverdale Transit Center. Two berths at this proposed are currently being planned for possible 350 kW inductive on-route charging capability. As the design continues to progress, on-route charging loads should be considered and communicated to PSE to provide adequate electrical capacity for the site.

Port Orchard Foot Ferry Dock

The Port Orchard Foot Ferry Terminal is served electricity out of PSE's East Port Orchard substation along Mitchell Avenue, approximately 1.7 miles southeast of the ferry terminal.

Various overhead conductor sizes meander from the substation for approximately 1.2 miles to Rockwell Avenue. At Rockwell Avenue, the distribution circuit transitions to underground to cross Bay Street before emerging south of Bay Street and continuing with small overhead conductor for nearly 0.5 miles to Bay Street. Underground conductor crosses Bay Street and feeds the ferry dock area.

Four South Base runs would benefit from on-route charging at the ferry dock allowing all but one existing run to convert to electric buses. Future development at the ferry dock should consider on-route charging loads and those loads should be communicated to PSE to determine the impacts to the electrical grid.

Bainbridge Island Ferry Terminal

The Bainbridge Island Ferry Terminal is served electricity out of PSE's Murden Cove substation along Sportsman Club Road, approximately 3.1 miles north of the ferry terminal. The distribution line consists of a mix of underground and overhead conductors to the ferry terminal.

The Washington Department of Transportation has recently committed to converting several ferries to electric. This will likely require improvements to the distribution lines which would pass the transit center as well. The power factor for this feeder (electrical demand divided by the total electrical load over a 24 hour period) would likely be poor if the ferry is only charged for a brief period after each crossing. The utility would prefer a more consistent load on this line to mitigate the large spikes over a short duration. If electric buses were able to charge during periods when the ferries are not at the dock and charging, ample capacity should be available to charge the buses with minimal utility improvements.

On-route bus charging at the Bainbridge terminal could help complete 15 additional runs out of the North Base without any additional charging at any other on-route chargers. By combining on-route charging at Bainbridge with that at North Viking Transit Center, nine additional runs could be completed and 19 runs would then be capable of charging exclusively from on-route chargers and not require charging at the base.

Due to the number of buses that utilize the Bainbridge terminal and the fact that many of those buses are parked there concurrently, several on-route chargers would be required at this location. The quantity of chargers and the impacted load was not evaluated at this time due to other complications of modifying the existing facility.

North Viking Transit Center

The North Viking Transit Center is located adjacent to the North Base and both are supplied by the same utility infrastructure. The North Base utility implications are discussed above. On-route charging at this facility would put additional stresses on the electrical facilities, but these stresses would not likely coincide with the base charging which would not have as severe effect on the utility.

On-route charging at the North Viking Transit Center is generally supplemented by additional on-route charging at the Bremerton or Bainbridge ferry terminals. Only one additional run could be completed solely by charging at the North Viking Transit Center.

Bremerton Transit Center/Ferry Terminal

The Bremerton Substation serving the Bremerton Transit Center is located approximately 0.9 miles northwest of the transit center, near Warren Avenue and 10th Street. The existing overhead line along Warren Street is large conductor until it drops below ground at the intersection of Burwell Street. The transit center is served by underground conductor from the riser location along Warren Avenue.

Similar to the Bainbridge Island ferry upgrades, the ferry at the Bremerton terminal will likely be converted to electric in the future. Bus charging at the Bremerton Transit Center could see similar benefits as at Bainbridge as well as similar complications to installing on-route charging at a heavily used facility with limited room to expand.

On-route bus charging at the Bremerton terminal could help complete 14 additional runs out of the Charleston Base without any additional charging at any other on-route chargers. Eleven runs would then be capable of charging exclusively from on-route chargers and not require charging at the base.

Due to the number of buses that utilize the Bremerton terminal and the fact that many of those buses are parked there concurrently, several on-route chargers would be required at this location. The quantity of chargers and the impacted load was not evaluated at this time due to other complications of modifying the existing facility.

West Bremerton Transit Center

The West Bremerton Transit Center is not currently heavily utilized and may be relocated in the future. This transit center also does not have extensive layovers so on-route charging is not beneficial. PSE was not engaged in determining the electrical capabilities at this location.

Kingston Route Stop

The Kingston Ferry location is served by two separate distribution feeders originating at the Kingston Substation approximately 2.8 miles northwest of the ferry, along Hansville Road.

