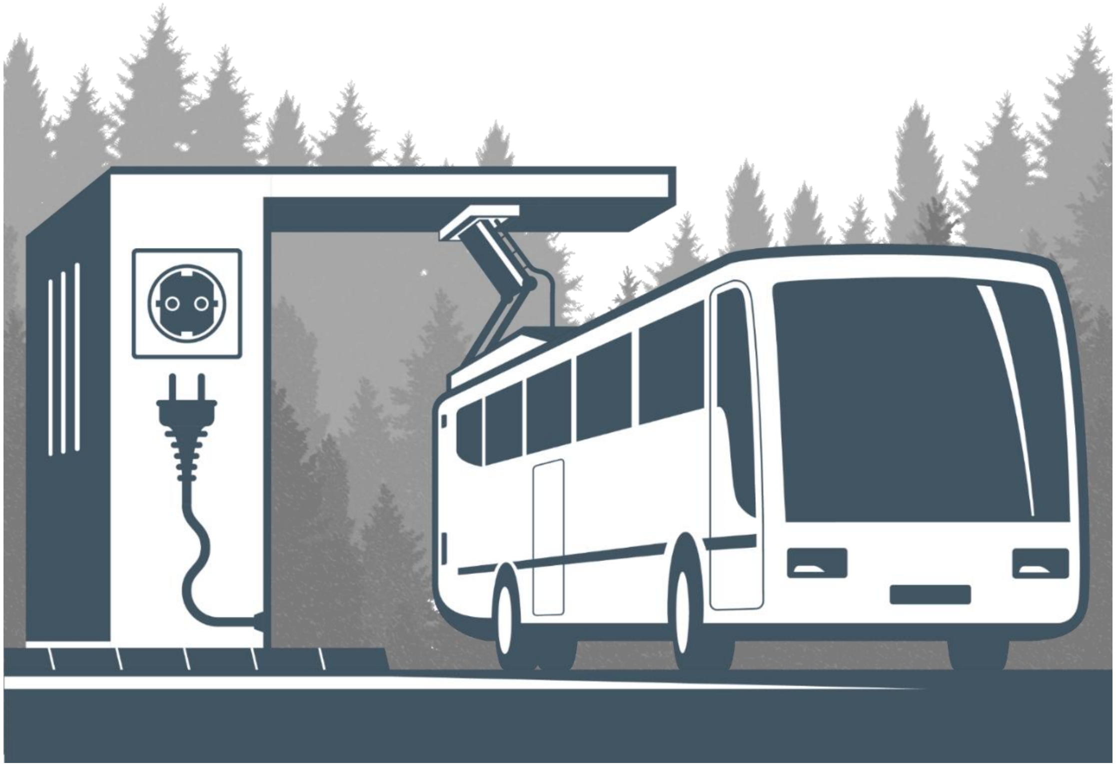

Bus Electrification Transition Plan for BSOOB

Transit
Biddeford | Saco | Old Orchard Beach

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1. Executive Summary

BSOOB, the bus agency serving the Biddeford-Saco-Old Orchard Beach area in Maine, is currently in the early stages of transitioning its diesel bus fleet to battery electric vehicles. The agency has procured and begun operating two electric buses and has installed two chargers, each with one dispenser, at its depot. As the agency looks ahead to full fleet electrification, a thorough analysis was conducted to develop a feasible transition strategy for the agency. This report summarizes the results of the analysis for asset configuration, emissions, and the costs associated with the transition.

Through this analytical process, BSOOB has expressed a preference for fleet and infrastructure asset configurations that will provide a feasible transition to battery electric drivetrain technologies while supporting the agency’s operational requirements and financial constraints. The selected configuration calls for a total agency fleet size of 18 battery electric buses, while ensuring viable operation for BSOOB’s fixed-route services, Zoom commuter route, and seasonal trolleys. To support the additional battery electric buses, the agency also plans to procure, install, and commission two additional charging systems at its depot that, together with additional dispensers on the existing chargers, will have the capacity to support overnight charging of up to 12 buses simultaneously. The agency has also already obtained funding for two pantograph-style chargers at Saco Transportation Center for use during service hours.

One of the primary motivations behind BSOOB’s continued transition to battery electric drivetrain technologies is to achieve emissions reductions compared to their existing mostly diesel operations. As part of this analysis, an emissions projection was generated for the proposed future battery electric fleet. The results of this emissions projection estimate that the new fleet will provide up to a 91% reduction in emissions compared to BSOOB’s pre-electrification operations.

A life cycle cost estimate was also developed as part of the analysis to assess the financial implications of the transition. The cost estimate includes the capital costs to procure the new vehicles, charging systems, and supporting infrastructure, as well as the operational and maintenance expenditures. The costing analysis indicates that BSOOB can anticipate a 44% increase in capital expenditures due to the transition. It is estimated, however, that there will be a 13% annual reduction in operational and maintenance costs due to the improved reliability and efficiency of battery electric drivetrain technologies. In summation, the cost estimate predicts that BSOOB will see roughly 1% life cycle cost savings by transitioning to an entirely battery electric bus fleet.

The conclusion of the analysis is that battery electric buses can feasibly support BSOOB’s operations. Furthermore, these buses offer the potential for the agency to greatly reduce emissions and to slightly reduce the life cycle costs required to operate its buses. Therefore, BSOOB is encouraged to proceed with the strategy as described in this transition plan.

2. Introduction

As part of its efforts to reduce emissions to slow the effects of climate change, the State of Maine has developed a "Clean Transportation Roadmap", which encourages Maine's transit agencies to transition their bus fleets to hybrid and battery electric vehicle technologies.

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

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

In response to the Governor's Roadmap and the FTA requirements, BSOOB, in association with the Maine Department of Transportation (Maine DOT) and its consultant Hatch, have developed this fleet transition plan. In addition to the FTA requirements, this transition plan also addresses details on BSOOB's future route plans, vehicle technology options, building electrical capacity, emissions impacts, resiliency, and financial implications.

3. Existing Conditions

BSOOB is a small transit agency providing service to the Biddeford-Saco-Old Orchard Beach, Maine area. The agency currently owns and operates a revenue fleet of twenty diesel vehicles and two battery-electric buses. These vehicles include standard low-floor transit buses, high-floor commuter coaches for Zoom service to Portland, and vintage trolley-style for the Silver Line (Route 54) and seasonal service in Old Orchard Beach. A major fleet replacement program is currently underway, updating the fleet to ensure reliable operation and reduce the spare factor.

Section Summary

- BSOOB operates ten routes with a 22-bus fleet, two of which are battery-electric buses
- Peak summer service requires nine buses

Table 1 Current Vehicle Roster

Bus Type/Roster Number	Number of Buses	Procurement Date
Eldorado Low Floor (16/17/26/29)	4	2010
MCI Coach (18)	1	2002
Loring Low Floor (24/28/35)	3	2003
Gillig 40' Bus (857/861)	2	2006
Prevost Coach (7752/7753)	2	2020
Hometown Trolley (2159, 2161-7)	8	2021
Proterra ZX5+ (554/555)	2	2022

BSOOB has six fixed routes that operate on a 75-minute pulse schedule from Saco Transportation Center, as well as one commuter express route to downtown Portland and three seasonal trolley routes in the Old Orchard Beach area. Most routes operate the same service pattern throughout the day, though the Green Line (60) also runs several short-turn trips to serve Ready Seafood, a major local employer. Connections are available to other transit agencies, as shown in Figure 1 below.

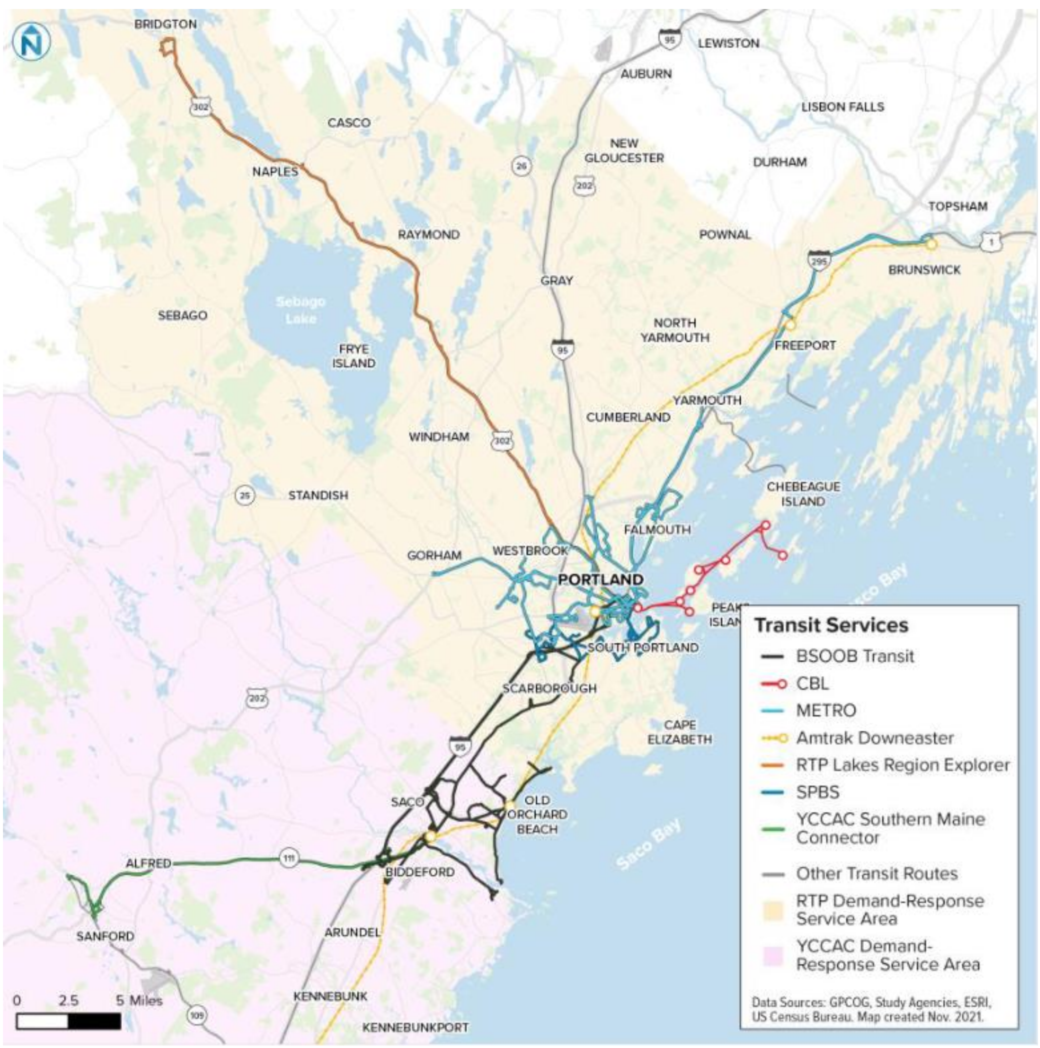

Figure 1 Map of BSOOB and Other Regional Transit Services (Source: GPCOG/Transit Together)

- **Orange/Black (Routes 50/51)**
  Serves Biddeford.
  Operates every 75 minutes daily.
- **White/Blue (Routes 52/53)**
  Serves Saco and Old Orchard Beach.
  Operates every 75 minutes daily.
- **Silver (Route 54)**
  Operates as a Saco/Biddeford circulator, with some trips to University of New England.
  Operates every 15 minutes (circulator) and every 60-90 minutes (UNE) daily.
- **Green (Route 60)**
  Connects Saco to Portland via Route 1.
  Operates every 150 minutes daily.
  Some additional trips connect Saco to Ready Seafood on weekdays only.
- **Zoom (Route 70)**
  Connects Biddeford and Saco to Portland via I-95, rush hours only.
  Operates six trips a day on weekdays only.
- **Old Orchard Beach Trolley**
  Operates southwest from downtown Old Orchard Beach.
  Operates every half hour daily during the summer season.
- **Pine Point Trolley**
  Operates north from downtown Old Orchard Beach.
  Operates every hour daily during the summer season.
- **Saco Trolley**
  Operates west from downtown Old Orchard Beach.
  Operates every hour daily during the summer season.

The Orange and Black Lines (Routes 50/51), as well as the White and Blue Lines (Routes 52/53), share a vehicle; aside from this the routes typically operate as self-contained blocks. The present route structure was created in 2019; BSOOB plans to tweak it further to serve riders' needs. The general concept of a pulse system with a hub at Saco Transportation Center is expected to remain, however. Therefore, the existing routes were modeled as a representative example of the future state of the network.

4. Vehicle Technology Options

Section Summary

- Buses will need diesel heaters for winter operation
- Manufacturers' advertised battery capacities do not reflect actual achievable operating range

As discussed in Section 3, BSOOB's revenue service fleet is composed of 35'-40' transit buses, 45' commuter coaches, and vintage-style trolleys. A summary of hybrid and battery electric vehicle models that are commercially available (provided in Appendix A) demonstrates that there is a variety of possible vehicles for BSOOB to utilize. For battery electric buses, battery capacity can be varied on many commercially available bus platforms to provide varying driving range.

