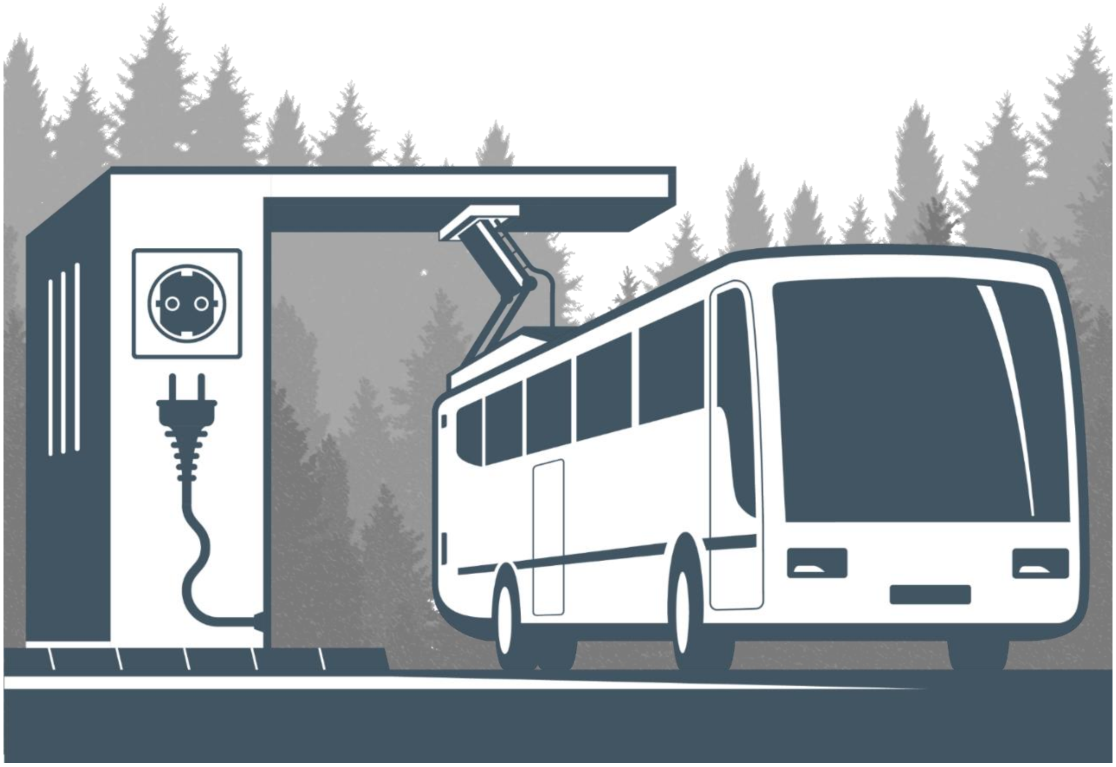

Bus Electrification Transition Plan for South Portland Bus Service (SPBS)

City of South Portland

Prepared by:

HATCH

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Table of Contents

1. Executive Summary

South Portland Bus Service (SPBS) is currently considering transitioning its bus fleet to battery electric drivetrain technologies. To effectively plan for this transition a thorough analysis was conducted to develop a feasible 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, SPBS has selected fleet and infrastructure asset configurations that will provide a feasible transition to battery electric drivetrain technologies while supporting the agency's operational requirements. The selected configuration transitions the agency's 7 diesel buses to a fleet of 8 battery electric buses (BEB). To support the battery electric buses, the agency will also procure, install and commission 2 charging systems that will have the capacity to support charging of up to 6 buses simultaneously. The maintenance facility and utilities will also require upgrades to properly charge and maintain the new bus fleet.

One of the primary motivations behind SPBS's transition to battery electric drivetrain technologies is to achieve emissions reductions compared to their existing diesel operations. As part of this analysis, an emissions projection was generated for the proposed future battery electric fleet. The results of this emissions projections estimate that the new fleet will provide up to an 87% reduction in emissions compared to SPBS's existing diesel 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 SPBS can anticipate a 47% increase in capital expenditures due to the transition. It is estimated, however, that there will be a 7% 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 SPBS will see roughly 2% additional life cycle cost by transitioning to battery electric buses.

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

2. Introduction

The state of Maine is currently making plans to reduce emissions to slow the effects of climate change. As part of these plans the Governor's office has developed a "Clean Transportation Roadmap", encouraging 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-emission vehicles and related infrastructure and avoid displacement of the existing workforce.

In response to the Governor's Roadmap and the FTA requirements, South Portland Bus Service (SPBS), 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 South Portland's future route plans, vehicle technology options, building electrical capacity, emissions impacts, resiliency, and financial implications.

3. Existing Conditions

SPBS is a small transit agency providing service to the South Portland area. The agency currently owns and operates a fleet of 7 transit buses, all of which are diesel powered, shown in Table 1 below.

Section Summary

- SPBS operates three (soon to be four) routes with a seven-bus fleet
- Peak service requires three (soon to be four) buses

Table 1 Current Transit Bus Roster

Bus Type/Roster Number	Fuel Efficiency (MPG)	Procurement Date	Projected Retirement Date
GILLIG 35'/Low Floor Bus	4.8	2011	2023
GILLIG 35'/Low Floor Bus	4.8	2011	2023
GILLIG 35'/Low Floor Bus	4.8	2014	2026
GILLIG 35'/Low Floor Bus	4.8	2014	2026
GILLIG 35'/Low Floor Bus	4.8	2016	2028
GILLIG 35'/Low Floor Bus	4.8	2016	2028
GILLIG 35'/Low Floor Bus	4.8	2022	2034

SPBS currently operates three fixed route bus services, and plans to add a fourth:

1. **Route 21 Willard Square**. This route begins at Pillsbury Street and Cottage Road. Major stops on the inbound to Portland portion of the route include SMCC, Ferry Village - High Street and Sawyer Street, Mill Creek Transit Hub, and Forest and Congress Street in Portland. Major stops on the southbound to Willard Square and SMCC portion of the route include Forest and Congress Street, Mill Creek Transit Hub, Ocean Street and Sawyer Street, and Pillsbury Street and Cottage Road. Weekdays, the bus runs from 6:35 a.m. to 11:15 p.m. On Saturdays and Sundays, the bus runs from 6:40 a.m. to 6:40 p.m.

2. **[Future] Route 21 Campus Connector (CC).** This planned route will increase frequency between SMCC and Portland as well as provide more direct access to Maine Medical Center from South Portland. It is expected to operate via Broadway in South Portland, stopping at the Mill Creek Transit Hub, then over the Casco Bay Bridge to Portland, where it will operate via High St to the University of Southern Maine – Portland and finally via Bedford St. and Deering Avenue to Maine Medical Center. On the return trip it will run via the Western Promenade and Danforth St. to the Casco Bay Bridge, from where it will continue via the Mill Creek Transit Hub and Broadway back to SMCC.

3. **Route 24A Maine Mall via Main Street**. This route begins at Redbank. Major stops on the inbound to Portland via Main Street portion of the route include Gannett Drive, Running Hill Road, Maine Mall JC Penney, Redbank, Main Street and Westbrook Street, Cash Corner on Main Street, Broadway at Evans Street, Mill Creek Transit Hib, and Forest and Congress Street. Major stops on the southbound to Maine Mall via Main Street include Forest and Congress Street, Mill Creek Transit Hub, Broadway at Evans Street, Cash Corner on Main Street, Main Street and Westbrook Street, Redbank, Maine Mall JC Penney, and Walmart. Weekdays, the bus runs from 5:20 a.m. to 11:15 p.m. On Saturdays and Sundays, the bus runs from 7:00 a.m. to 6:30 p.m.