These two feeders both originate underground and then transition to overhead near Highway 104. HDR has worked with PSE to redesign both circuits to supply larger loads more reliably in downtown Kingston and to the ferry terminal area. One of these circuits was planned for the possible electric ferry load. Similar to the Bainbridge and Bremerton terminals, the electric utility could likely support any potential on-route bus charging in Kingston if completed during times when the ferries are not charging.

Of the bus runs that stop for any duration at Kingston, many of these can be fully charged by on-route facilities at either North Viking or Bainbridge Transit Centers. The only remaining run (Run 99-92) that does not fully charge at other locations does not spend enough time at the Kingston stop to fully charge the bus battery, so on-route bus charging is not recommended at this location at this time.

Utility Framework

Kitsap Transit plans to purchase electric buses and install the support infrastructure in phases. Additional contact will be required with PSE to determine system improvements at the time of new construction. Even though existing infrastructure is capable of supporting electric bus charging at a certain point, loads change over time and may not be capable of supporting such loads in the future. Kitsap Transit will need to supply basic information regarding the loading request in order to make sure the chargers receive adequate power.

PSE Contacts

PSE has several departments and staff that are helpful in obtaining information for new service requests, available line capacity, electric vehicle charging, account information, etc.

New Service Requests

Most new construction projects will require a new service request. These PSE staff are a starting point of contact and may request additional information regarding the project and are the gatekeepers to additional staff. Typical information required for new service requests are discussed below.

Planning, Design and Construction Engineering

In order to determine the extent of additional utility infrastructure improvements, PSE planning engineers will need to review existing loading in the area and evaluate the additional load request. Planning engineers help to determine if the substation transformer capacity is adequate, whether distribution conductors need to be replaced, and what size transformers and fuses are required. This information is then conveyed to the design and construction engineers so they can plan how to construct the improvements. PSE's system planners were very helpful during this study in determining the capabilities of the existing system supplying power to each of Kitsap Transit's three bus bases.

Design engineers will develop a plan set that can be used to construct the improvements. A design or construction engineer will typically visit the site and discuss the needs and physical layout with Kitsap Transit to provide the correct equipment and understand the physical location. The design often combines maps of PSE's system with maps of the newly developed property. This design also provides electrical loading details, transformer and conductor sizes, and construction unit details. Due to the typical electric bus impacts to PSE's system, most of the design effort will be completed by PSE's distribution engineering team. It is at this stage that PSE will typically provide a scope of work and a fee to complete the work.

Once the design has been completed and Kitsap Transit has approved the price, then the design package will be turned over to PSE's construction crews.

Key Account Representative

Kitsap Transit has several services/meters across PSE's territory and draws a sizeable electrical load from PSE. Due to the complexities and size of Kitsap Transit's load, a key account representative is available generally to discuss billing related questions such as what would be the monthly cost impact by adding a new facility or charger. The Key Account Representative can also provide additional leverage if Kitsap Transit is not receiving timely responses to engineering and design efforts.

Electric Vehicles and New Products

Electric vehicles are continuing to rapidly develop and may significantly impact the electric utilities. PSE has developed a branch to specifically handle electric vehicles and other new products. This team was helpful in assisting during this study as well.

Key Information

When requesting additional service capabilities or expanding electric charging at an existing facility, the following key information will help PSE to plan and design and system improvements more efficiently.

- A site map is required, and it is helpful if this map is in AutoCAD and/or GIS format. The map should include property lines, as well as existing and proposed roads, buildings, fences and driveways. Some of this information may not be required for an existing site that already has electrical service.
- The site map should also include utility locations such as water, storm sewer, sanitary sewer, vaults, or poles. The charger locations should also be indicated on the map as well.
- The projected electrical load will also be required in order to properly size PSE's system improvements. For electric vehicle charging, the load is simply the number of planned

chargers multiplied by the load of each charger. This information is generally provided by the charge head manufacturer. For a 150 kW charger, the delivered load should be divided by the charger efficiency to determine the total load draw from the utility. For example at 95 percent efficient, the charger will draw 158 kW from the utility.
    - An electrical panel board diagram can be prepared during the electrical design and provided to PSE as well.
- Provide a point of contact for PSE to contact for design and construction questions.

Utility Summary

PSE's existing infrastructure between the substation and each of the three bus bases is currently adequate to provide reliable power to charge the initial amount of electric buses at each of the three bases. This includes up to 17 chargers at Charleston, 24 chargers at North Base, and seven chargers at South Base. Additional distribution transformers will be required to be installed at each base to serve the chargers at each base. These transformers would be sized by PSE to meet the requested load.