For this study, battery electric transit-style buses were assumed to have either a 'short-range' 225kWh or 'long-range' 450kWh battery capacity, which are representative values for the range of batteries offered by the industry. Commuter and trolley-style vehicles were modeled to have 389 and 320 kWh batteries respectively, based on commercially available vehicles. The transit and commuter buses were assumed to have diesel heaters, which minimize electrical energy spent on interior heating during the winter months. Two types of safety margins were also subtracted from the nominal battery capacities of the buses. First, the battery was assumed to be six years old (i.e. shortly before its expected replacement at the midlife of the bus). As batteries degrade over time, their capacity decreases. To account for this, the battery capacity was reduced by 20%. Second, the bus was assumed to need to return to the garage before its level of charge falls below 20%. This is both a manufacturer's recommendation – batteries have a longer life if they are not discharged to 0% – and an operational safety buffer to prevent dead buses from becoming stranded on the road. Combining these two margins yields a usable battery capacity of 64% of the nominal value. Finally, as the industry is advancing quickly and technology continues to improve, a 3% yearly improvement in battery capacity was assumed.

5. Infrastructure Technology Options

Transit and other commercial buses typically require DC fast chargers. Transit buses are typically not equipped with an on-board transformer that would allow them to be charged with level 2 AC chargers.

The DC fast chargers typically come in two types of configurations:

1. Centralized
2. De-centralized

Section Summary

- Hatch recommends continuing to install centralized chargers at the depot
- A plug-in style dispenser will need to be added to the Saco TC charging station if compatibility with trolley- and cutaway-style vehicles is required

A decentralized charger is a self-contained unit that allows for the charging of one vehicle per charger. The charging dispenser is typically built into the charging cabinet. In contrast, in a centralized configuration, a single high-power charger can charge multiple vehicles through separate dispensers. The power is assigned to the dispensers dynamically based on the number of vehicles that are charging at the same time. Similarly, centralized systems can support high-powered pantograph chargers. Examples of both configurations are shown in Figure 2.

Figure 2 Example Charging Systems (Source: ABB):

Left – Charging Cabinet (System) and Three Dispensers (Charge Boxes)

Right – Overhead Pantograph Charger and Centralized Cabinets

Like the vehicles, charging infrastructure to support battery electric buses is available in numerous configurations. One of the primary metrics that can be customized is the charging power. For this study, it was assumed that BSOOB's future plug style charging systems would match the ones already procured – which have 150 kW of power that can be divided among three dispensers – while any future pantograph chargers would have up to 450 kW of power. These charging system power values have become standard to the transit bus industry. Appendix A shows additional commercially available charging system options and configurations.

BSOOB plans to install two pantograph-style chargers at Saco Transportation Center, which is the hub of the network. These chargers are only compatible with transit-style buses, which have conductive bars on the roof. To provide compatibility with the vintage trolley-style vehicles currently operating on the Silver Line (54), as well as potentially Zoom commuter coaches or YCCAC's Southern Maine Connector cutaway vehicles, the chargers would need to be adapted to include a plug-in receptacle. With an appropriately configured charge management system, designed to provide power to either a pantograph or plug-in dispenser but not both at the same time, this would not require any additional charging cabinets or an increase in the utility feed size. Though the comparatively simple additional hardware would make a retrofit economical, the most effective option would be to install the plug dispenser during initial construction. Hatch recommends adding this to the Saco Transportation Center charger specification as a priced option.

6. <u>Route Planning and Operations</u>

<u>Section Summary</u>

- Electric buses are typically sold in two battery capacity configurations – short and long range
- Neither electric bus configuration offers comparable operating range to diesel buses – so detailed operations modeling is needed
- To avoid wasteful deadheading, on-route charging is required for fixed-route services
- By the next procurement cycle, the commuter service is expected to be electrifiable with no operational changes
- Depot swapping is recommended for electric trolley operation

BSOOB's current operating model (for its diesel vehicles) is similar to that of many transit agencies across the country. Each vehicle leaves the garage at the appropriate time in the morning, operates (on the same route or pair of routes) for the entire day, and then returns to the garage once service has concluded in the evening. Although BSOOB's schedulers must account for driver-related constraints such as maximum shift lengths and breaks, the vehicles are assumed to operate for as long as they are needed. This assumption will remain true for hybrid buses, which have comparable range to diesels, but may not always be valid for electric vehicles, which have reduced range in comparison to diesel buses. BSOOB has operated its new electric buses accordingly, with one vehicle typically covering the morning Orange/Black (Routes 50/51) run and the other the evening run, even during the comparatively mild weather conditions since their introduction in May 2022. Performance during the winter months is expected to be worse; even when diesel heaters are installed, as was assumed in this study, icy road conditions and cold temperatures degrade electric bus performance. Therefore, battery electric buses may not provide adequate range for a full day of service, year-round, on many of BSOOB's routes and blocks, particularly if recommended practices like pre-conditioning the bus before leaving the garage are not always followed.

6a. Operational Simulation

To assess how battery electric buses' range limitations may affect BSOOB's operations a simulation was conducted. A simulation is necessary because vehicle range and performance metrics advertised by manufacturers are maximum values that ignore the effects of gradients, road congestion, stop frequency, driver performance, severe weather, and other factors specific to BSOOB's operations. As mentioned above, it was not necessary to simulate hybrid operations because the vehicles offer comparable range to diesel buses.

Hatch conducted a route-specific electric bus analysis by generating "drive cycles" for several routes that represented the typical modes of BSOOB's operations, ranging from slower-speed in-city routes to higher-speed routes through the suburbs. For each representative route, the full geography (horizontal and vertical alignment), transit infrastructure (location of key stops), and road conditions (vehicle congestion, as well as traffic lights, stop signs, crosswalks, etc.) were modeled, and the performance of the vehicle was simulated in worst-case weather conditions (cold winter) to create a drive cycle. These BSOOB-specific drive cycles were used to calculate energy consumption per mile and therefore total energy consumed by a vehicle on each route.

As discussed in the previous section, all fixed-route services were evaluated against two common electric bus configurations: 'short-range' 225 kWh or 'long-range' 450 kWh battery capacity. Commuter services were compared with a currently available 389 kWh coach bus, and the trolley routes were analyzed with a 320-kWh trolley-style vehicle. As technology advances, Hatch assumed that these battery capacities will increase at a rate of 3% per year, allowing for additional range. In accordance with the expected first vehicle acquisition date in the fleet transition schedule in Section 8, this battery capacity increase was taken to 2024 for short-range transit buses, 2033 for commuter coaches, and 2034 for trolley-style vehicles. No battery capacity increase was considered for long-range transit buses, as BSOOB has already acquired two of these. Combined with the safety margins discussed in Section 4, this yielded usable battery energy of 152 kWh for short-range transit buses, 288 kWh for long-range transit buses, 346 kWh for coaches, and 293 kWh for trolleys. Clearly, if battery electric bus technology advances faster than anticipated, or if the existing fleet maintains its current reliability over time, there will be a higher operating margin in bus electrification, allowing more service expansion and increased competition during procurements. Conversely, if technology develops more slowly or the existing fleet requires replacement sooner, less service expansion will be possible, and electrification of the commuter and trolley fleets may need to be deferred.

Table 2 below presents the mileage and energy requirement for each block, with green shading denoting those blocks that can be operated by the specified bus by the first vehicle acquisition date and red shading denoting those that cannot. It should be noted that the energy requirements are slightly higher for long-range buses because of their higher weight due to the increased number of battery cells. For this analysis the Silver Line (54) was assumed to operate transit-style vehicles for compatibility with the Saco TC pantograph chargers.

Table 2 Energy Requirements by Block

Block	Mileage	'Short-Range' Bus		'Long-Range' Bus	
		kWh Required	Mileage Shortage/Excess	kWh Required	Mileage Shortage/Excess
Orange 50/Black 51	195.2	438.8	-125.4	467.3	-73.6
White 52/Blue 53	222.1	456.1	-147.6	485.2	-90.1
Green 60	327.8	620.1	-247.3	653.6	-183.3
Silver 54	227.4	479.6	-128.3	505.6	-82.0
Green 60 (Seafood)	34.1	64.5	46.4	68.0	110.4
Zoom 70	253.8	-	-	344.9	4.1
Saco Trolley	187.4	-	-	416.1	-51.3
OOB Trolley	166.2	-	-	369.2	-30.4
Pine Point Trolley	162.2	-	-	359.9	-26.3

6b. Operational Alternatives

As shown in Table 2, short-range buses can only accommodate the Green Line (60) Ready Seafood block, and even long-range buses are insufficient for the majority of blocks. To address the operational shortcomings of the battery electric buses a few options were considered. To maintain study focus, changes to passenger-facing schedules were not considered; optimization of schedules for electric bus operation is recommended only after an operating model is chosen to avoid over-committing to one particular schedule. More information about the tradeoffs between the operating strategies below is presented in Appendix B and E.

The operationally easiest option is to maintain existing operations, with electric vehicles operating on blocks where they can complete the entire day's service and hybrid vehicles covering all other blocks. This would allow BSOOB to continue operations without being impacted by vehicle range constraints. This is feasible for the Zoom service, which has a lengthy midday layover period that can be used for charging; therefore, this study assumed electrification of the Zoom service with no operating changes. For the other services, however, adopting hybrids would not correspond with BSOOB's existing and upcoming electric vehicle procurements, would not lower emissions as much as adopting electric vehicles, and would introduce complications with operating and maintaining a split fleet. Therefore, hybrid vehicles were not considered further in this study.

Another possibility is to operate using "depot swapping," with electric buses operating as long as they are able to and then returning to the depot to charge while a fresh bus takes over their block. By cycling buses in and out of service throughout the day, BSOOB would be able to mitigate the range limitations of battery electric buses without requiring field infrastructure. However, this option requires additional deadheading, leading to wasted mileage and operator time. In addition, this option would require a substantial increase in fleet size because depot chargers are traditionally lower-power (slower) than on-route chargers, and additional time would be needed for vehicles to deadhead to and from the depot. For these reasons, BSOOB is not considering this option for the fixed-route services operating from Saco Transportation Center. Due to uncertainty regarding an on-route charger in downtown Old Orchard Beach to support trolley operation, depot swapping was assumed for the seasonal trolley service.

An alternative possibility is to recharge buses during layovers over the course of the day. This could be achieved with either "short-range" or "long-range" buses. Short-range buses, though they are less expensive to purchase, operate a shorter distance between charges. Operationally, this has an impact on fleet size requirements. Given BSOOB's existing schedules, long-range buses can complete a full day of operation by charging only during their existing layover times. Short-range buses cannot do so (due to limited layover time, the presence of only two chargers, and the need to avoid charging during system-peak times to reduce electricity costs). Therefore, an additional bus would be required for the fixed-route network's peak service, ensuring that one bus is always charging at Saco TC while the other buses operate. Because of the small size of the fleet, this increase in peak service requirement would likely require a total fleet size increase of two vehicles.

For layover charging to be most efficient, the schedule (and perhaps even the route structure) would need to be optimized for the needs of the buses. For example, for the short-range bus alternative, coordination of driver meal breaks with bus charging times can ensure that drivers are not waiting unproductively while the bus charges (and can even simplify scheduling, as a driver and a bus would stay together throughout the driver's shift, with meal and charging breaks happening at the same time). Careful selection of route interlines can help balance layover durations with the time required for charging. For example, the schedule for the energy-intensive Green Line (60) provides 18 minutes of layover time after each 150-minute trip, while the White/Blue Line (52/53) timetable allows a total of 45 minutes of layover time in the same time period. Therefore, interlining vehicles between these two blocks may be prudent to give all vehicles adequate charging time. As BSOOB continues to gain experience operating electric vehicles, Hatch recommends continual tweaks to the schedules and blocks, ensuring that vehicles have adequate charging time independent of weather, seasonal traffic, and other factors.

As BSOOB plans to fully electrify its fixed-route fleet in the near future, there is little uncertainty regarding the products that will be available on the market. For the trolley and commuter services, however, the relationship between vehicle technology development and fleet replacement timeline is important. If vehicle technology improves sooner than expected, fleet replacement can be accelerated, and perhaps the electric trolley fleet will be able to operate throughout the day without requiring depot swapping or an on-route charger. However, if vehicle technology develops more slowly than this study's forecast, more depot swaps may be necessary throughout the day (for trolleys) and depot swapping may need to be introduced, increasing fleet size (for commuter coaches).