4. **Route 24B Maine Mall via Community Center**. This route begins at the Mill Street Transit Hub. Major stops on the inbound to Portland via Community Center portion of the route

include Gannett Drive, Maine Mall JC Penney, Brick Hill Redbank, Cash Corner on Broadway, Highland Community Center, Mill Creek Transit Hub, and Forest and Congress Street. Major stops on the southbound to Maine Mall via Community Center include Forest and Congress Street, Mill Creek Transit Hub, Highland Community Center, Cash Corner on Broadway, Brick Hill Redbank, Maine Mall JC Penney, and Walmart. Weekdays, the bus runs from 6:20 a.m. to 9:45 p.m. There is no weekend service.

Figure 1 shows the SPBS route map.

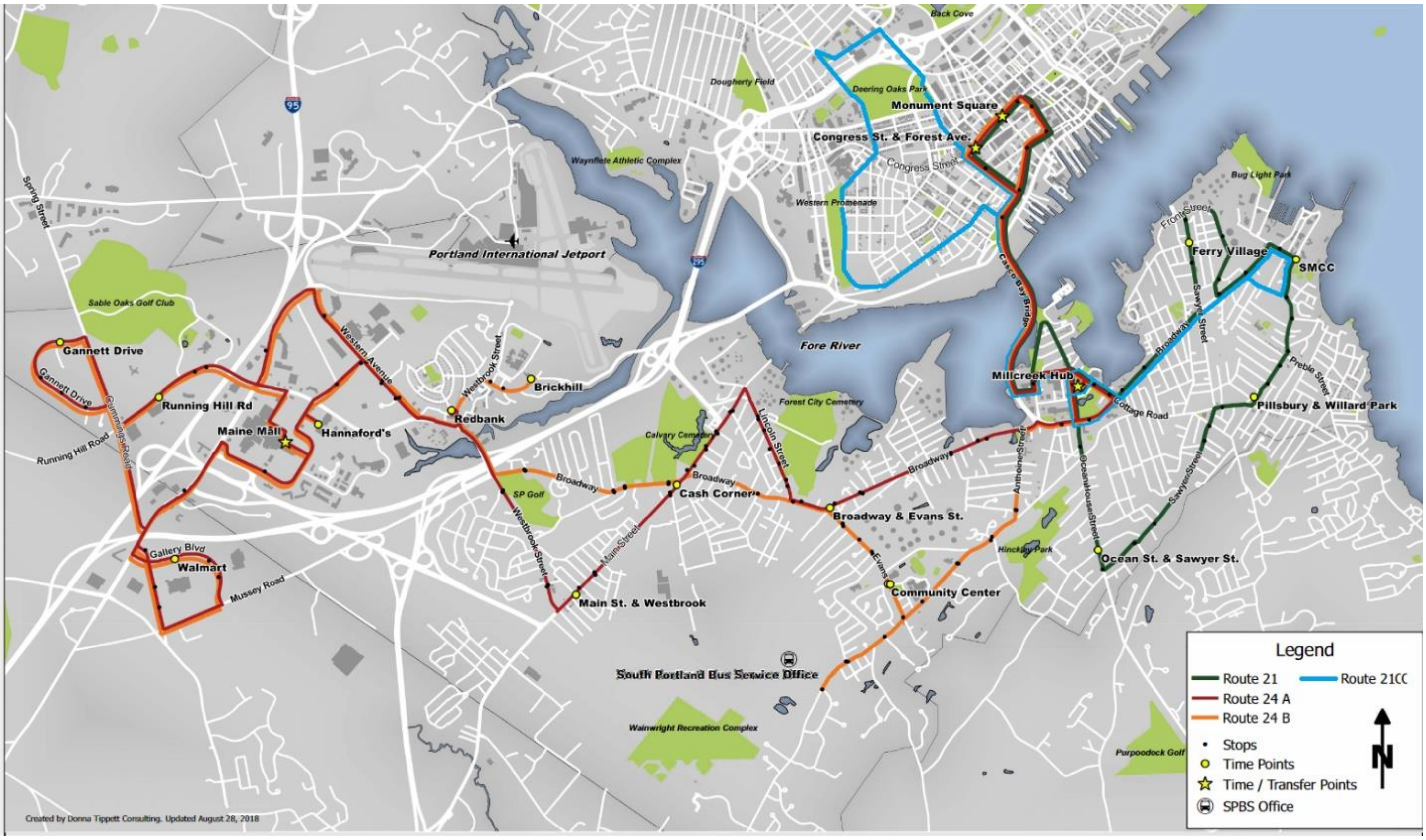

Figure 1 South Portland System Map Including Future Route 21 Campus Connector

All three current routes operate along Congress Street in Downtown Portland – a major transfer point – providing connections to Greater Portland Metro routes and BSOOB Transit. The planned Route 21 Campus Connector (CC) service will not serve Congress Street, however. In addition, the Transit Together study, ongoing as of this writing, may result in changes to the SPBS route structure; some potential changes include the merger of Routes 24A and 24B, the truncation of Route 24 to Mill Creek Transit Hub, and the addition of a South Portland Vision Route. As no specific proposed route structure has yet been chosen, this study considered the route network as it exists today, with the addition of the planned Route 21 Campus Connector (CC) service.

Drivers and buses are typically assigned to "jobs" which entail operating on the same route throughout the course of the day. While the agency primarily operates buses on the same routes throughout the day, SPBS interlines Routes 21 and 24A on Sundays.

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, SPBS's revenue service fleet is composed of 35' transit buses. A summary of battery electric vehicle models that are commercially available (provided in Appendix A) demonstrates that there is a variety of possible vehicles for SPBS 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 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. The 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 last longer if they are not discharged to 0% – and an operational safety buffer to prevent dead buses from becoming stranded on the road. These two margins yield a usable battery capacity of 64% of the nominal value (144 or 288 kWh). 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

A centralized charger is a self-contained unit that allows charging one vehicle per charger. The charging dispenser is typically built into the charging cabinet. In contrast, in a decentralized 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. Figure 2 shows an example of such a charging system from ABB.

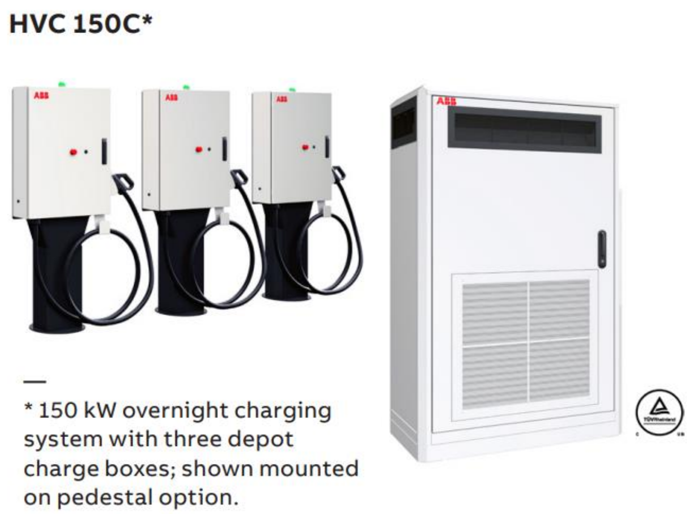

Figure 2 Example Charging System: Charging Cabinet (System) and Three Dispensers (Charge Boxes) (Source: ABB)

Similarly, de-centralized systems can support high-powered pantograph chargers, as shown in Figure 3. These chargers are appropriate for on-route or layover charging, so long as technological limitations and other factors, described in Section 6b, are taken into consideration with regards to operational impact and risk mitigation.