After determining the potential number of electric buses deployed strictly with base charging and understanding several of the challenges of on-route charging, it was determined that on-route charging would not be pursued at this time and conversations with PSE for these locations were tabled for the future. For those three transit center sites that may be suitable for early adoption of on-route bus charging, the Silverdale Transit Center would likely be the earliest adopter but the return on investment at this site would be minimal. Charging loads at this facility should be considered during the design process and discussed with PSE to ensure proper service capabilities.

Conclusions and Recommendations

Zero-emission bus technologies are evolving rapidly. Battery electric buses are the most common zero-emission bus technology due to their fuel source, ease of use, and the advanced state of the technology. BEB range issues still have to be addressed by bus OEMs. Kitsap Transit, as well as numerous other transit agencies are experiencing poor real-world performance relative to tests and claimed performance capabilities.

Due to the fact that BEBs cannot be deployed in the same way that CNG replaced diesel, much more up-front planning is required. Kitsap Transit has decided to cautiously wade into the electric bus deployment and thoroughly plan for the future conversion. This section details several elements to provide a smoother approach to expanding Kitsap Transit's electric bus fleet, some of which are already being implemented.

1. Fleet Size: Kitsap Transit is starting small and developing an understanding of the implications of electric bus deployments. One new electric bus was purchased from Proterra and deployed it on a route in Bremerton. Kitsap Transit determined that the length of the bus did not fit the compact roads and had trouble completing a longer route given the terrain.
    a. Lessons Learned:
        i. Kitsap Transit has redeployed that bus on a flatter route. The best route to deploy this bus will continue to be evaluated, and the bus will be permanently relocated to the North Base.
        ii. Kitsap Transit has standardized on a 40-foot long bus for all future installations to better match the existing bus mobility and operability.
2. Technology Choice: Through this study, Kitsap Transit has determined battery electric buses are preferred over many of the other ZEB technologies. Hydrogen fuel and hybrid hydrogen electric buses present challenges primarily due to the hydrogen fuel source such as storage, cost, and accessibility.
3. Staff Training: Through deployment of Kitsap Transit's existing electric bus, operational differences between electric bus and traditional diesel buses have become more evident. These differences include braking and acceleration, which impact fuel efficiency. The limitations of the larger buses and electric motors are also apparent. Kitsap Transit will continue to refine new driver training for these electric buses. Training should also include charging and battery optimization as well.
4. Stakeholder Collaboration: Numerous stakeholders are critical to successfully deploying electric buses, including Kitsap Transit staff, bus riders, local and state agencies, and the local utility.
    a. Kitsap Transit staff are critical to the deployment. Not only is driver training crucial, but electric buses will impact financial, maintenance, and operation decisions as well. Several key staff have been involved with this planning study and have provided important input that has been reflected in this study.
    b. Bus ridership will not likely change significantly based on the bus fuel, but many likely prefer the cleaner, quieter electric buses. In addition, Kitsap Transit should continue to reach out to riders to educate them on which routes operate electric buses and why other routes may not.

c. Local agencies are often responsible for permitting and grant applications. Early engagement with these agencies may reduce construction costs, provide financial assistance, and possibly reduce permitting lead times.
d. One of the most critical elements to electric bus deployment is engaging the electric utility and understanding the electrical implications. Throughout their deployment process, Kitsap Transit has continued to engage Puget Sound Energy not just to request additional electrical service but also to understand the existing utility capabilities at each of the three bases. Utility planning for large loads, such as those required for electric bus charging, takes time and construction requires even more time and could delay electric bus deployment.
    i. Kitsap Transit has worked with PSE to install a single bus charger at Charleston Base for the existing Protera bus.
    ii. In early 2019, PSE was again engaged for a new service for eight chargers at North Base.
    iii. PSE has also been engaged in this study to understand the utility's electrical capabilities at each of the three bases. PSE provided helpful input regarding the infrastructure grant application, including utility improvement costs.