7. Charging Schedule and Utility Rates

Section Summary

- The local utility has proposed a new rate structure for charging EVs which will include cost penalties for charging during peak demand periods
- As a result, a charging schedule was developed to help BSOOB charge its buses economically
- BSOOB would operate most economically by adopting the B-DCFC (IGS-S-TOU) rate structure for both the depot and Saco TC charging station

Developing a charging schedule is recommended practice while developing a transition plan as charging logistics can have significant effects on bus operations and costs incurred by the agency. From an operational perspective, charging buses during regular service hours introduces operational complexity by requiring a minimum duration for certain layovers. The operational configuration and fleet composition selected by BSOOB, and described in the previous section of this report, assumes that buses will be charged during both the overnight period and during layovers throughout the day.

BSOOB's current electricity rates are determined by Central Maine Power's 'MGS-S-TOU' rate. However, this rate structure is only applicable for services with peak load of 400kW or less. As discussed below, the peak load for BSOOB's garage and on-route charging location will exceed CMP's 400 kW limit for the 'MGS-S-TOU' rate, requiring BSOOB to adopt the 'IGS-S-TOU' rate structure instead. Hence, the 'IGS-S-TOU' rate structure, as shown in Table 3, was used as the current rate structure for the purpose of this analysis. Under this rate table BSOOB would pay a flat "customer charge" monthly, regardless of usage. BSOOB also pays a distribution charge per kW for their single highest power draw (kW) that occurs during each month. The distribution charge is dependent on the time of the day and calculated based on the rate schedule outlined in the Table 3 below. This peak charge is not related to Central Maine Power's grid peak and is local to BSOOB's usage. Finally, BSOOB is charged an 'energy delivery charge' of $0.003747 per kWh, and an 'energy cost' of $0.12954 per kWh. These costs are recurring and are dependent on the amount of energy used by BSOOB throughout the month.

To encourage the adoption of electric vehicles (EV), Maine's Public Utilities Commission (PUC) requested that utilities, including Central Maine Power, propose new rate structures for vehicle charging. In response to this request, Central Maine Power proposed a 'B-DCFC' utility schedule filed under Docket No. 2021-00325. The new proposed rate structure was approved effective July 1st, 2022. To qualify for this rate, Central Maine Power requires that customers like BSOOB install a new meter and dedicated service for their charging equipment to accurately account for the power draw associated with charging. Table 3 below outlines the other differences between the existing 'IGS-S-TOU' and the new 'B-DCFC (IGS-S-TOU)' rate structure that would apply to BSOOB (hereafter referred to as 'B-DCFC' for brevity). The new rate structure would provide BSOOB with a lower monthly 'distribution charge' but introduces a Transmission charge that is calculated based on Central Maine Power's grid peak, termed the 'coincidental peak'. The agency can avoid this transmission service charge, that is calculated on monthly basis, by not charging vehicles during periods when Central Maine Power's grid load is peaking. The historic data indicates that the daily system peak for Central Maine Power happens between 3 PM and 7 PM. Therefore, it is advisable for BSOOB to develop a charging plan which avoids charging buses during these hours.

Table 3 Utility Rates Structure Comparison

	Current Rates (IGS-S-TOU)	Future Rates (B-DCFC)
Customer Charge	$147.19 per month	$147.19 per month
Peak Demand Charge	$16.84 per non-coincidental peak kW (calculated monthly)	$2.60 per non-coincidental peak kW (calculated monthly)
Shoulder Demand Charge	$2.60 per non-coincidental peak kW (calculated monthly)	$2.60 per non-coincidental peak kW (calculated monthly)
Off-peak Demand Charge	$0.00 per non-coincidental peak kW (calculated monthly)	$0.00 per non-coincidental peak kW (calculated monthly)
Transmission Charge	$0.00 per non-coincidental peak kW (calculated monthly)	$19.35 per coincidental peak kW (calculated monthly)
Energy Delivery Charge	$0.003747 per kWh	$0.003747 per kWh
Energy Cost	$0.12954 per kWh	$0.12954 per kWh

Accordingly, a charging schedule was optimized around the operational plan developed in the previous section of the report and the above listed utility schedules. The results of this optimization are shown in Figure 3 for depot charging at the 13 Pomerleau St facility and Figure 4 for on-route charging at Saco Transportation Center. It can be seen in the figures that the optimized charging schedule assumes buses will be charged overnight (between 9 PM and 5 AM) as well as during the day at the depot using the plug-in chargers. The optimized charging schedule also includes midday charging using future overhead fast chargers, planned for Saco Transportation Center, between 9 AM and 3 PM as well as in the evening. Although overhead chargers on the market today can achieve a 450 kW charging rate, this analysis assumed a maximum rate of 200 kW per charger, which is sufficient for BSOOB's operations. This reduced rate accounts for real-world variabilities including charging speed ramp up time, slower charging during battery conditioning in cold weather, reduced layover time available for charging due to traffic delays, and other factors. This charging schedule avoids charging during the Central Maine Power grid's 'coincidental peak' (between 3 PM and 7 PM), allowing BSOOB to avoid a monthly 'transmission charge', should the agency decide to adopt the Central Maine Power's special optional 'B-DCFC' rate schedule for its charging operation.

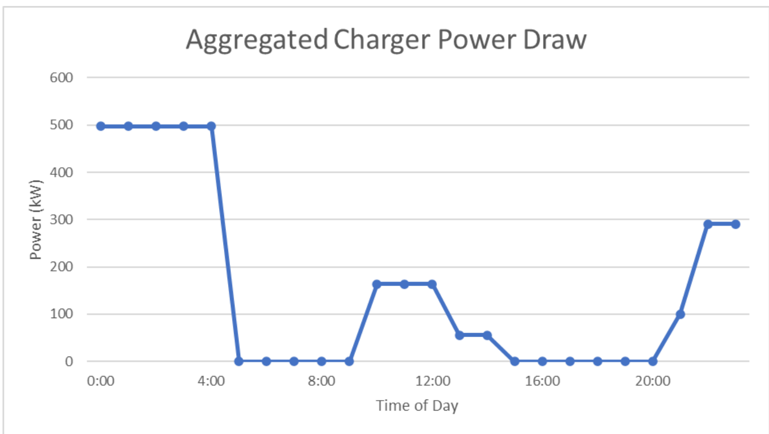

Figure 3 Proposed Depot Charging Schedule for BSOOB's Future Fleet

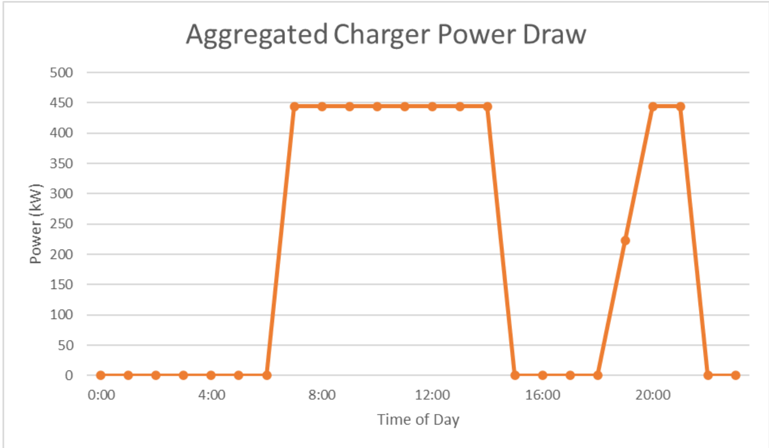

Figure 4 Proposed On-route Charging Schedule for BSOOB's Future Fleet

Below is an estimate of expected operational costs associated with the proposed charging schedule, based on both the existing 'IGS-S-TOU' and the new optional 'B-DCFC' rates.

Depot – 13 Pomerleau St facility

Daily kWh consumption = 3,397 kWh
Monthly Non-coincidental peak = 498 kW
Monthly coincidental peak = 0 kW

Under Current IGS-S-TOU Rate Structure:

$$Daily\ Charge = Daily\ kWh\ consumption\ \times (Energy\ Delivery\ Charge + Energy\ Cost)$$
$$= 3{,}397\ kWh\ \times (\$0.003747 + \$0.12954)$$
$$= \$452.78$$

$$Monthly\ Charge = Max\ ((Highest\ Power\ during\ Peak\ Period \times Peak\ Demand\ Charge), (Highest\ Power\ during\ Shoulder\ Period \times Shoulder\ Demand\ Charge), (Highest\ Power\ during\ Off - Peak\ Period\ \times Off - Peak\ Demand\ Charge))$$
$$= Max\ \big((163\ kW \times 16.82), (163\ kW \times \$2.60), (498\ kW \times \$0)\big)$$
$$= Max\ (\$2{,}750.53, \$421.00, \$0)$$
$$= \$2{,}750.53$$

Under New B-DCFC Rate Structure:

$$Daily\ Charge = Daily\ kWh\ consumption\ \times (Energy\ Delivery\ Charge + Energy\ Cost)$$
$$= 3{,}397\ kWh\ \times (\$0.003747 + \$0.12954)$$
$$= \$452.78$$

$$Monthly\ Charge = Monthly\ Charge = Max\ ((Highest\ Power\ during\ Peak\ Period \times Peak\ Demand\ Charge), (Highest\ Power\ during\ Shoulder\ Period \times Shoulder\ Demand\ Charge), (Highest\ Power\ during\ Off - Peak\ Period\ \times Off - Peak\ Demand\ Charge)) + (Monthly\ coincidental\ Peak\ \times Transmission\ Charge)$$
$$= Max\ \big((163\ kW \times 2.60), (163\ kW \times \$2.60), (498 \times \$0)\big) + (0\ kW\ \$19.35)$$
$$= Max\ (\$424.67, \$424.67, \$0)) + (\$0)$$
$$= \$424.67$$

On-Route – Saco Transportation Center

Daily kWh consumption = 1,167 kWh
Monthly Non-coincidental peak = 444 kW
Monthly coincidental peak = 0 kW

Under Current IGS-S-TOU Rate Structure:

$$Daily\ Charge = Daily\ kWh\ consumption\ \times (Energy\ Delivery\ Charge + Energy\ Cost)$$
$$= 1{,}167\ kWh\ \times (\$0.003747 + \$0.12954)$$
$$= \$155.55$$

$$Monthly\ Charge = Max\ ((Highest\ Power\ during\ Peak\ Period \times Peak\ Demand\ Charge), (Highest\ Power\ during\ Shoulder\ Period \times Shoulder\ Demand\ Charge), (Highest\ Power\ during\ Off - Peak\ Period\ \times Off - Peak\ Demand\ Charge))$$
$$= Max\ \left((444\ kW \times 16.82), (444\ kW \times \$2.60), (444\ kW \times \$0)\right)$$
$$= Max\ (\$7{,}484.44, \$1{,}155.56, \$0)$$
$$= \$7{,}484.44$$

Under New B-DCFC Rate Structure:

$$Daily\ Charge = Daily\ kWh\ consumption\ \times (Energy\ Delivery\ Charge + Energy\ Cost)$$
$$= 3{,}397\ kWh\ \times (\$0.003747 + \$0.12954)$$
$$= \$155.55$$

$$Monthly\ Charge =$$
$$Monthly\ Charge = Max\ ((Highest\ Power\ during\ Peak\ Period \times Peak\ Demand\ Charge), (Highest\ Power\ during\ Shoulder\ Period \times Shoulder\ Demand\ Charge), (Highest\ Power\ during\ Off - Peak\ Period\ \times Off - Peak\ Demand\ Charge)) + (Monthly\ coincidental\ Peak\ \times Transmission\ Charge)$$
$$= Max\ \left((444\ kW \times 2.60), (444\ kW \times \$2.60), (444 \times \$0)\right) + (0\ kW\ \$19.35)$$
$$= Max\ (\$1{,}155.56, \$1{,}155.56, \$0)) + (\$0)$$
$$= \$1{,}155.56$$

Table 4 below summarizes the savings from switching from BSOOB’s current time of use rate structure to the new B-DCFC time of use rate structure.

Table 4 Utility Cost Savings from Adopting (B-DCFC) Utility Rate

Annual Utility Cost	Current Rate (IGS-S-TOU)	Proposed Rate (B-DCFC)
Depot	$139,276.34	$111,365.94
Saco TC	$143,019.51	$67,072.84
Total	$282,295.85	$178,438.79
% Savings Offered by B-DCFC Rate	37%	

As this estimate shows, the optional 'B-DCFC' rate structure would save BSOOB 37% in utility costs. These savings are, again, achieved by avoiding charging during the coincidental peak between 3 PM and 7 PM, and the reduced monthly 'peak demand' charges under the "B-DCFC" rate structure. If the charging schedule were adjusted to charge during the coincidental peak, it could lead to an increase of up to $9,636.30 per month from a 'transmission charge' at the Depot and $8,591.40 per month at Saco TC. Therefore, it is critical that BSOOB only charges the buses, whether using plug-in or overhead pantograph type chargers, outside the coincidental peak window between 3 PM and 7 PM or procures a smart charging management system which is programmed to avoid charging during the coincidental peak. Furthermore, it is also important that BSOOB monitors changes in Central Maine Power's coincidental peak window and adjusts its charging schedule accordingly.