Figure 3 Example Charging System: Overhead Pantograph Charger and de-centralized cabinets (Source: ABB)

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 SPBS's future plug style charging systems would have 150 kW of power, while any potential future pantograph chargers would have 450 kW of power. These charging system power values have become standard to the transit bus industry. Appendix A shows additional commercially available options charging system options and configurations.

6. Route Planning and Operations

> ***Section Summary***
>
> - 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
> - Particularly with short-range buses, blocks should be optimized for BEB operation. This includes interlining and extra layover time to allow for charging
> - Long-range electric buses can cover one of SPBS's four blocks without layover charging

SPBS's current operating model is similar to that of many transit agencies across the country. Each vehicle leaves the garage at the appropriate time in the morning, operates (typically on the same route) for the entire day, and then returns to the garage once service has concluded in the evening. Although SPBS's schedulers must account for driver-related constraints such as maximum shift lengths, the vehicles are assumed to operate for as long as they are needed. This assumption may not always be valid for electric vehicles, which have reduced range in comparison to diesel buses. Even when diesel heaters are installed, as was assumed in this study, poor road conditions and cold temperatures degrade electric bus performance in the winter. Therefore, battery electric buses may not provide adequate range for a full day of service, year-round, on many of SPBS'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 SPBS'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 SPBS's operations.

Hatch conducted a route-specific electric bus analysis by generating "drive cycles" for several routes that represented the typical modes of SPBS's operations, ranging from slower-speed in-city routes to higher-speed routes in the less dense areas of South Portland. 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 South Portland-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 routes were evaluated against two common electric bus configurations: 'short-range' 225kWh or 'long-range' 450kWh battery capacity. As technology advances, Hatch assumed that these battery capacities will increase at a rate of 3% per year, allowing for additional range. Combined with the safety margins discussed in Section 4, this yields battery capacities of 172 kWh and 344 kWh by 2028 (which is the year SPBS expects to have a majority-electric fleet).

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 2028 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.

Table 2 Energy Requirements by Route

Route	Mileage	'Short-Range' Bus		'Long-Range' Bus	
		kWh Required	Mileage Shortage/Excess	kWh Required	Mileage Shortage/Excess
21	228	558	-155	592	-94
21CC	109	269	-39	285	22
24A	217	529	-148	558	-84
24B	258	573	-166	604	-102

6b. Operational Alternatives

As shown in Table 2, no routes can be served in their entirety with 'short-range' buses, and only one route can be operated with 'long-range' buses. To address the operational shortcomings of the battery electric buses a few options were considered. One option, which was not selected by SPBS stakeholders, is to adopt hybrid vehicles to bypass the range restriction altogether. Because hybrid vehicles have the same range as diesel vehicles do, they can operate as far as necessary over the course of a day. However, as this solution would meet neither the State's nor the South Portland City Council's goals for emissions reduction, it was not considered further in this report.

Another possibility is to install on-route chargers at transit hubs and recharge buses at the hubs throughout the day. This represents a substantial change from a typical transit agency's mode of operations, so there are several notable factors to be taken into consideration. On-route chargers would help SPBS's electric bus operations by increasing the agency's resiliency options in a power outage. Because the agency would now have multiple charging locations under its oversight, a power outage at the depot would not inhibit service. Additionally, an on-route charger would allow the agency more operational flexibility, for example to extend service hours. Finally, by recharging buses without requiring them to deviate from their routes, an on-route charger would minimize deadheading. However, there are also several disadvantages to an on-route charger that warrant consideration. The primary one is related to the choice to invest significant capital in a specific field location, as doing so commits the agency to using the charger location as a terminal for the multi-decade lifespan of the charging equipment. (Use of the charger mid-route, with passengers on board, is not recommended due to the time required for connection and disconnection from the charger and power ramp-up and ramp-down). This could heavily impact route planning and scheduling, especially if all routes do not terminate at the chosen location; interlining would need to be introduced to provide all buses access to the on-route charger. It would also preclude a variety of route changes, ranging from major (such as a route extension to a new development) to minor (such as moving a layover location down the block due to nearby construction). Lastly, the implementation of on-route chargers would create operational dependance on field assets, a risk which SPBS would need to be prepared to mitigate. This is a concern for both planned outages – such as charger maintenance and neighborhood construction – and unplanned disruptions such as breakdowns. The agency would need to prepare contingency plans for operation without the charger and be ready to implement them at a moment's notice. Although Hatch does not recommend on-route charging at this time for the reasons outlined above, it is possible that changes to SPBS's plans in the future could necessitate the purchase of this type of equipment. For this reason, possible on-route charging locations and further considerations are discussed in Section 9.

The compromise option, and the one that was selected by SPBS stakeholders, is to implement "depot swapping." After operating for several hours, buses would deadhead from a terminal to the garage, recharge, and then deadhead back to the terminal to reenter service (perhaps on a different route than the one they operated previously). Although this does require some additional mileage and operator hours due to newly introduced deadheading, this would be fairly minor due to the depot's proximity to SPBS's terminals and potential schedule optimization (discussed below). This approach also has several advantages. First, it eliminates the agency's dependence on any specific points in its network. Both short- and long-term reroutes will be as easy to implement as they are today. Second, it will allow the agency to leverage advances in electric bus technology. Over the last decade electric bus performance has improved dramatically, and this is expected to continue in coming years. Concentrating all chargers at the depot will make it more economical for SPBS to operate electric buses for longer and longer intervals as range of new vehicles improves. Finally, implementing depot swapping will minimize the effect that traffic congestion has on operations. Unlike with an on-route charger, where a bus cannot connect to the charger if the previous vehicle was delayed and is still charging, the depot's multiple chargers allow operational resilience by reducing the effect that one bus delay has on other buses.

To ensure efficient electric bus operation, the schedule (and perhaps even the route structure) would need to be optimized for the needs of the buses. For example, coordination of driver shift changes with bus charging times can ensure that drivers are not sitting around unproductively while the bus charges (and can even simplify scheduling, as a driver and a bus would stay together throughout the day and all driver swaps would occur at the depot). Careful selection of route interlines can help balance bus charge levels throughout the day. For example, a Route 21 bus arriving in downtown Portland with low charge levels can be scheduled to depart on Route 24B, which passes by the depot, allowing the bus to be switched for a fresh one. Short-turn trips, starting/ending at the depot, could also be added. This would provide useful service to passengers, potentially including school dismissal-time trips or other gaps in the schedule, and also allow buses to be rotated in and out of service without deadheading. More information about the tradeoffs between these operating strategies is presented in Appendix B.

Notably, all of the above options are likely to require increased fleet size. Electric buses will need time to charge; unless the schedule allows for guaranteed layover times long enough for charging, additional buses will be needed to operate in place of those that are charging. The Federal Transit Administration (FTA) acknowledges this in its Report No. 0182, stating that “zero-emission bus technology is rapidly improving, but in the practical process of planning, procuring, and implementing these buses, a transit agency cannot assume a 1:1 replacement ratio”. The report also notes that agencies with fewer than 50 buses in revenue service, like SPBS, do not have an FTA-mandated spare ratio. In other words, a small increase in SPBS fleet size is not expected to create regulatory challenges.