Near-Term Deployment

In November 2019, Kitsap Transit applied for a Washington Department of Transportation Grant to improve electrical infrastructure and install six, 62.5 kW chargers at Charleston Base. The near-term electric bus deployment began to be formulated at that point and has been expanded to include the following:

- 2019-2020
    - Complete installation of new utility transformer and one, 62.5 kW charger at North Base
        - Relocate the Proterra bus from Charleston to North Base and eliminate deadheading between the bases.
    - Secure grant for utility improvements and additional chargers at Charleston Base. Complete design and begin construction.
        - While the grant application would install six, 62.5 kW chargers, based on recent charger improvements it is recommended to install three, 150 kW chargers to charge six buses.
    - Take ownership of one new Gillig electric bus for deployment at Charleston Base using existing charger.
- 2021
    - Complete installation of new chargers and utility infrastructure at Charleston Base based on the grant application and funding.
    - Procure three additional electric buses for operation out of Charleston Base (four total).
- 2022
    - Install up to four, 150 kW chargers at Charleston Base.
    - Procure three additional electric buses for operation out of Charleston Base (seven total).
- 2023

    - Procure three additional electric buses for operation out of Charleston Base (10 total).
- 2024
    - Procure and operate three additional electric buses for operation out of Charleston Base (13 total).
        - Thirteen buses are the maximum recommended at Charleston Base based on current run cards. Fewer buses would be needed if mid-day charging is utilized.

The near-term deployment strategy allows Kitsap Transit to operate 13 electric bus routes out of Charleston Base and one bus out of North Base. Through operations at these locations, Kitsap Transit can experiment with mid-day charging, and if successful at Charleston Base, can expedite additional charging at North Base redeploy several buses for operation.

Estimated near-term capital costs for charger installation and bus purchases are included in Table 18.

Table 18: Near-term Capital Costs

Year	Location	New Buses	New Chargers	Capital Cost	Notes
Existing	North	0	1	*	Bus presently at Charleston, to be moved when chargers installed at North
	Charleston	1**	1**	$0	
2020	Charleston	1	0	$800,000	
2021	Charleston	3	3	$3,934,000***	
2022	Charleston	3	4	$3,123,000	
2023	Charleston	3	0	$2,549,000	
2024	Charleston	3	0	$2,600,000	
Total		**14**	**9**	**$13,006,000**	

*North Base Charger to be completed by end of 2019 and cost was not included for this study.
**Charleston bus and charger were installed in 2018. Bus was relocated to North Base in 2019.
***Cost includes estimated utility improvement costs for additional transformer and meter.

Estimated power requirements are included in Table 19. Power purchase costs in Table 19 are based on optimized charging using a 150 kW charger.

Table 19: Near-term Annual Power Purchase Costs

Year	Estimated Energy Demand (kW)	Estimated Daily kWH	Monthly Summer Demand Cost	Monthly Winter Demand Cost	Monthly kWH Cost	Estimated Annual Electrical Cost
2020	157.9	514	$1,940	$1,315	$660	$50,720
2021	315.8	763	$3,880	$2,625	$975	$60,760
2022	315.8	1417	$3,880	$2,625	$1,815	$66,780
2023	315.8	1809	$3,880	$2,625	$2,315	$72,440
2024	315.8	2178	$3,880	$2,625	$2,785	$76,350

Overall, this strategy allows Kitsap Transit to proceed at a moderate pace for deploying electric buses. This is a pace that allows them to work out kinks in the system but also make consistent progress toward an electric fleet.

Mid-Term Deployment

Kitsap Transit should re-evaluate their electric bus deployment strategy at the end of the near-term period and determine if any modifications need to be made to the deployment strategy. Kitsap Transit has stated that anywhere from two to eight electric buses may be purchased annually until the electric bus fleet is optimized. For the purpose of this study, four buses would likely be purchased per year.

During this period, Kitsap Transit should re-evaluate the electric buses and determine if any changes to the strategy are required. It is also during this period that a new maintenance facility should be constructed for electric buses, if not already constructed at a new base. A recommended 25,000 square foot maintenance facility would be adequate to service six standard maintenance bays, two preventative maintenance bays, a 5,000 square foot maintenance shop/storage, and provide a 2,600 square feet for support facilities. Separate bus and staff parking would also be provided.