It should also be noted that the above charges are calculated based on a typical weekday load during the summer trolley season. Weekend, holiday, and off-season calculations would follow a similar calculation for daily charges. The typical weekday and weekend/holiday charges are combined with monthly charges to calculate the annual utility cost for BSOOB's operation.

8. Asset Selection, Fleet Management and Transition Timeline

Section Summary

- Hatch recommends considering a broad range of vehicles for BSOOB's commuter and trolley services to decrease procurement cost
- Hatch recommends purchasing, rather than leasing, BEB batteries
- Hatch agrees with BSOOB's decision to install centralized pantograph chargers at the Saco Transportation Center

With operational and charging plans established, it was then possible to develop procurement timelines for infrastructure and vehicles to support those plans. BSOOB, like almost all transit agencies, acquires buses on a rolling schedule. This helps lower average fleet age, maintain stakeholder competency with procurements and newer vehicles, and minimize scheduling risks. However, this also yields a high number of small orders. For any bus procurement – and especially for a newer technology like electric buses – there are advantages to larger orders, such as lower cost and more efficient vendor support. BSOOB is encouraged to seek opportunities to consolidate its fleet replacement into larger orders, either by merging orders in adjacent years or by teaming with other agencies in Maine that are ordering similar buses.

As an additional complication, BSOOB currently operates a mix of vehicle types. This is done to tailor the vehicle operated to the service type provided (fixed-route, commuter, tourist-focused). The drawback to this decision, in the context of electric buses, is that it may pose a constraint on the number of possible vendors. Many electric bus manufacturers (such as Proterra and New Flyer) do not offer commuter coaches or vintage trolley-style vehicles. The vendors that do (such as BYD) are likely to have more limited options, largely due to the smaller market for those vehicles. Although the market is changing quickly, and within the next few years more diverse electric bus models are likely to be introduced, Hatch recommends that BSOOB consider broadening its specifications where possible to allow the largest possible range of vendors to participate. For example, Gillig does not offer commuter coaches or vintage trolley-style vehicles but offers standard transit buses equipped with commuter amenities (such as padded seats and overhead luggage racks) or styled as vintage trolleys (with wooden seats and brass handrails); expanding the pool of competing vendors by considering such vehicles will likely save BSOOB money and could increase parts commonality with the fixed-route fleet. To maintain a fair comparison, however, this analysis assumes that the existing fleet will be replaced during its expected retirement year with the same bus type as operated now. Although the recommended final fleet size is lower than BSOOB's fleet size today, the increased reliability of electric buses and expected 12-year replacement cycle (compared with some of BSOOB's existing buses which are twenty years old) will contribute to improved vehicle reliability and reduced spare factor.

Another key decision to consider when developing a transition plan is battery ownership. Some BEB vendors offer bus battery leasing programs, where the agency can lease the battery for a twelve-year bus lifecycle instead of purchasing it. These programs allow the agency to lower up-front capital cost (as the batteries are a large portion of a BEB's purchase price). Proterra, for example, markets its leasing program as bringing the purchase cost of a BEB (roughly $1,000,000) down to be comparable with that of a diesel bus (approximately $550,000). Also, under the terms of the lease the vendor typically guarantees battery performance; if the battery degrades beyond a specified minimum level the vendor will replace it at no expense to the agency. This is particularly advantageous for demanding duty cycles, which are most likely to accelerate battery degradation and warrant midlife battery replacement. However, these programs have several disadvantages for agencies as well. First, in exchange for reduced capital cost a lease will require annual payments, increasing an agency's operating cost. The illustrative financial model Proterra provides, for instance, indicates a lease payment of $35,000 annually. As federal grants are typically easier to obtain for one-time capital spending than for yearly operating funds, this may increase agency funding needs in the long term. Second, the terms of such leases usually require the agency to return the battery at the end of the 12-year lease. This means that the agency will be unable to operate the bus for longer than twelve years, and will not be able to reuse the battery in any second-life applications. (Although second-life technology is in its early stages, given the large number of batteries being produced it is very likely that options for battery recycling or reuse for wayside storage capacity will soon become available.) Finally, the pricing models for most battery leases generally assume midlife replacement. Although the cost calculations in this report also assumed midlife replacement, with optimized battery usage it may be possible to use the initially provided battery for the full 12-year life. Some agencies have reported nearly no battery degradation after years of operation; as the electric bus market expands more data will become available on transit bus battery performance. In summary, battery leasing is an innovative funding strategy that gives agencies financial flexibility and lowers their exposure to risk. However, considering the operations cost implications and benefits of battery ownership, Hatch recommends that BSOOB avoid leases, instead purchasing its batteries outright.

With respect to infrastructure procurements, the maintenance facility will eventually need to have enough chargers to accommodate all of BSOOB's electric buses. Although the cost of one charger itself is more or less constant regardless of how many are being purchased, the additional costs such as utility feed upgrades, duct installation, structural modifications, and civil work make it economical to install all the support infrastructure at once. When additional electric buses arrive and more chargers are required, the only work that should be necessary is installation of the chargers themselves. BSOOB's existing chargers and already-funded additional dispensers will be sufficient to accommodate four buses charging at one time; more chargers will be required as fleet electrification continues. Hatch recommends that when this charger expansion occurs, provision be made for enough chargers for a fully electric fleet.

To serve the charging requirements described in the previous section for the proposed electric fleet, expanding the already-installed centralized charging architecture is recommended for the maintenance facility. Centralized chargers will give BSOOB the most flexibility in its charging operation by providing a minimum of 50kW per vehicle but allowing for charging power of up to 150 kW when other dispensers on the same charger are not in use. Because each charger typically has three dispensers, BSOOB will require a minimum of two additional chargers, plus four additional dispensers on the existing chargers (for a total of twelve dispensers) to ensure there is a dedicated dispenser for each of the ten electric buses needed to provide peak service. A dedicated dispenser per vehicle allows overnight charging without requiring a staff member to move buses or plug in chargers overnight. This will also provide the recommended allowance of spare dispensers to accommodate dispenser cable failures, "hot standby" buses, vehicle maintenance, and possible future expansion. Table 5 summarizes of the proposed vehicle and infrastructure procurement schedule, up to and including replacement of the two existing BEBs.

Table 5 Proposed Fleet and Charging System Transition Schedule

Year	Buses Procured	Infrastructure Procured
2023		Two pantograph chargers at Saco Transportation Center
2024	Two long-range 35' electric 450kWh buses	Two additional dispensers for existing 150kW centralized chargers
2025		
2026	Four long-range 35' electric 450kWh buses	Two 150kW centralized chargers with six dispensers + two further dispensers for existing 150kW centralized chargers
2027		

Year	Buses Procured	Infrastructure Procured
2028		
2029		
2030		
2031		
2032		
2033	Two 45’ electric 541kWh buses	
2034	Ten (two long-range 35’ electric 450kWh buses, eight electric 458kWh trolleys)	

Hatch recommends that BSOOB operate its electric buses across all of the fixed-route services. This experience will help BSOOB continue to gain experience with electric bus operations and make any scheduling or routing adjustments that may be needed. Finally, spreading electric buses out across the network will ensure that the benefits of electric vehicles (elimination of tailpipe emissions, reduced noise, etc.) are distributed equitably across the service region. This may also prove valuable from a Title VI perspective, particularly as local demographics continue to change over the coming years. Rotating the electric vehicles across the routes will ensure that no area is disproportionately negatively impacted by BSOOB operations.

9. Building Spatial Capacity

Section Summary

- The 13 Pomerleau St facility has sufficient space for required infrastructure and potential expansion
- The Saco TC is a feasible location for on-route charging.

BSOOB’s main storage and maintenance facility is the maintenance garage at 13 Pomerleau St in Biddeford, Maine. The garage is equipped with two 150kW DCFC charging cabinets for the agency’s new Proterra buses, each of which is equipped with one dispenser, as shown in Figure 5. Though indoor space is limited, there is sufficient space to accommodate the installation of two additional dispensers, which will be needed for the next order of electric buses. The maintenance area is also sufficiently spacious to accommodate a dedicated back-shop space for electric bus components, which will be increasingly important as the electric fleet continues to grow.

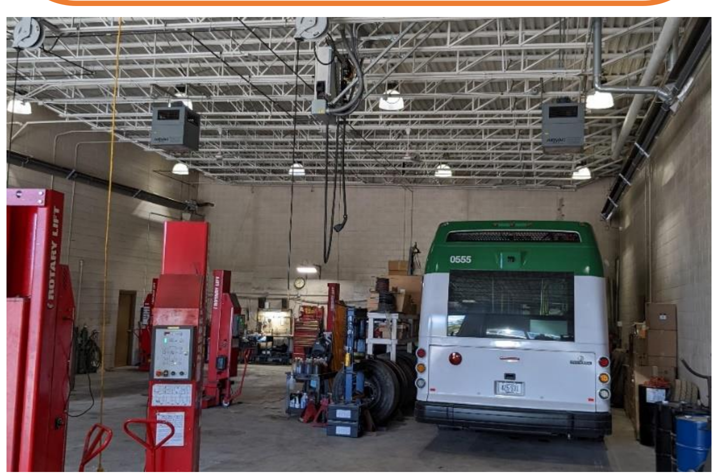

Figure 5 13 Pomerleau St Facility with DC Fast Chargers

Except for the new buses, most buses are typically stored outside the garage and only stored inside during extreme winter weather. Therefore, it is logical to

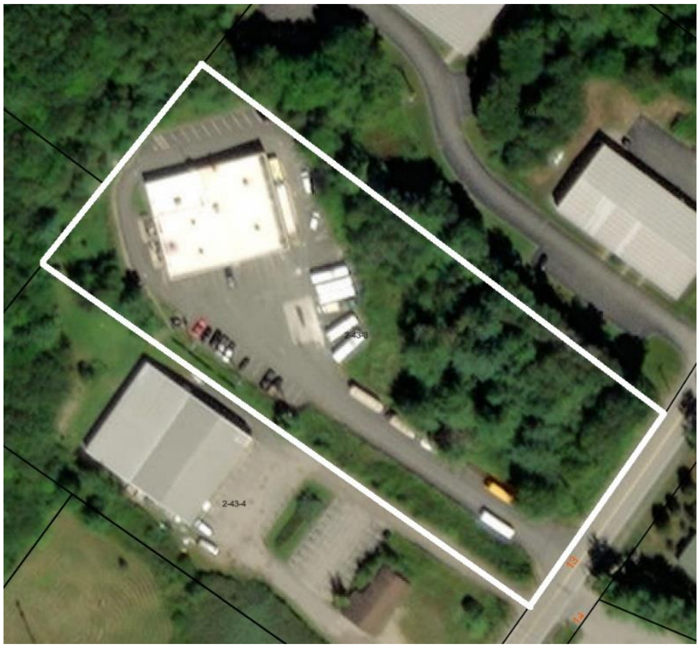

Figure 6 Aerial View Showing 13 Pomerleau St. Property Lines (Source: BiddGIS)

place most of the additional overnight chargers outdoors, for which there is sufficient space available. BSOOB's long-term plans include paving additional areas of its property to create an expanded, fenced storage area; as shown in Figure 6, there is ample space available to do so.

The Saco Transportation Center, located at 138 Main St. in Saco, is the terminal for all fixed-route services. This major transit hub will require an on-route charging station to ensure service robustness. The hub is well-positioned to allow this, as there are lengthy bus-only areas in the parking lot. As shown in Figure 7, there is an office building as well as enough space to support on-route charging infrastructure. Chargers could feasibly be installed either in the front bus layover area or rear long-term parking lot, though the existing (front) layover area shown in Figure 8 is recommended. Further details on the proposed layout of the on-route chargers are provided in Section 12. The Saco Transportation Center location will only accommodate vehicle charging; maintenance will continue to occur at the 13 Pomerleau facility as previously mentioned.

Figure 7 Saco Transportation Center (138 Main St.) Parking Lot and Building

Figure 8 Saco Transportation Center (138 Main St.) Bus Layover Area

10. Electrical, Infrastructure, and Utility Capacity

Section Summary

- The existing service at the garage is insufficient for full electrification
- Separately metered service at Saco TC will let BSOOB take advantage of the DCFC specific utility rate structure in the future

Central Maine Power is the utility provider for BSOOB's primary charging location at 13 Pomerleau St. As part of its electrification efforts, BSOOB has been partnering with Central Maine Power to install the required electrical infrastructure.