Once the electric buses are procured, Hatch recommends that SPBS operate them across all of the routes. This is particularly important in the beginning period, when SPBS receives its first few electric buses and is getting accustomed to them. Although the modeling shows that the runs listed above cannot be operated a full day during worst-case winter conditions, during the majority of the year electric buses will be able to operate systemwide for most of the day. This experience will help SPBS understand electric bus operations and make any scheduling or routing adjustments that may be needed. In addition, this approach will simplify dispatching by reducing the number of sub-fleets that need to be considered separately. During most of the year drivers will be able to choose any bus when pulling out onto any route, ensuring that the benefits of electric vehicles (elimination of tailpipe emissions, reduced noise, etc.) are distributed equitably across the city. Finally, this may also prove valuable from a Title VI perspective, particularly as city 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 SPBS operations.

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 SPBS charge its buses economically

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 reduces vehicle availability and adds logistical complexity. Fortunately, the operational configuration and fleet composition selected by SPBS, and described in the previous section of this report, provides sufficient operating flexibility to avoid charging during peak times.

From a cost perspective, developing a charging schedule is important as the local utility, Central Maine Power, offers a special rate schedule for DC fast charging operation. The rate structure applies a variable pricing depending on the time of day that power is supplied. SPBS's current electricity rates are determined by Central Maine Power's 'MGS-S' rate table, as shown in Table 3. Under this rate table SPBS pays a flat "customer charge" monthly, regardless of usage. SPBS also pays a single distribution charge of $16.64 per kW for their single highest power draw (kW) that occurs during each month. This peak charge is not related to Central Maine Power's grid peaks and is local to SPBS's usage. Finally, SPBS is charged an 'energy delivery charge' of $0.001745 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 SPBS 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 quality for this rate, Central Maine Power requires that the customers like SPBS 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 'MGS-S' and the new 'B-DCFC' rate structures. The new rate structure would provide SPBS with a reduced monthly 'customer 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 SPBS to develop a charging plan which avoids charging buses during these hours.

Table 3 Utility Rates Structure Comparison

	Current MGS-S Rates	B-DCFC Rates
Customer Charge	$50.01 per month	$50.01 per month
Distribution Charge	$16.64 per non-coincidental peak kW (calculated monthly)	$4.39 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	$0.001745 per kWh	$0.001745 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 4. It can be seen in the figure that the optimized charging schedule assumes buses will be charged overnight (between 9 PM and 5 AM) or during midday hours. This charging schedule would also avoid charging during the Central Maine Power grid's 'coincidental peak' (between 3 PM and 7 PM), which would allow SPBS to avoid a monthly 'transmission charge', should SPBS adopt Central Maine Power's 'B-DCFC' rate schedule.

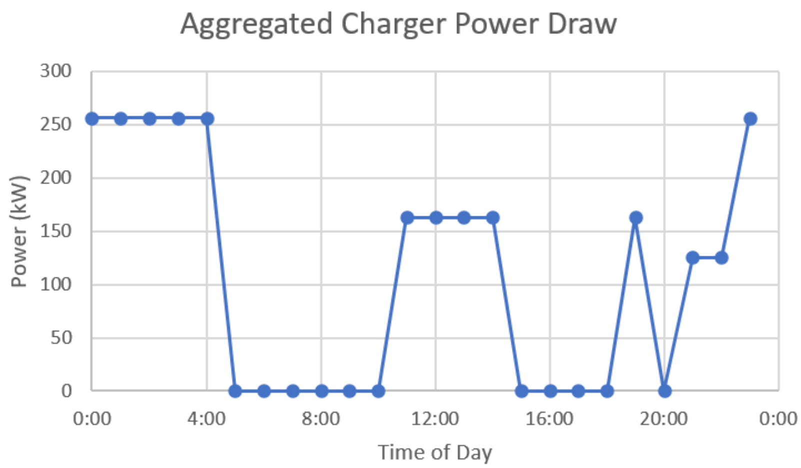

Figure 4 Proposed Charging Schedule for SPBS's Future Fleet

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

Daily kWh consumption = 2,233 kWh
Monthly Non-coincidental peak = 257 kW
Monthly coincidental peak = 0 kW

<u>Under Current MGS-S Rate Structure:</u>

$$Daily\ Charge = Daily\ kWh\ consumption\ \times (Energy\ Delivery\ Charge + Energy\ Cost)$$
$$= 2{,}233\ kWh\ \times (\$0.00175 + \$0.12954)$$
$$= \$293.17$$

$$Monthly\ Charge = (Monthly\ Non - coincidental\ Peak\ \times Distribution\ Charge) + (Monthly\ Non - coincidental\ Peak\ \times Transmission\ Charge)$$
$$= 257kW \times 16.64$$
$$= \$4{,}276.48$$

<u>Under New B-DCFC Structure:</u>

$$Daily\ Charge = Daily\ kWh\ consumption\ \times (Energy\ Delivery\ Charge + Energy\ Cost)$$
$$= 2233\ kWh\ \times (\$0.00175 + \$0.12954)$$
$$= \$293.17$$

$$Monthly\ Charge = (Monthly\ Non - coincidental\ Peak\ \times Distribution\ Charge) + (Monthly\ Coincidental\ Peak\ \times Transmission\ Charge)$$
$$= (257\ kW\ \times \$4.39) + (0\ kW \times \$19.35)$$
$$= \$1{,}128.23$$

As this estimate shows, the proposed 'B-DCFC' structure would save SPBS $3,148.25 per month. These savings are, again, achieved by avoiding charging during the coincidental peak between 3 PM and 7 PM, and the reduced monthly 'customer' and 'distribution' charges that are being proposed. If the charging schedule was adjusted to charge during the coincidental peak, it could lead to an increase of up to $4,972,95 per month from a 'transmission charge'. Therefore, it is critical that SPBS only plugs the buses in after 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 SPBS 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. Weekend and holiday calculation 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 South Portland Bus Service's operation.

8. Asset Selection, Fleet Management, and Transition Timeline

Section Summary

- Hatch recommends installing centralized chargers at the 929 Highland facility.
- Hatch recommends merging vehicle orders in adjacent years for greater economies of scale

With operational and charging plans established, it was then possible to develop procurement timelines for infrastructure and vehicles to support those plans. SPBS, like almost all transit agencies, acquires buses on a rolling schedule. This helps to keep a low average fleet age, maintain stakeholder competency with procurements and new vehicles, and minimize scheduling risks. However, this also yields a high number of small orders. For any bus procurement – and especially for a newer technology like electric buses – there are advantages to larger orders, such as lower cost and more efficient vendor support. SPBS 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. This is particularly true for the first order of electric buses, where the inevitable learning curves are best handled with a larger fleet rather than a single bus.

With respect to infrastructure procurements, SPBS's main facility at 929 Highland Ave. will eventually need to have enough chargers to accommodate all of SPBS's electric buses. The depot will need sufficient chargers for the eight electric buses prescribed in this transition plan by 2035. 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 of 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.