- 2025
    - Install four, 150 kW chargers capable of charging eight buses at North Base.
    - Procure and operate three electric buses for operation out of North Base (four total).
    - Begin design of an electric bus maintenance facility.
- 2026
    - Procure four electric buses and operate out of North Base (eight total).
    - Utilize chargers installed in 2025 to charge buses purchased in 2026.
    - Construct new electric bus maintenance facility.
- 2027
    - PSE to install an additional distribution transformer and upgrade existing infrastructure at North Base for additional electric buses.
    - Install five, 150 kW chargers at North Base capable of charging ten buses.
    - Procure and operate four additional electric buses out of North Base (12 total).
- 2028
    - Procure and operate four additional electric buses out of North Base (16 total).
- 2029
    - Procure and operate three additional electric buses out of North Base (19 total).
    - Begin planning for electric bus deployment at South Base. Engage PSE and permit agencies in planning process.
- 2030
    - PSE to install a distribution transformer and upgrade existing infrastructure at South Base for electric buses.
    - Install two, 150 kW chargers at South Base capable of charging four buses.
    - Procure and operate four additional electric buses out of Souh Base (4 total).

Mid-term bus deployment is summarized in Table 20.

Table 20: Mid-term Deployment

Year	Location	New Buses	New Chargers
2025	North	3	4
2026	North	4	0
2027	North	4	5
2028	North	4	0
2029	North	3	0
2030	South	4	2
Total		**22**	**11**

Note: The mid-term deployment does not include the existing charger and bus operating from North Base beginning in 2019.

At the end of this mid-term period, Kitsap Transit will have utility and charging infrastructure in place to operate electric buses on all routes that have runs less than 96 miles and capable of operating on battery charge. Mid-day charging will be required to achieve this at several bases. Several spare electric buses may also be available at this time. Technological advances will likely even improve the bus range and increase the number of viable electric bus routes.

At the end of the mid-term period, electric bus deployments for each base include the following, assuming mid-day charging is utilized to maximize electric bus usage.

- Charleston Base:
    - 13 buses deployed
    - 8 buses required to cover 13 runs
    - Up to 5 spare electric buses
- North Base:
    - 19 buses deployed
    - 19 buses required to cover 25 runs
- South Base:
    - 4 buses deployed
    - 4 buses required to cover 7 runs
- System wide:
    - 36 electric buses deployed
    - 44 bus runs operating electric buses
    - New electric bus maintenance facility constructed

Estimated power requirements for bus charging are included in Table 21.

Table 21: Mid-term Annual Power Purchase Costs

Year	Estimated Energy Demand (kW)	Estimated Daily kWH	Monthly Summer Demand Cost	Monthly Winter Demand Cost	Monthly kWH Cost	Estimated Annual Electrical Cost
2025	315.8	4,135	$3,880	$2,630	$5,290	$102,460
2026	473.7	5,567	$5,820	$3,940	$7,120	$143,930
2027	473.7	6,445	$5,820	$3,940	$8,240	$157,410
2028	631.6	7,636	$7,760	$5,250	$9,770	$195,190
2029	631.6	8,125	$7,760	$5,250	$10,390	$202,700
2030	789.5	9,258	$9,700	$6,570	$11,840	$239,600

Utility infrastructure improvement costs are difficult to predict for this mid-term period as existing loads may change in the future. Additionally, the charger and bus costs will likely decrease as the technology continues to stabilize, standards are refined, and mass production increases. For these reasons, mid-term capital utility costs are not included at this time.

Long-Term Strategy

At this time, it can only be assumed that the bus batteries, charging, and bus efficiencies will continue to improve, but it is impossible to predict what these improvements will mean to the range of these buses. Several factors may maximize the number of bus runs that Kitsap Transit can deploy electric buses.

Kitsap Transit should continue to adjust bus runs to optimize the number of runs that can utilize electric buses. While electric buses on every run might be desirable, the range of these buses must see improvement so that an excessive number of buses do not operate on a large number of short runs with the sole justification of converting the entire fleet to electric buses. The electric bus cost should be balanced with the practical deployment. Depending on the route needs, it may be quite some time before electric bus technology matches the route needs, and electric buses may never match the existing diesel bus characteristics.

To optimize electric bus run times, Kitsap Transit will eventually need to consider on-route charging. Piloting on-route charging at Silverdale or Port Orchard may offer an opportunity to evaluate on-route charging capabilities; however, the return on investment at these two facilities would be low due to the relatively few additional buses that benefit from these charger locations.

On-route charging at the large transit centers (Bainbridge, Bremerton, and North Viking) present complications for construction. Existing infrastructure, heavily utilized routes, and space limitations would all need to be addressed to complete the construction. However, 36 additional runs would then be capable of operating electric buses and 30 routes may no longer need charging at the bases. On-route charging would also dramatically alter the charging costs and should also be considered.