As part of BSOOB's initial deployment of electric vehicles, CMP installed a dedicated service to supply power to the new chargers. This is provided via a 12.47 kV high-voltage service that is stepped down to 480V through a 300 kVA on-site transformer, shown in Figure 9. This transformer will not be sufficient to electrify BSOOB's entire fleet, including commuter and trolley services, which as mentioned previously will require a total peak charging rate of 498 kW (assuming optimal use of charge management software). As a result, when BSOOB procures and installs its next set of new chargers in 2026, Hatch recommends that the current transformer be also upgraded at the same time. This will allow the infrastructure to be fully installed and configured at once without requiring expensive piecemeal upgrades as electrification advances.

Figure 9 Dedicated Transformer for BEB Chargers at 13 Pomerleau St.

Saco Transportation Center, on the other hand, does not yet have the required electrical infrastructure for vehicle charging, so installation of a separately metered service will likely be required. Figure 10 shows some of the electrical assets that are present on the site; there are also conduits present as provisions for future charger installation. Although full specifications on the existing electrical infrastructure there were not available at the time of writing, high-voltage connections or other electrical equipment remaining from the former wind turbine at the site (which was installed on the site shown in Figure 11 and decommissioned in 2018) may be reusable for supplying the charging cabinets. Additional details regarding the electrical capacity of the Saco Transportation Center site may be available in previous studies conducted for BSOOB.

Figure 10 Saco TC Electrical Hut and Generator

Figure 11 Site of Former Wind Turbine at Saco TC

11. Risk Mitigation and Resiliency

Section Summary

- As with any new technology, electric bus introduction carries the potential for risks that must be managed
- Power outages have occurred rarely, but resiliency options should be considered
- Solar in conjunction with on-site energy storage system can be a viable option for resiliency, reducing GHG and offsetting electricity cost

Every new vehicle procurement brings about a certain degree of operational risk to the agency. Even when the existing fleet is being replaced 'in-kind' with new diesel buses, there are new technologies to contend with, potential build quality issues that must be uncovered, and maintenance best practices that can only be learned through experience with a particular vehicle. Bus electrification makes some failure modes impossible – for example by eliminating the diesel engine – but introduces others. For example, the ability to provide service becomes dependent on the continuous supply of electricity to the charging location. Although BSOOB has taken the key step of starting to operate electric vehicles, allowing the agency to get accustomed to BEB operation firsthand, as electrification continues in the coming years and BSOOB becomes increasingly reliant on BEBs it will remain important to understand these risks and the best ways to mitigate them.

11a. Technological and Operational Risk

The vehicle and wayside technology required for electric bus operation is in its early stages; few operators have operated their electric fleets or charging assets through a complete lifecycle of procurement, operation, maintenance, and eventual replacement. As detailed in the earlier Transit Vehicle Electrification Best Practices Report, this exposes electric bus purchasers to several areas of uncertainty:

- Technological robustness: By their nature as newer technology, many electric vehicles and chargers have not had the chance to stand the test of time. Although many industry vendors have extensive experience with diesel buses, and new vehicles are required to undergo Altoona testing, some of the new designs will inevitably have shortcomings in reliability.
- Battery performance: The battery duty cycle required for electric buses – intensive, cyclical use in all weather conditions – is demanding, and its long-term implications on battery performance are still being studied. Though manufacturers have recommended general principles like battery conditioning, diesel heater installation, and preferring lower power charging to short bursts of high power, best practices in bus charging and battery maintenance will become clearer in coming years.
- Supply availability: Compared with other types of vehicles, electric buses are particularly vulnerable to supply disruptions due to the small number of vendors and worldwide competition for battery raw materials such as lithium. As society increasingly shifts to

electricity for an ever-broader range of needs, from heating to transportation, both the demand and the supply will need to expand and adapt.

+ Lack of industry standards: Although the market has begun moving toward standardization in recent years – for example through the adoption of a uniform bus charging interface – there are many areas (e.g. battery and depot fire safety) in which best practices have not yet been developed. This may mean that infrastructure installed early may need to be upgraded later to remain compliant.
+ Reliance on wayside infrastructure: Unlike diesel buses, which can refuel at any public fueling station, electric buses require DC fast chargers for overnight charging and specialized pantograph chargers for midday fast charging. Particularly early on, when there is not a widespread network of public fast chargers, this may pose an operating constraint in case of charger failure.
+ Fire risk: The batteries on electric buses require special consideration from a fire risk perspective (see Section 12b).

All these risks are likely to be resolved as electric bus technology develops. BSOOB is in a good position in this regard, as it has already begun operating electric vehicles and can draw upon lessons learned as the electric fleet grows. Nevertheless, given BSOOB's leadership position in bus electrification it will be prudent for the agency to continue its transition to electric vehicles with an eye toward operating robustness in case of unexpected issues. Hatch recommends several strategies to continue maximizing robustness:

+ With further BEB orders, continue requiring the electric bus vendor to have a technician on site or nearby in case of problems. This is most economical when the technician is shared with several nearby agencies.
+ Reach a "mutual aid" agreement with another urban transit agency in Maine that would let BSOOB borrow spare buses in case of difficulties with its fleet.
+ Retain a small backup fleet of diesel buses to ensure they can substitute for electric buses if any incidents or weather conditions require it.
+ Develop contingency plans in case the on-route chargers fail and midday depot swapping is required.

11b. Electrical Resiliency

Electricity supply and energy resilience are important considerations for BSOOB when transitioning from diesel to electric bus fleets. As the revenue fleet continues to be electrified, the ability to provide service is dependent on access to reliable power. In the event of a power outage, there are three main options for providing resiliency:

+ Battery storage
+ Generators (diesel or CNG generators)
+ Solar Arrays

Table 6 summarizes the advantages and disadvantages of on-site storage and on-site generation systems. The most ideal solution for BSOOB will need to be determined based on a cost benefit analysis.

Table 6 Comparison of Resiliency Options

Resiliency Option	Pros	Cons
Battery Storage	• Can serve as intermittent buffer for renewables. • Cut utility cost through peak-shaving.	• Short power supply in case of outages. • Batteries degrade over time yielding less available storage as the system ages. • Can get expensive for high storage capacity.
Generators	• Can provide power for prolonged periods. • Lower upfront cost.	• GHG emitter. • Maintenance and upkeep are required and can be costly.
Solar Arrays	• Can provide power generation in the event of prolonged outages. • Cut utility costs.	• Cannot provide instantaneous power sufficient to support all operations. • Constrained due to real-estate space and support structures. • Requires Battery Storage for resiliency usage.

11.b.1. Existing Conditions

The 13 Pomerleau facility currently does not have resilient systems in place that would be able to support battery electric bus operations should there be an electrical service interruption. BSOOB plans to install a generator in coming years, but it has not yet been funded or constructed. The Saco Transportation Center is similar – although there is a generator present, it appears sized to support low-power building loads (e.g. lighting) during an outage rather than high-power bus charging. This would mean that a prolonged power outage would deprive BSOOB of the ability to operate service as it continues transitioning to electric bus operations.

11.b.2. Outage Data and Resiliency Options

After noting no viable resiliency systems in place, Hatch assessed potential resiliency options. The first step in that assessment was to analyze the power outage data for the utility feeds that supply power to BSOOB's two main facilities to determine the requirements for backup power. Following is a summary of the outages at each of the locations in the last five years. Appendix C shows the outage data provided by Central Maine Power for reference.

- 13 Pomerleau Bus Storage/Maintenance Facility – This facility has seen eight outages in the last 5 years. Out of these, four were insignificant and only lasted for ten minutes or less. Three outages lasted between approximately 1 and 1.5 hours. Only one outage was long enough to impact for operation of BEBs, lasting for approximately 7.5 hours.
- Saco Transportation Hub – This location had 3 outages over the time period analyzed. Two were of significant duration, lasting approximately 1 and 8 hours.

The resiliency system requirements are determined below based on the worst outage instance outlined above and the charging needs for the full fleet during this type of outage scenario. The on-site energy storage requirement to charge the fleet during that outage period would be 3.75 MWh. Assuming a 20% safety factor on top of the required energy, the size of the on-site energy storage system would need to be approximately 4.67 MWh. The power requirement for a generator was determined by the power draw of the number of chargers required to charge the peak service fleet of ten vehicles. Assuming BSOOB purchases two new 150 kW centralized chargers to add to its existing array of two 150 kW chargers (as recommended in this report), and allowing for 90% charger efficiency and 20% spare capacity, the resulting on-site generation capacity required would be approximately 750 kVA.

Hatch next generated cost estimates associated with the two resiliency system options for the 13 Pomerleau facility. Table 7 summarizes the approximate project cost for implementing each option. Note that as these are conceptual proposals on which no decision has been made, these costs are not included in the life cycle costs in Section 14.

Table 7 Resiliency Options for Worst Case Outage Scenarios

	Size	Capital Cost
Option 1 On-site Battery Storage	4.67 MWh	$2.94 M
Option 2 On-site Diesel Generation	750 kVA	$450,000

The above analysis and corresponding options are based on the historic outage data, and an assumption that full service is operated during the outage. Since outages like these occur very rarely, the above resiliency options may be oversized for most use cases resulting in a poor return on the capital investments. As the utility industry evolves over the course of BSOOB's electrification transition, the agency will have to choose an appropriate level of resiliency investment based on historical and anticipated needs.

11.b.3. Solar Power

In addition to the above two options for backup power, on-site solar generation should also be considered to add resiliency, offset the energy cost, and further reduce BSOOB's GHG impact by utilizing clean energy produced on-site. As mentioned previously, however, solar does not reliably provide enough instantaneous power to provide full operational resilience. The on-site solar production can provide backup power in some specific scenarios, but a battery storage system is necessary for solar to be considered part of a resiliency system. The function of a solar arrays would primarily be to offset energy from the grid and reduce utility costs.

An on-site solar system was evaluated for the 13 Pomerleau facility because the roof of the facility structure provides a large surface area that could be utilized for a solar array as illustrated in Figure 12 below. The solar array could potentially be installed in either of two ways:

1. Install the panels on racks on the facility roof.
2. Build an elevated structure over the parking area allowing cars and buses to park underneath and for the panels to serve as a canopy.

Although Option 1 (shown in Figure 12) is likely more practical and economical because it uses existing roof space, BSOOB will need to conduct a structural analysis to determine the loadbearing capacity of the roof and the upgrades that would be required to add solar panels. Alternatively, BSOOB can consider Option 2 as part of its outdoor storage area expansion project.

Figure 12 13 Pomerleau Facility Proposed Solar Array

Table 8 outlines parameters for the solar power system that could be installed on the facility roof as well as the expected annual energy production and resulting cost savings from offsetting energy consumed from the grid.

Table 8 13 Pomerleau Facility Roof

Solar System Design Parameters	
Solar System Sizing Method:	Available Area
Cumulative Solar Array Area	8,675 ft^2
Maximum Number of Panels	390 panels
Maximum System Power	166 kW
Annual Production Coefficient	1,283 hours
Sunny Days Per Year	196 days
Annual Solar Energy Production	212,862 kWh
Annual Electric Usage	1,068,484 kWh
Maximum Percent of Electrical Usage Offset	20%
Electricity Rate	$0.12954 / kwh
System Cost	**$460,000**
Utility Bill Savings Per Year	**$27,500**
Simple Payback Period Without Grants	**16.6 years**
Payback Period with 80% Federal Grants	**3.3 years**

Based on the above parameters, the maximum daily production for sunny days is estimated to be approximately 1.1 MWh. Since the energy requirement for charging during the outage scenario of 7.5 hours is estimated to be 3.75 MWh, solar does not provide enough energy to support operations in the event of an outage even on sunny days.

Solar power generation is also not recommended as a primary resiliency system as power outages are not evenly distributed throughout the year. They are most likely to occur due to winter storms – during the time of the year when the least amount of solar energy is available due to cloud cover.

An on-site battery storage system could complement solar as it would allow for storing of energy produced during the daytime for use during overnight charging. This would not only result in cost savings from the grid energy offset, but it would also result in savings due to a smaller utility feed requirement and lower non-coincidental peak for the site. In addition, having on-site solar energy production can help further reduce BSOOB's GHG contribution by reducing the grid energy that is partially produced using the GHG emitting conventional energy sources.

If solar is considered for the site, the on-site storage system should be sized according to the full solar production. A more detailed study should be conducted to determine the battery energy requirements.

12. Conceptual Infrastructure Design

12a. Conceptual Layouts

To assist BSOOB with visualizing the required infrastructure transition, conceptual plans were next developed based on the previous information established in this report. As outlined previously, Hatch recommends that further overnight charging infrastructure be installed in the 13 Pomerleau facility, and on-route charging should be installed at the Saco Transportation Center.