To serve the charging requirements described in the previous section for the proposed electric fleet, a centralized charging architecture is recommended for the 929 Highland facility. Centralized chargers will give SPBS 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. SPBS will require a minimum of 2 chargers with 3 dispensers each for a total of 6 dispensers to ensure there is a dedicated dispenser for each of its five electric buses needed for peak service. A dedicated dispenser per vehicle allows overnight charging without requiring a staff member to move buses or plug in chargers overnight. It is also recommended to have an extra dispenser as a spare for resiliency and for charging and maintaining spare vehicles, which the proposed configuration allows. Table 4 provides a summary of the proposed vehicle and infrastructure procurement schedule:

Table 4 Proposed Fleet and Charging System Transition Schedule

Year	Buses Procured	Infrastructure Procured	Buses Replaced
2026	Three 35' electric 450 kWh buses	Two 150kW centralized chargers (three dispensers each) + electrical upgrades	Two Gillig 35' buses (procured in 2014)
2027			
2028	Two 35' electric 450 kWh buses		Two Gillig 35' buses (procured in 2016)
2029			
2030			
2031			
2032			
2033			
2034	One 35' electric 450 kWh bus		One Gillig 35' bus (procured in 2022)
2035	Two 35' electric 450 kWh buses		Two Gillig 35' buses (procured in 2023)

9. Building Spatial Capacity

SPBS's main facilities are located at 929 Highland Ave. in South Portland, as shown in Figure 5. The primary structures on-site include the agency's only bus storage bay and a maintenance building.

Section Summary

- The existing 929 Highland facility should have sufficient space for chargers and fleet storage.
- In the potential future case that SPBS would like to install on-route chargers, Hatch recommends that the agency coordinate with other nearby agencies to select the most appropriate location.

Buses and other municipal vehicles are maintained and serviced in the maintenance building, shown in Figure 6. The maintenance building also has a storeroom which inventories parts for the fleets maintained at the facility. The maintenance building will likely provide ample space for maintenance of electric buses in the future, although a designated area should be established for maintaining and storing components specific to the new fleet, such as batteries. Furthermore, if the agency wishes to maintain components such as motors on-site, a back shop area will need to be established for this work.

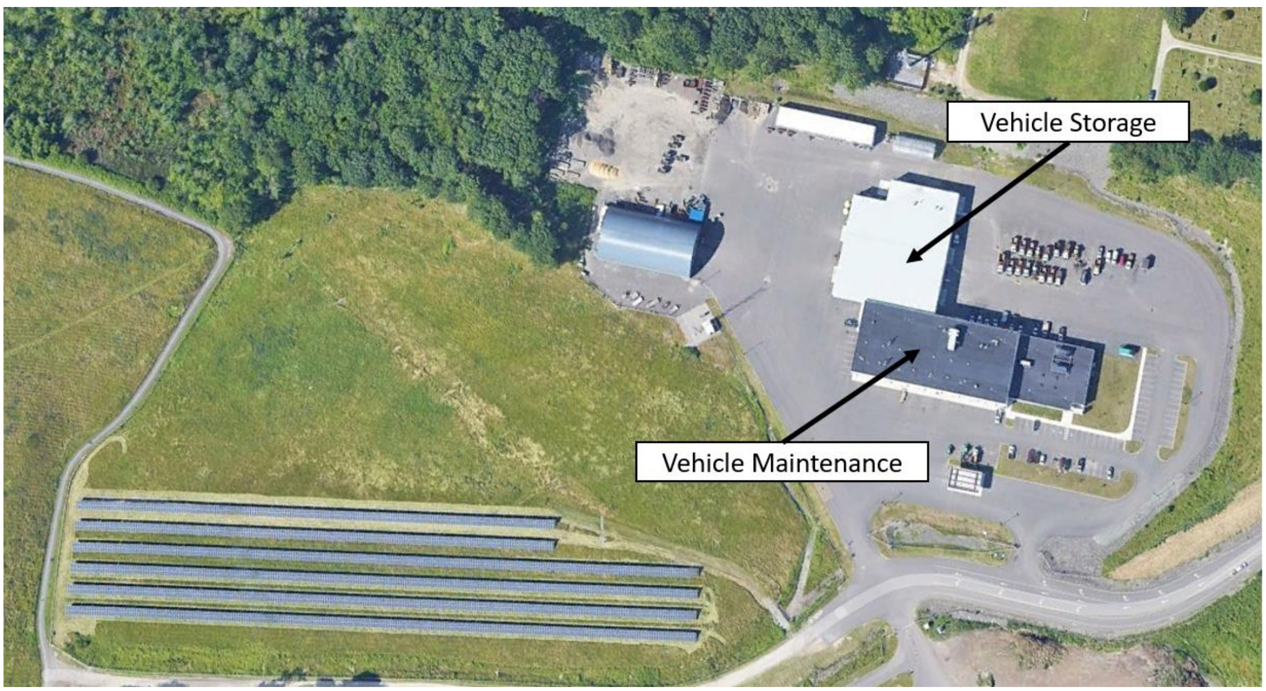

Figure 5 SPBS's Main Facilities (929 Highland Ave) (Source: Google Maps)

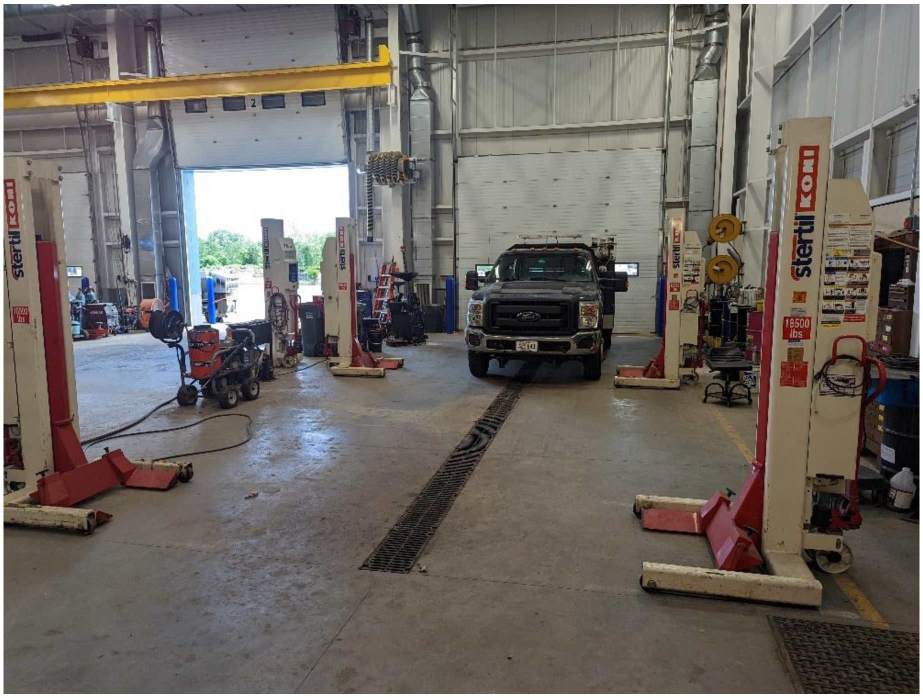

Figure 6 Main Vehicle Maintenance Area

Currently buses are parked indoors in a storage bay, which is paved and insulated, and could likely fit at least 12 buses at maximum capacity, as shown in Figure 7. The storage bay provides adequate space for storing the future battery electric bus fleet proposed in this report. Furthermore, the facility provides enough space to install the number of chargers and support systems for charging the future battery electric bus fleet.

Figure 7 Bus Storage Bays

SPBS operates through multiple transit hubs including Mill Creek (41 Thomas St.), Redbank (intersection of Macarthur Cir. E and Westbrook St.), the Maine Mall (364 Maine Mall Rd.), and downtown Portland (including Monument Square at 456 Congress St.). With respect to bus electrification, none of SPBS's current hubs are clear candidates for layover charging.

Mill Creek, shown in Figure 8, should have sufficient space to feasibly install on-route chargers and cabinets along Thomas St., and has an existing Transit Hub building which could accommodate the electrical infrastructure needed to support any future chargers. However, since it is a mid-route location, charging at Mill Creek would require dwell times that interrupt service.

Figure 8 Mill Creek Transit Hub (41 Thomas St.)

At Redbank, the only existing infrastructure is a bus shelter, as shown in Figure 9. The open land behind the shelter should provide sufficient space to install an on-route charging station should SPBS choose to do so at this location. However, Redbank is not served by Route 21 and, as with Mill Creek, charging here would delay passengers' journeys as it is a mid-route location. Furthermore, as a residential area, there may be resistance from the local community to installing a large pantograph system.

Figure 9 Redbank (Intersection of Macarthur Cir. E and Westbrook St.)

The Maine Mall, shown in Figure 10, is the most spacious of any of the potential charging locations, with acres of parking lots and ancillary areas available for potential charging infrastructure. It is also served by Metro and BSOOB, which would allow potential economies of scale through charger sharing. Further, it is a terminal, allowing charging to occur during layovers. However, it is not served by Route 21, reducing its effectiveness as a charging location for SPBS, and it is privately owned land, complicating any negotiations for charger installation and maintenance. Furthermore, malls have been declining nationwide, making installation of a charger at this location a risk in the event that the mall closes.

Figure 10 Maine Mall JC Penney Bus Stop (Source: Google Earth)

Downtown Portland is a regional transit hub, with service from Metro, BSOOB, RTP, and SPBS all converging at its center. Although SPBS does not directly serve the main public transit hub in the area – Metro's Elm Street Pulse – its routes stop one block away at Monument Square, shown in Figure 11 below. However, the agency does not own any property nearby and acquiring any would be difficult in such a highly congested area of Portland. Due to the large number of converging routes, the most intuitive place for charger installation would be Monument Square or another nearby location, but coordination with other transit agencies and city and state governments would be needed to find land for, build, and operate a charging station. It should be noted that recent planning studies for the Portland area have suggested that not all of SPBS's routes will continue to service the downtown area. The uncertainty regarding SPBS's downtown service makes the installation of an on-route charger at this location a risk.

Figure 11 Monument Square Transit Hub (456 Congress St.)

10. Electrical, Infrastructure, and Utility Capacity

Central Maine Power is the utility provider for the South Portland area. As part of the development of this transition plan, SPBS has been partnering with Central Maine Power to communicate its projected future utility requirements at the following location to support battery electric buses:

- Bus Storage/Maintenance Facility – 929 Highland Ave.
- Mill Creek – 41 Thomas St.
- Redbank – intersection of Macarthur Cir. E and Westbrook St.
- Maine Mall – 364 Maine Mall Rd.
- Monument Square – 456 Congress St.

Section Summary

- The existing service at the garage is likely sufficient to support the charging infrastructure
- Separately metered, or sub-metered, service will allow the agency to take advantage of the DCFC specific utility rate structure

The 929 Highland facility has a 480V 3-phase panel (No. BWHP) that currently feeds a pressure washer and a stepdown transformer for the storage building. This panel appears to have enough spare capacity for the required charging needs at the storage building, which are estimated to be 256kW during the overnight charging period when all vehicles are charging simultaneously. However, as discussed in Section 7 above, the utility requires the charging infrastructure to have its dedicated metering to qualify for the special EV charging "B-DCFC" rate structure. To avoid the expense of installing a new electrical service, SPBS can explore installation of a submeter for the charging infrastructure so that the consumption of DCFCs can be separately billed using the "B-DCFC" rate structure. SPBS will need to coordinate with the Central Maine Power to determine if this would be a possible solution.

If sub-metering the charging load from existing 480V 3-phase panel is not an option, the utility costs will be higher ($3,148.25) because SPBS will be charged according to the existing utility rate structures, unless a new dedicated 400kVA 480V 3-phase service is installed for the charging infrastructure.

Hatch has confirmed with Central Maine Power that it can accommodate a new 400kVA service at the 929 Highland facility for DC Fast Charging. Central Maine Power has provided initial estimate for the new transformers and service feed to be approximately $50,000.

For the potential on-route charging locations listed below, CMP has confirmed that a new transformer and service will be required (because there is no accessible infrastructure) which would cost approximately $50,000 for each site.

- Mill Creek
- Redbank
- Maine Mall
- Monument Square

11. Risk Mitigation and Resiliency

Section Summary

- As with any new technology, electric bus introduction carries the potential for risks that must be managed
- Significant power outages have occurred previously, so resiliency options must be considered
- The on-site generator option is considered most viable based on the frequency and duration of outages at the Highland Av. facility

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. Understanding these risks and the best ways to mitigate them is key to successful electric bus operation.

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 publicly 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. SPBS is in a good position in this regard, as it can draw lessons from BSOOB and Metro before placing its first electric bus order. Nevertheless, it will be prudent for SPBS to begin its transition to electric vehicles with an eye toward operating robustness in case of unexpected issues. Hatch recommends several strategies to maximize robustness:

+ Require 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 Metro, or another urban transit agency in Maine, that would let SPBS borrow spare buses in case of difficulties with its fleet
+ Retain diesel buses for at least two years after they are retired to ensure they can substitute for electric buses if any incidents or weather conditions require it

11b. Electrical Resiliency

Electricity supply and energy resilience are important considerations for SPBS when transitioning from diesel to electric bus fleets. As the revenue fleet is 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 5 summarizes the advantages and disadvantages of on-site storage and on-site generation systems. The most ideal solution for SPBS will need to be determined based on a cost benefit analysis.

Table 5 Comparison of the 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

SPBS currently has some resilient systems in place to support their future battery electric bus operations should there be an electrical service interruption. The agency has a backup generator at the 929 Highland facility, as shown in Figure 12. The unit is used to provide power for lighting and other facility needs during power outages but is not sized for vehicle charging in the future. Furthermore, the generator is not connected to the power systems at the 929 Highland facility where vehicles are likely to be charged. There is also a solar array which is connected to the electrical grid adjacent to the facility, as well as plans for additional solar capacity on the surrounding land.

Figure 12 Existing Diesel Generator Providing Power to the Depot During Outages

11.b.2. Outage Data and Resiliency Options

Hatch assessed potential resiliency options to work in conjunction with SPBS's existing systems. The first step in that assessment was to analyze the power outage data for the utility feeds that supply power SPBS's 929 Highland facility 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.

+ Bus Storage/Maintenance Facility – This facility has seen 16 outages in the last 5 years. Out of these, most outages lasted under two hours. However, in six of the instances, the outages were long enough to be a cause for concern for operation of electric vehicles. These six outages lasted for approximately 24.5, 10.5, 6, 5, 5, and 3.5 hours.
+ Mill Creek – This location had thirteen outages over the time period analyzed. Many of these were of significant duration, with the longest taking 23 hours to resolve. There were outages of 7, 6, 5, 4, 2, and 2 hour duration as well.
+ Redbank – There were five outages at this site. Most of the outages lasted for approximately an hour.
+ Maine Mall – There were nine outages at this site, of which four occurred on the same day. Though most of these outages were of very short duration, four of them lasted for 6, 5.5, 3, and 3 hours.
+ Monument Square – No outages are reported for this site by the utility in the last five years.