Section Summary

- Hatch recommends installing chargers in the 13 Pomerleau facility outdoor storage area, and two layover chargers at the Saco Transportation Center
- The risk of a BEB fire is low but must be considered and mitigated

As previously mentioned, there are already two existing centralized charging cabinets with one dispenser each; the dispensers are suspended from an overhead structure inside the facility. To fully utilize the capacity of the indoor storage bay where the existing chargers are installed, it is recommended to purchase two additional dispensers to allow four buses to be charged simultaneously for overnight charging or maintenance purposes. Given the previously mentioned spatial constraints of the 13 Pomerleau facility, any further chargers would likely need to be installed outdoors, complementing BSOOB's current practice of outdoor bus storage. This will minimize capital and operational impacts of charger installation. One possible layout for future charger installation is shown in Figure 13. Aside from the charging infrastructure itself, BSOOB would also need to invest in security measures to deter overnight bus vandalism (such as fences, cameras, and lighting), install fire detection measures as outlined in Section 12b, and develop snow-clearing procedures to ensure that the plow operators clear the areas adjacent to the chargers without damaging the chargers themselves.

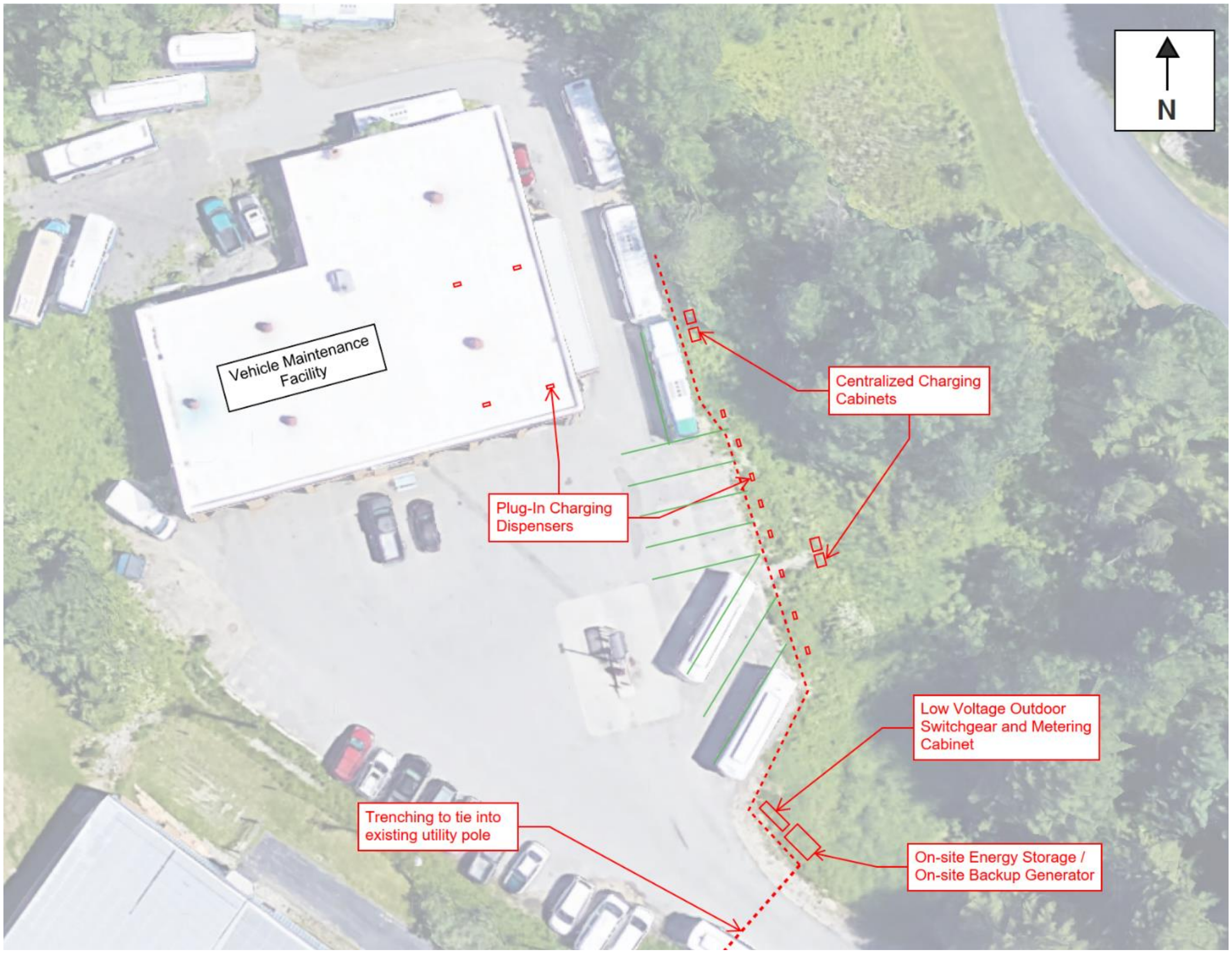

Figure 13 13 Pomerleau St. Overnight Charger Layout Option

At Saco Transportation Center, there are two main parking lots in the front and rear of the transit building. Buses currently use a dedicated area in the front lot for layover. This parking lot also has space for short term car parking. The rear lot is used for long term parking. Hatch recommends installing the layover pantograph chargers (potentially with an additional plug-in dispenser as discussed in Section 5) in the existing front lot bus layover area, as also recommended by GPCOG's Transit Stop Access Prioritization Project. Key considerations in favor of using the front lot include bus maneuverability, sidewalk space, nearby underground utilities, sight lines around parked buses, snow clearance, and security. Figure 14 below shows the recommended charger locations.

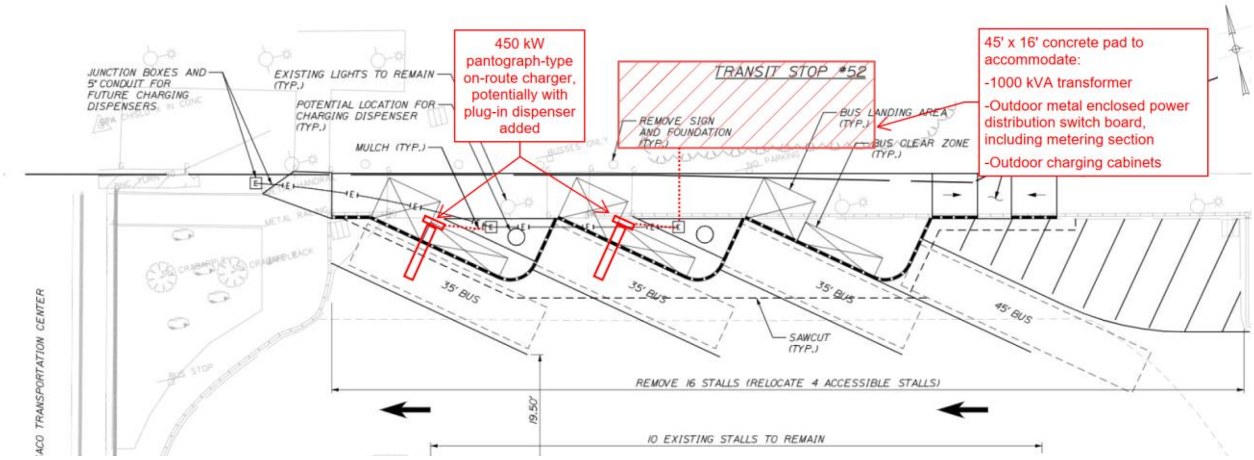

Figure 14 Saco Transportation Center On-Charger Layout Option (Source: GPCOG)

12b. Fire Mitigation

An electric bus's battery is a dense assembly of chemical energy. If this large supply of energy begins reacting outside of its intended circuitry, for example due to faulty wiring or defective or damaged components, the battery can start rapidly expelling heat and flammable gas, causing a "thermal runaway" fire. Given their abundant fuel supply, battery fires are notoriously difficult to put out and can even reignite after they are extinguished. Furthermore, without prompt fire mitigation the dispersed heat and gas will likely spread to whatever is located near the bus. If this is another electric bus then a chain reaction can occur, with the heat emanating from one bus overheating (and likely igniting) the batteries of another bus. This can endanger all the buses in the overnight storage area.

For the aforementioned risks that battery electric vehicle operations introduce, mitigations are recommended. On the vehicles themselves, increasingly sophisticated battery management systems are being developed, ensuring that warning signs of battery fires – such as high temperature, swelling, and impact and vibration damage – are quickly caught and addressed. Though research is ongoing, most battery producers believe that with proper manufacturing quality assurance and operational monitoring the risk of a battery fire can be minimized.

The infrastructure best practices for preventing fire spread with electric vehicles are still being developed. Although BSOOB's risk is partially mitigated because the majority of the buses will be stored outdoors while charging, Hatch still recommends that BSOOB monitor any development of standards for fire suppression and mitigation of facilities housing battery electric vehicles (which currently do not exist). There are partially relevant standards for the storage of high-capacity batteries indoors for backup power systems, such as UL9540, NFPA 70, and NFPA 230, and the primary components of any fire mitigation strategy are well understood. These include detectors for immediate discovery of a fire, sprinklers to extinguish it as much as possible, and barriers to prevent it from spreading to other buses, the maintenance facility, or the nearby fueling island. In terms of staffing, it is recommended that staff be located nearby to respond in case of a fire and move unaffected buses out of harm's way. If BSOOB staff are not present at the depot overnight, Hatch recommends coordinating with the local fire department to ensure that first responders are trained on procedures to prevent a vehicle fire from spreading. Each of these factors requires specific consideration with respect to BSOOB's operations. Hatch recommends that BSOOB commission a fire safety study as part of detailed design work for the next charger installation project to consider these factors.

13. Policy Considerations and Resource Analysis

Section Summary

- A wide range of funding sources is available to BSOOB to help fund electrification
- State and local support will be required as well

Immediately before the pandemic, BSOOB's operating budget was roughly $3.0 million per year. The agency's funding sources are summarized in Figure 15. As can be seen in the figure, BSOOB's largest source of funding comes from federal assistance. For bus, facility, and infrastructure costs the agency's primary federal funding comes from the Urbanized Area Formula Funding program (49 U.S.C. 5307), and the Buses and Bus Facilities Competitive Program (49 U.S.C. 5339(b)) through the FTA.

As the agency transitions to battery electric technology, additional policies and resources will become applicable to BSOOB. Table 9 provides a summary of current policies, resources and legislation that are relevant to BSOOB's fleet electrification transition.

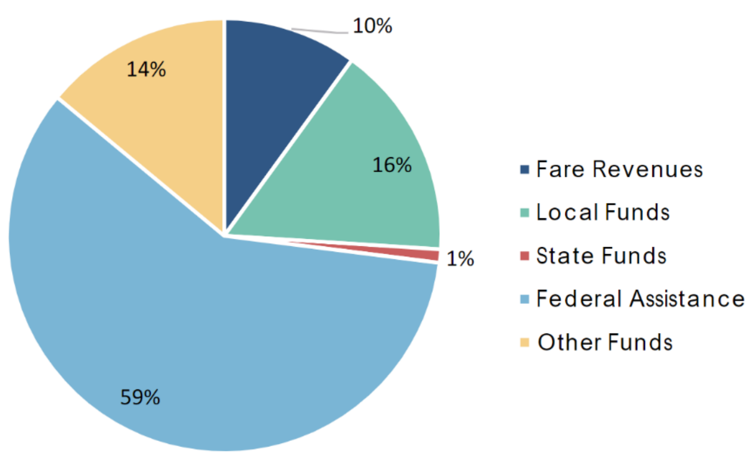

Figure 15 Current Agency Funding Summary (Source: Maine DOT)

Despite the large number of potential funding opportunities available to transit agencies seeking to transition to battery electric technologies, these programs are competitive and do not provide BSOOB with guaranteed funding sources. Therefore, this analysis assumes that BSOOB will only receive funding through the largest grant programs that provide the highest likelihood of issuance to the agency. Specifically, this analysis assumed that BSOOB will receive 80% of the capital required to complete the bus, charging system, and supporting infrastructure procurements outlined in this transition plan through the following major grant programs:

+ Urbanized Area Formula Funding (49 U.S.C. 5307),
+ Low or No Emission Grant Program (FTA 5339 (c)
+ Buses and Bus Facilities Competitive Program (49 U.S.C. 5339(b))

It is assumed that all other funding required to complete this transition will need to be provided through state or local funds.