The outage data was compared with operational requirements to determine the appropriate sizing of the resilient systems. SPBS specified that the resiliency system should be sufficient to support the operation of five electric buses in the event of outages. The resiliency system requirements are determined below based on the historic outage data summarized above and the fleet operation requirements as indicated by SPBS.

The battery storage requirements for the 929 Highland facility were calculated assuming historical worst case outage duration of 24.5 hours. The total energy requirement to charge the entire fleet during that outage period would be 2,233 kWh. 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 2.8 MWh. Alternatively, SPBS could choose to install a generator for vehicle charging. The power requirement for an additional generator at the 929 Highland facility was determined by the power draw of the minimum number of chargers required to simultaneously support the five vehicles. Assuming SPBS purchases the two centralized chargers with three dispensers each, as specified in this report, two chargers would be required to support five buses. Assuming that all chargers SPBS would purchase would be rated at a minimum 150kW, would have an efficiency of 90%, and a 20% space capacity, the resulting on-site generation capacity required would be approximately 420 kVA.

Hatch next generated cost estimates associated with the four resiliency system options for the site. Table 6 summarizes the requirement for the first two resiliency options for each site and the associated 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 lifecycle costs in Section 14.

Table 6 Resiliency Options for Worst Case Outage Scenarios

	Size	Capital Cost
Option 1 On-site Battery Storage	2.8 MWh	$1.75M
Option 2 On-site Diesel Generation	420 kVA	$250,000

The above analysis and corresponding options are based on the historic outage data, and on maintaining full SPBS operation during the outage. Since outages like these occur very rarely, and reduced service may be acceptable, the above resiliency options may be oversized for most use cases resulting in a poor return on the capital investments.

11.b.3. Solar Power

As mentioned previously, solar does not reliably provide enough instantaneous power to provide full operational resilience. 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 the current solar array systems at the 929 Highland facility is primarily to offset energy from grid and reduce utility costs or to earn revenue for SPBS by selling the excess electricity back to the gird. The existing on-site solar systems at the 929 Highland facility were reviewed to determine the portion of the energy produced by the solar array that could be potentially stored to provide resilience.

According to the ReVision Energy solar feasibility assessment from October 2019, the estimated solar system size at 929 Highland facility is 498.4 kW. On a sunny day in Portland, the number of hours of sunlight averages around 6.6 hours. Based on this assumption, the solar production on sunny days is estimated to be 3.3 MWh. 40% of this production is allocated to public works, 30% to parks and the remaining 30% is available to buses, which means that the estimated daily production on an average sunny day available for bus use is roughly 1 MWh. As discussed previously, the bus operation would need 2.8 MWh of power during a 24-hour outage.

In addition, there are other challenges because of which the solar power generation is not recommended as a primary resiliency system. For example, the power outages are 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. Secondly, for the days when solar production is available, an on-site battery storage system is necessary for storing energy produced during the daytime for use during overnight charging. With the long durations of outages that are historically experienced at the 929 Highland facility, the required on-site battery storage system is very large making it a very costly option compared to an on-site generator.

A combination of solar and energy storage system can provide limited support to the SPBS operation during various types of outages. Moreover, an on-site energy storage system can also help with savings due to a smaller utility feed requirement and lowering non-coincidental peak for the site.

A more detailed study should be conducted to determine the feasibly of integrating battery energy system into SPBS operation so the benefits of the existing and planned future arrays at 929 Highland facility can be maximized.

12. Conceptual Infrastructure Design

12a. Conceptual Layouts

To assist SPBS with visualizing the required infrastructure transition, conceptual plans were next developed based on the previous information established in this report. Hatch recommends that SPBS determine the costs of the following:

- Installing new ductwork from the building to the proposed cabinet location, and from there to the charger location.
- Upgrading the fire suppression system in consideration of housing battery and charging systems in the depot (Per standards UL9540, NFPA 70 and 230).
- Expanding the server rack to support charge management systems.

Based on these recommendations, a conceptual infrastructure layout was developed for SPBS's 929 Highland facility, as shown in Figure 13.

Section Summary

- Hatch recommends installing wall-mounted chargers in the bus storage area, with supporting equipment nearby to the north

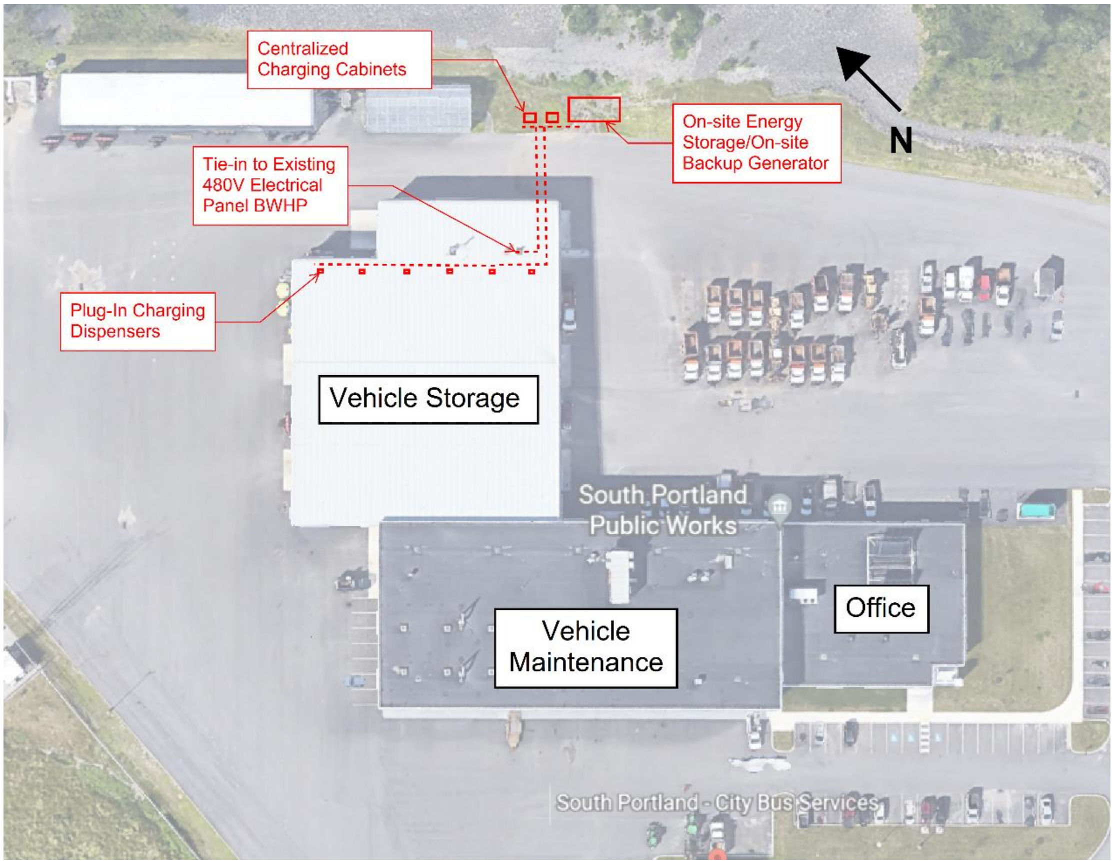

Figure 13 929 Highland Facility Infrastructure Conceptual Layout (Source: Google Maps)

Given the age of the facility and presence of spare electrical capacity, it is logical to connect to the existing electrical panel, rather than installing a new independent service.