Table 9 Policy and Resources Available to BSOOB

Policy	Details	Relevance to Agency Transition
The U.S. Department of Transportation's Public Transportation Innovation Program	Financial assistance is available to local, state, and federal government entities; public transportation providers; private and non-profit organizations; and higher education institutions for research, demonstration, and deployment projects involving low or zero emission public transportation vehicles. Eligible vehicles must be designated for public transportation use and significantly reduce energy consumption or harmful emissions compared to a comparable standard or low emission vehicle.	Can be used to fund electric bus deployments and research projects. (*Competitive funding)
The U.S. Department of Transportation's Low or No Emission Grant Program	Financial assistance is available to local and state government entities for the purchase or lease of low-emission or zero-emission transit buses, in addition to the acquisition, construction, or lease of supporting facilities. Eligible vehicles must be designated for public transportation use and significantly reduce energy consumption or harmful emissions compared to a comparable standard or low emission vehicle.	Can be used for the procurement of electric buses and infrastructure (*Competitive funding)
The U.S. Department of Transportation's Urbanized Area Formula Grants - 5307	The Urbanized Area Formula Funding program (49 U.S.C. 5307) makes federal resources available to urbanized areas and to governors for transit capital and operating assistance in urbanized areas and for transportation-related planning. An urbanized area is an incorporated area with a population of 50,000 or more that is designated as such by the U.S. Department of Commerce, Bureau of the Census.	This is one of the primary grant sources currently used by transit agencies to procure buses and to build/renovate facilities. (*Competitive funding)
The U.S. Department of Transportation's Grants for Buses and Bus Facilities Competitive Program (49 U.S.C. 5339(b))	This grant makes federal resources available to states and direct recipients to replace, rehabilitate and purchase buses and related equipment and to construct bus-related facilities, including technological changes or innovations to modify low or no emission vehicles or facilities. Funding is provided through formula allocations and competitive grants.	This is one of the primary grant sources currently used by transit agencies to procure buses and to build/renovate facilities. (*Competitive funding)

Policy	Details	Relevance to Agency Transition
The U.S. Department of Energy (DOE) Title Battery Recycling and Second-Life Applications Grant Program	DOE will issue grants for research, development, and demonstration of electric vehicle (EV) battery recycling and second use application projects in the United States. Eligible activities will include second-life applications for EV batteries, and technologies and processes for final recycling and disposal of EV batteries.	Could be used to fund the conversion of electric bus batteries at end of life as on-site energy storage. (*Competitive funding)
Maine Renewable Energy Development Program	The Renewable Energy Development Program must remove obstacles to and promote development of renewable energy resources, including the development of battery energy storage systems. Programs also available to provide kWh credits for solar and storage systems.	Can be used to offset costs of solar and battery storage systems. (*Non-Competitive funding)
Energy Storage System Research, Development, and Deployment Program	The U.S. Department of Energy (DOE) must establish an Energy Storage System Research, Development, and Deployment Program. The initial program focus is to further the research, development, and deployment of short- and long-duration large-scale energy storage systems, including, but not limited to, distributed energy storage technologies and transportation energy storage technologies.	Can be used to fund energy storage systems for the agency. (*Competitive funding)
The U.S. Economic Development Administration's Innovative Workforce Development Grant	The U.S. Economic Development Administration's (EDA) STEM Talent Challenge aims to build science, technology, engineering and mathematics (STEM) talent training systems to strengthen regional innovation economies through projects that use work-based learning models to expand regional STEM-capable workforce capacity and build the workforce of tomorrow. This program offers competitive grants to organizations that create and implement STEM talent development strategies to support opportunities in high-growth potential sectors in the United States.	Can be used to fund EV training programs. (*Competitive funding)
Congestion Mitigation and Air Quality Improvement (CMAQ) Program	The U.S. Department of Transportation Federal Highway Administration's CMAQ Program provides funding to state departments of transportation, local governments, and transit agencies for projects and programs that help meet the requirements of the Clean Air Act by reducing mobile source emissions and regional congestion on transportation networks. Eligible activities for alternative fuel infrastructure and research include battery technologies for vehicles.	Can be used to fund capital requirements for the transition. (*Competitive funding)

Policy	Details	Relevance to Agency Transition
Hazardous Materials Regulations	The U.S. Department of Transportation (DOT) regulates safe handling, transportation, and packaging of hazardous materials, including lithium batteries and cells. DOT may impose fines for violations, including air or ground transportation of lithium batteries that have not been tested or protected against short circuit; offering lithium or lead-acid batteries in unauthorized or misclassified packages; or failing to prepare batteries to prevent damage in transit. Lithium-metal cells and batteries are forbidden for transport aboard passenger-carrying aircraft.	Should be cited as a requirement in procurement specifications.
Maine Clean Energy and Sustainability Accelerator	Efficiency Maine administers the Maine Clean Energy and Sustainability Accelerator to provide loans for qualified alternative fuel vehicle (AFV) projects, including the purchase of plug-in electric vehicles, fuel cell electric vehicles, zero emission vehicles (ZEVs), and associated vehicle charging and fueling infrastructure.	Can be used to fund vehicle and infrastructure procurements. (*Competitive funding)
Maine DOT VW Environmental Mitigation Trust	The Maine Department of Transportation (Maine DOT) is accepting applications for funding of heavy-duty on-road new diesel or alternative fuel repowers and replacements, as well as off-road all-electric repowers and replacements. Both government and non-government entities are eligible for funding.	Can be used to fund vehicle procurements (*Competitive funding)
Efficiency Maine Electric Vehicle Initiatives	Efficiency Maine offers a rebate of $350 to government and non-profit entities for the purchase of Level 2 EVSE. Applicants are awarded one rebate per port and may receive a maximum of two rebates. EVSE along specific roads and at locations that will likely experience frequent use will be prioritized.	Can be used to subsidize charger purchases. (*Formula funding)
Efficiency Maine Electric Vehicle Accelerator	Efficiency Maine's Electric Vehicle Accelerator provides rebates to Maine residents, businesses, government entities, and tribal governments for the purchase or lease of a new PEV or plug-in hybrid electric vehicle (PHEV) at participating Maine dealerships.	Can be used to subsidize vehicle procurements. (*Formula funding)

14. Cost Analysis

Hatch calculated the life cycle cost (LCC) of the proposed transition strategy and compared it to maintaining BSOOB's pre-2022 all-diesel operations as a baseline, using a net present value (NPV) model. This allows all costs incurred throughout the fleet transition to be considered in terms of today's dollars. The costs, which are based on the weekday summer service levels analyzed above and scaled to account for weekends, holidays, and other seasons, include initial capital as well as operations and maintenance costs of the vehicles and supporting infrastructure for diesel and battery electric buses. Table 10 outlines the LCC model components, organized by basic cost elements, for diesel and battery electric bus technologies.

Section Summary

- Bus electrification will save BSOOB money over the long term, as electric vehicles cost less to maintain and fuel
- Upfront capital costs increase by approximately 44% and annual operating cost will decrease by approximately 13%, yielding a net 1% savings in total cost of ownership

Table 10: Life Cycle Cost Model Components

Category	Diesel (Base case)	Battery-Electric Buses
Capital	Purchase of the vehicles	Purchase of the vehicles
	Mid-life overhaul	Mid-life overhaul
		Battery replacement (or lease payments, if battery leasing is selected)
		EV charging Infrastructure
		Electrical infrastructure upgrades
		Utility feed upgrades
Operations	Diesel Fuel	Electricity
	Operator's Cost	Operator's Cost
		Demand charges for electricity
		Diesel Fuel for Auxiliary Heaters
Maintenance	Vehicle maintenance costs	Vehicle maintenance costs
		Charging infrastructure maintenance costs
Financial Incentives	Grants	Grants

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

Capital Investment

- The lifespan of a bus is 12 years, in accordance with BSOOB practice.
- Buses are overhauled at midlife. This is recommended for electric buses as the lifespan of a battery is approximately 6-7 years.

- Buses are replaced with buses of the same length, at their expected retirement year.
- The installation cost of the chargers at Saco Transportation Center is not included, as the project has already received federal funding that cannot be used for other purposes
- The installation cost of the first set of two additional charging dispensers at 13 Pomerleau St. is not included, as the project has similarly been funded with non-transferable money.
- BSOOB purchases the batteries on its electric buses, rather than leasing them.

Funding

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

Costs

- The proposed DCFC utility rate is implemented
- Discount rate (hurdle rate) of 7%
- Inflation rate of 3%

Table 11 lists the operating and capital costs that Hatch assumed for this study. These are based on BSOOB's figures and general industry trends and have been escalated to 2022 dollars where necessary.

Table 11 Cost Assumptions

Asset	Estimated Cost Per Unit (2022 $'s)
35' Diesel Transit Bus	$546,000
35' Battery Electric Transit Bus (225 kWh)	$813,000
35' Battery Electric Transit Bus (450 kWh)	$1,009,000
45' Diesel Commuter Coach	$600,000
45' Battery Electric Commuter Coach (541 kWh)	$1,096,000
Diesel Trolley-Style Bus	$325,000
Battery Electric Trolley-Style Bus (458 kWh)	$725,000
DC Fast Charger – Plug-in Garage (de-centralized unit and 3 dispensers)	$270,000
DC Fast Charger – Pantograph Overhead	$630,000

Expense	Estimated Cost (2022 $'s)
Diesel bus maintenance	$1.13 / mile
Electric bus maintenance	$0.85 / mile
Operator salary, benefits, overhead	$29.05 / hour
Diesel fuel	$3.14 / gallon

Because the electrification transition process will be gradual, life cycle cost calculations would necessarily overlap multiple bus procurement periods. Hatch addressed this issue by setting the start of the analysis period to be the year when the last diesel bus is proposed to be retired (2034), with the analysis period stretching for a full 12-year bus lifespan. For buses at midlife at the end of the analysis period, a remaining value was calculated and applied at the end of the time window.

The LCC analysis determines the relative cost difference between the baseline (diesel) case and the proposed case. Therefore, it only includes costs which are expected to be different between the two options. Costs common to both alternatives, such as bus stop maintenance, are not included as they do not have a net effect on the LCC comparison. Thus, the model indicates the most economical option but does not represent the full or true cost for either technology.

Table 12 and Figure 16 summarize the NPV for both technologies by cost category.

Table 12: Net Present Value Summary

Category	Diesel Baseline	Future Fleet	Cost Differential (Future Fleet vs. Baseline)
Vehicle Capital Costs	$2,851,328	$3,996,131	+44%
Infrastructure Capital Costs	$0	$118,036	
Vehicle Maintenance Costs	$3,233,183	$2,437,291	-13%
Infrastructure Maintenance Costs	$0	$47,628	
Operational Cost	$7,119,275	$6,537,309	
Total Life Cycle Cost	$13,203,786	$13,136,394	-1%

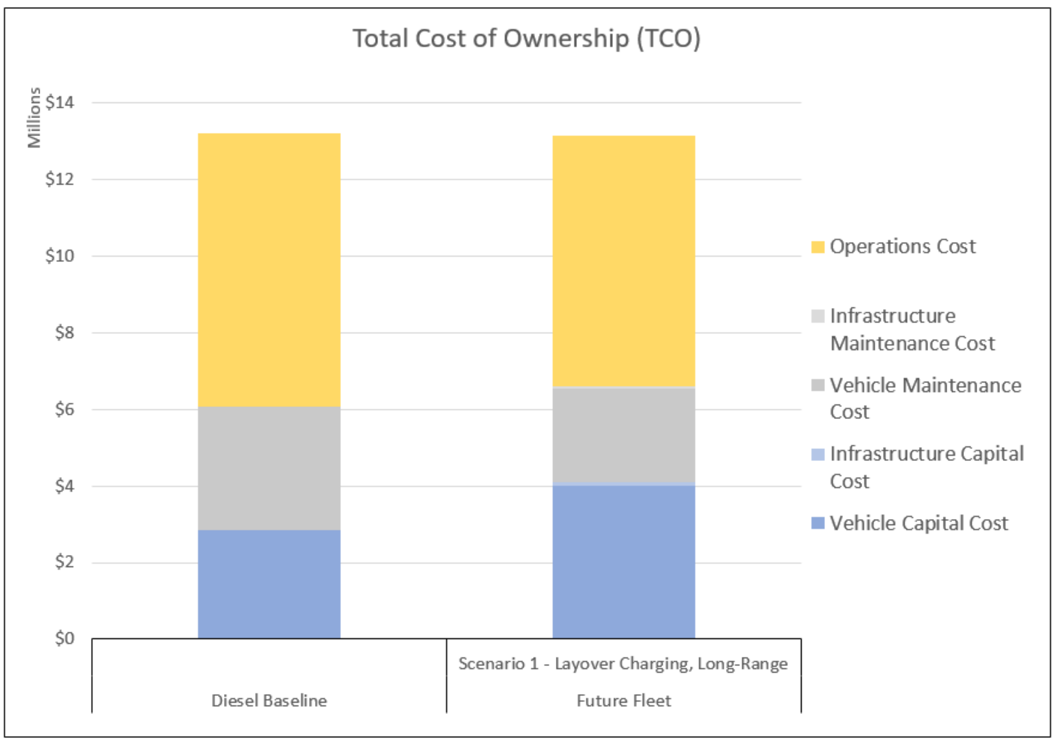

Figure 16 Life Cycle Cost Comparison

As shown in Figure 16, bus electrification reduces total system cost at the expense of increasing initial capital cost. Although there is some expense related to the charging equipment at the 13 Pomerleau facility and Saco Transportation Center, the bulk of the extra capital spending is on the vehicles themselves, as electric buses are much simpler mechanically than diesel buses but command a cost premium due to their large battery systems. This yields a 44% increase in capital costs over the diesel baseline. This initial, non-recurring cost is balanced out by the maintenance and operating savings over the lifetime of the vehicles. Because electric vehicles have fewer components to maintain and are cheaper to refuel than diesels, the maintenance and operating costs of the proposed fleet are 13% lower than of the diesel baseline. However, these costs recur daily – worn parts must be replaced and empty fuel tanks must be refilled throughout the lifetime of the vehicle. This means that over the long term the operations and maintenance savings outweigh the initial extra capital spending, yielding a net-present-value savings of approximately 1%.

The proposed fleet transition requires initial capital spending to reduce life cycle cost and achieve other strategic goals. This finding is common to many transit projects and is representative of the transit industry as a whole, with nearly all bus and rail systems requiring capital investments up front to save money in other areas (traffic congestion, air pollution, etc.) and achieve broader societal benefits over the long term. By extension, just as with the transit industry at large, policy and financial commitment will be required from government leaders to achieve the desired benefits. The federal government's contribution to these goals via FTA and Low-No grants is already accounted for, leaving state and local leaders to cover the remaining 44% increase in upfront capital cost.

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

Full details on the LCC model are provided as Appendix D.

15. Emissions Impacts

Section Summary

- Bus electrification will be critical to helping meet State emission goals
- Forecasted grid conversion to clean energy will maximize the benefit of bus electrification
- The transition is expected to reduce emissions by 81-91%

One of the motivations behind BSOOB's transition towards battery electric buses is the State of Maine's goals to reduce emissions. While specific targets for public transportation have not been established, the state goal to achieve a 45% overall emissions reduction by 2030 was considered as a target by BSOOB.

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

- Tank-to-wheel
- Well-to-tank
- Grid

The tank-to-wheel emissions impact considers the emissions reduction in the communities, where the buses are operated. As a tank-to-wheel baseline, the 'tailpipe' emissions associated with BSOOB's existing diesel fleet were calculated. These calculations used industry emissions averages for diesel buses and assumed an average fuel economy of 5 miles per gallon.

Battery electric bus propulsion systems do not create emissions, and therefore there are no 'tailpipe' emissions. As explained in Section 6, this transition plan does, however, assume that diesel heaters will be used on the battery electric buses during the winter months. Therefore, the emissions associated with diesel heaters are included in the tank-to-wheel estimates for battery electric buses.

Well-to-tank emissions are those associated with energy production. For diesel vehicles well-to-tank emissions are due to diesel production, processing and delivery. This emissions estimate used industry averages for the well-to-wheel emissions associated with the delivery of diesel fuel to BSOOB. For battery electric vehicles, well-to-tank emissions are due to the production, processing and delivery of diesel fuel for the heaters.

Battery electric vehicles have a third emissions source: grid electricity generation. The local utility, Central Maine Power, was not able to provide specific details on the emissions associated with its electricity production as part of this project. Therefore, the emissions calculations assumed an EPA and EIA average grid mix for Maine. Similar to the state's overall goals to reduce emissions, the state has also set the goal of reducing grid emissions by roughly 67% by 2030 by transitioning to more renewable energy production. To account for these future grid emissions reduction goals, calculations were completed based on the most recent actual data available (2020), as well as projections that assume that the 2030 targets are met. Table 13 and Figure 17 summarize the results of the emissions calculations. These results demonstrate that the transition plan will achieve 81% emissions reduction assuming the grid mix that existed in 2020, or 91% emissions reduction assuming that Central Maine Power is able to meet the state's goals to reduce grid emissions by the year 2030. In either case, BSOOB's transition plan will achieve a reduction in emissions in excess of the 45% goal established by the State of Maine.

Table 13 CO_2 Emissions Estimate Results

Scenario	Well-to-Tank (kg)	Tank-to-Wheel (kg)	Grid (kg)	Total (kg)	Reduction over Baseline
Diesel Baseline	543,941	936,196	---	1,480,137	----------
Future Fleet (Assuming 2020 grid mix)	25,835	44,466	212,809	283,111	81%
Future Fleet (Assuming 2030 grid mix)	25,835	44,466	70,227	140,529	91%

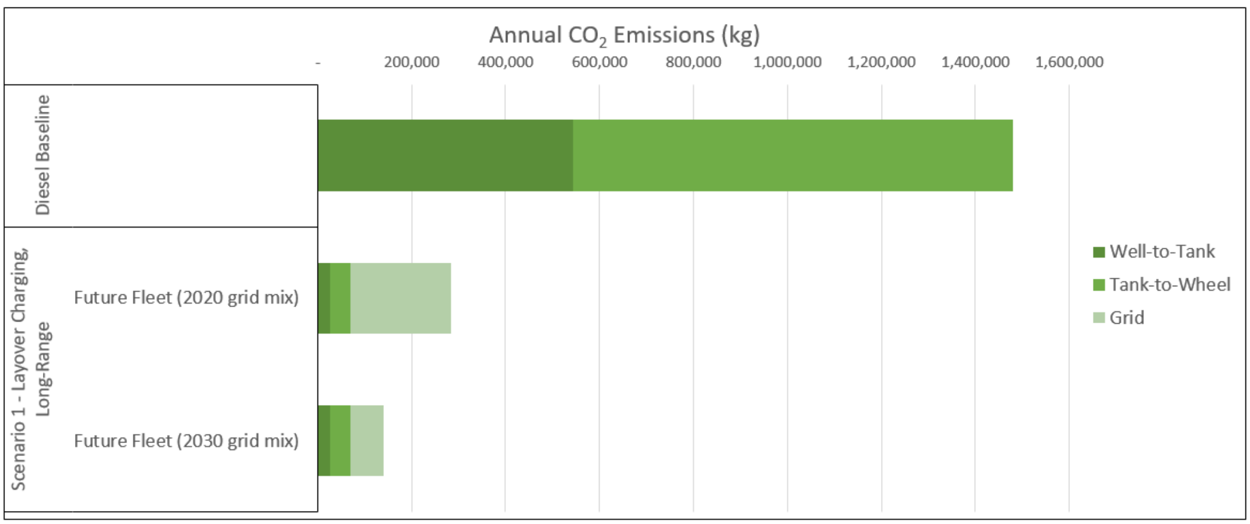

Figure 17 Graph of CO_2 Emissions Estimate Results

Should BSOOB seek to achieve greater emissions reductions than those calculated here, the agency may consider the following options:

- Purchase green energy agreements through energy retailers to reduce or eliminate the emissions associated with grid production.
- Use spare buses, particularly trolleys during the winter off-season, as mobile peak-shaving batteries (allowing them to feed the grid during periods of high demand) to reduce grid emissions and potentially generate revenue

16. Workforce Assessment

Section Summary

- Once the initial training is completed and staff turnover occurs over time, maintaining employees' skills in BEB operations and maintenance will be critical to BEB success
- Hatch recommends partnering with local colleges and other transit agencies to share skills

As part of its first procurement of electric buses, BSOOB staff received training and special tools for operating, charging, and maintaining BEBs. Ensuring that this knowledge remains with the agency despite future staff turnover will be key to successful fleet electrification. Because BSOOB is a comparatively small agency and electric vehicle maintenance is currently a relatively niche market, the agency cannot solely rely on knowledge transfer between employees or on hiring pre-trained personnel. Agency leaders will have to continuously monitor the skillset of their employees and improve training as needed. To ensure that both existing and future staff members can operate BSOOB's future system a workforce assessment was conducted. Table 14 details the key skills that BSOOB's workforce groups will need to maintain for safe and effective electric bus operation.

Table 14 Workforce Skill Gaps and Required Training

Workforce Group	Key Skills and Required Ongoing Training
Maintenance Staff	High voltage systems, vehicle diagnostics, electric propulsion, charging systems, and battery systems
Electricians	Charging system functionality and maintenance
Agency Safety/Training Officer/First Responders	High Voltage operations and safety, fire safety
Operators	Electric vehicle operating procedures, charging system usage
General Agency Staff and Management	Understanding of vehicle and charging system technology, electric vehicle operating practices

To address these training requirements Hatch recommends that BSOOB consider the following training strategies:

+ Add requirements to future vehicle procurement contracts for staff refresher training on the safe operation and maintenance of electric vehicles.
+ Coordinate with other peer transit agencies, especially within the state of Maine, to transfer 'lessons learned' both to and from BSOOB. Send staff to transit agency properties – both those that already operate BEBs and those that are just procuring them – to stay up to date on agencies' experiences and the newest BEB technology.
+ Coordinate with local vocational and community colleges to learn about education programs applicable to battery electric technologies, similar to the one Southern Maine Community College recently introduced. If no nearby programs are available, consider partnering with a school to develop a curriculum.

As electric vehicles become increasingly widespread, BSOOB should take note of any potential differences between skills that incoming employees may already have – such as operating their personal electric cars – and the knowledge needed for operation and maintenance of electric transit buses. Transit buses pose special challenges that must be considered when training new staff members. Hatch recommends that BSOOB participate in industry conferences and workshops with other agencies around the US to understand the best way to keep its employees fully trained and up to date.

17. Alternative Transition Scenarios

> ***Section Summary***
>
> - Hatch recommends reviewing this report annually for comparison with technology development and BSOOB operations

As part of this study, BSOOB was presented with alternative fleet and infrastructure transition scenarios that would also satisfy the agency's operational requirements. These alternatives considered other vehicle battery configurations, different fleet sizes, other charging locations, and different operational plans. Through discussions, however, BSOOB currently favors the transition plan presented in this report. Details on the alternative plans are presented in Appendix B, D, and E. Should BSOOB's plans or circumstances change in the future, it is possible that one of the alternative transition plans presented may become more advantageous. Hatch recommends that BSOOB review this transition plan on an annual basis to reevaluate the assumptions and decisions made at the time this report was authored.

18. Recommendations and Next Steps

The urban transit industry is currently at the beginning stages of a wholesale transition. As electric vehicle technology matures, climate concerns become more pressing, and fossil fuels increase in cost, many transit agencies will transition their fleets away from diesel-powered vehicles in favor of battery-electric. By introducing its first two electric vehicles BSOOB has taken the first step toward fleet electrification, and the agency stands well-positioned to continue this process in the coming years. In partnership with Maine DOT, other transit agencies in Maine, as well as other key stakeholders, BSOOB will be able to reduce emissions, noise, operating cost, and other negative factors associated with diesel operations, while complying with the Clean Transportation Roadmap and operating sustainably for years to come.

For BSOOB to achieve sustainable and economical fleet electrification, Hatch recommends the following steps:

- Proceed with transitioning the agency's buses and infrastructure in the manner described in this report.
- For the vehicles:
  - Consider ordering buses as part of larger orders or partnering with other agencies or the DOT to form large joint procurements.

  - Consider flexibility in vehicle types, particularly for commuter and trolley vehicles, to increase competition on future vehicle procurements.
  - Purchase bus batteries outright, rather than leasing them.
  - With further BEB orders, continue requiring the electric bus vendor to have a technician on site or nearby in case of problems. This is most economical when the technician is shared with several nearby agencies.
  - Reach a "mutual aid" agreement with another urban transit agency in Maine that would let BSOOB borrow spare buses in case of difficulties with its fleet.
  - Retain a small fleet of diesel backup buses to ensure they can substitute for electric buses if any incidents or weather conditions require it.
- For the infrastructure at the 13 Pomerleau facility:
  - Continue upgrading the electrical utilities to support additional charging infrastructure.
  - During the next installation of chargers, include provisions for sufficient infrastructure to electrify the entire fleet, to reduce future piecemeal work.
  - Conduct a fire safety analysis in accordance with Section 12b and standards UL9540, NFPA 70 and 230, including staff training for fire response.
- For the infrastructure at the Saco Transportation Center:
  - Add a priced option to the specification for installation of a plug-in dispenser, for use by BSOOB's trolley-style vehicles or YCCAC's Southern Maine Connector
  - Develop contingency plans in case the layover chargers fail and midday depot swapping is required.
- For other components of the transition:
  - Tweak operating schedules as required for optimal BEB operation.
  - Add requirements to future procurements for staff refresher training.
  - Participate in industry conferences and coordination with other Maine transit agencies to share best practices for staff training programs, as described in Section 16. Coordinate with local education institutions as well.
  - Coordinate transition efforts with peer transit agencies, CMP, and Maine DOT.
  - Continually monitor utility structures and peak charge rates and adjust charging schedules accordingly.
  - Develop a funding strategy to account for the 44% increase in capital expenditure.
  - Review this transition plan annually to update based on current assumptions, plans, and conditions.

Appendices

A. Vehicle and Infrastructure Technology Options
B. Operations Simulation Presentation
C. Utility Outage Data
D. Life Cycle Costing Models
E. Alternative Transition Strategy Presentation