At the request of SPBS, a conceptual infrastructure layout was developed for potential future on-route charging at Redbank, as shown in Figure 14.

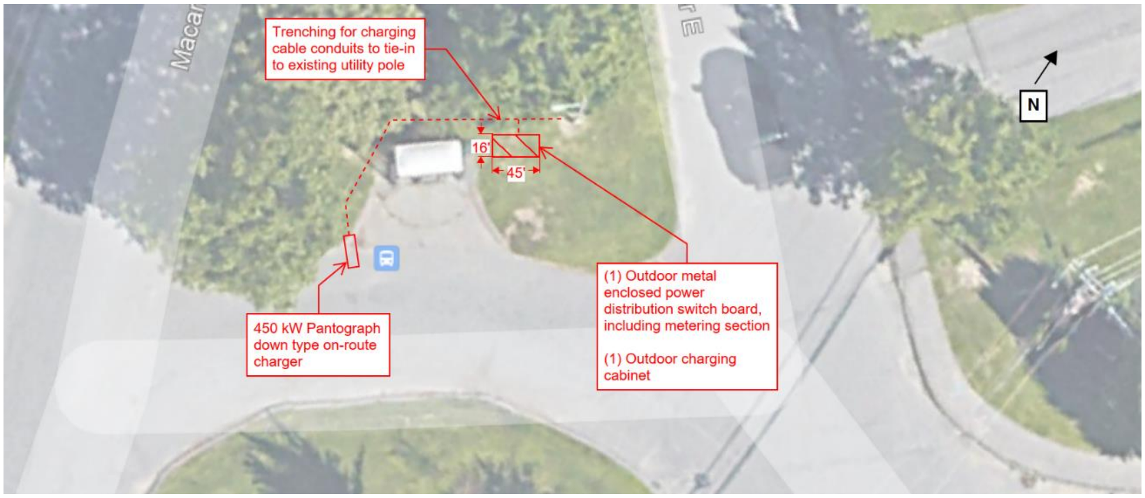

Figure 14 Redbank Charger Location Concept (Source: Google Maps)

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 SPBS's risk is partially mitigated because of the comparatively small fleet size, Hatch still recommends that SPBS 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 or the garage structure. 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, or that responding staff be trained to move unaffected buses out of the way where possible. Each of these requires specific consideration with respect to SPBS's. Hatch recommends that SPBS commission a fire safety study as part of detailed design work for the charger installation to consider these factors.

13. Policy Considerations and Resource Analysis

SPBS's current operating budget is roughly $1.6 million per year. The agency's funding sources are summarized in Figure 15. As can be seen in the figure, SPBS'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

Section Summary

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

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.

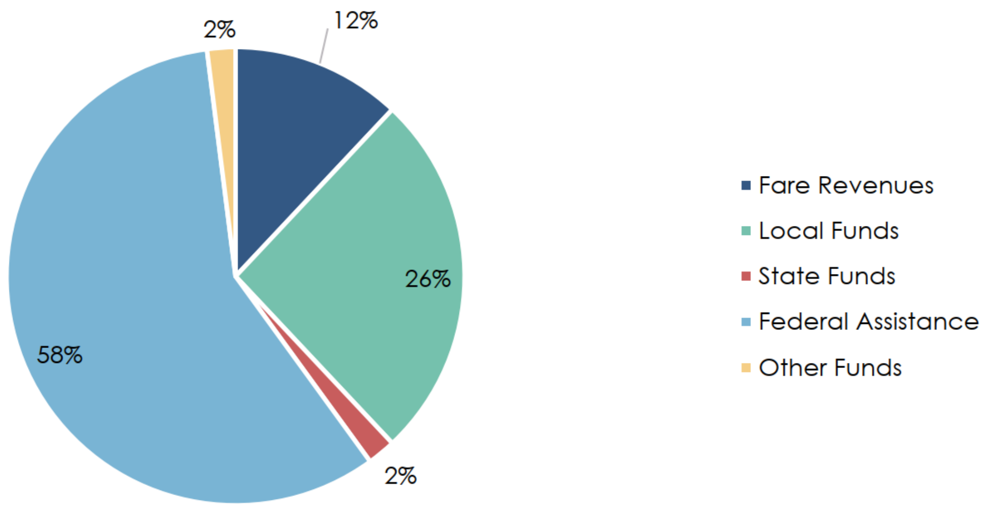

Figure 15 Current Agency Funding Summary (Source: Maine DOT)

As the agency transitions to battery electric technology, additional policies and resources will become applicable to SPBS. Table 7 provides a summary of current policies, resources and legislation that are relevant to SPBS's fleet electrification transition.

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 SPBS with guaranteed funding sources. Therefore, this analysis assumes that SPBS will only receive funding through the largest grant programs that provide the highest likelihood of issuance to the agency. Specifically, this analysis assumed that SPBS 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 7 Policy and Resources Available to SPBS

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.
The U.S. Department of Transportation's Low or No Emission Grant Program	Financial assistance is available to local and state government entities for the purchase or lease of low-emission or zero-emission transit buses, in addition to the acquisition, construction, or lease of supporting facilities. Eligible vehicles must be designated for public transportation use and significantly reduce energy consumption or harmful emissions compared to a comparable standard or low emission vehicle.	Can be used for the procurement of hybrid or electric buses and infrastructure
The U.S. Department of Transportation's Urbanized Area Formula Grants - 5307	The Urbanized Area Formula Funding program (49 U.S.C. 5307) makes federal resources available to urbanized areas and to governors for transit capital and operating assistance in urbanized areas and for transportation-related planning. An urbanized area is an incorporated area with a population of 50,000 or more that is designated as such by the U.S. Department of Commerce, Bureau of the Census.	This is one of the primary grant sources currently used by transit agencies to procure busses and to build/renovate facilities.
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 busses and to build/renovate facilities.

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.
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 at the bus storage facility.
Energy Storage System Research, Development, and Deployment Program	The U.S. Department of Energy (DOE) must establish an Energy Storage System Research, Development, and Deployment Program. The initial program focus is to further the research, development, and deployment of short- and long-duration large-scale energy storage systems, including, but not limited to, distributed energy storage technologies and transportation energy storage technologies.	Can be used to fund energy storage systems for the agency.
The U.S. Economic Development Administration's Innovative Workforce Development Grant	The U.S. Economic Development Administration's (EDA) STEM Talent Challenge aims to build science, technology, engineering, and mathematics (STEM) talent training systems to strengthen regional innovation economies through projects that use work-based learning models to expand regional STEM-capable workforce capacity and build the workforce of tomorrow. This program offers competitive grants to organizations that create and implement STEM talent development strategies to support opportunities in high-growth potential sectors in the United States.	Can be used to fund EV training programs.
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.

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 (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.
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
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.
Efficiency Maine Electric Vehicle Initiatives	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.

14. Cost Analysis

Hatch calculated the life cycle cost (LCC) of the proposed transition strategy and compared it to maintaining SPBS's current 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 service levels analyzed above and scaled to account for weekends and holidays, include initial capital as well as operations and maintenance costs of the vehicles and supporting infrastructure for diesel and battery electric buses. Table 8 outlines the LCC model components, organized by basic cost elements, for diesel and battery electric bus technologies.

Section Summary

- Bus electrification will save SPBS money over the long term, as electric vehicles cost less to maintain and fuel
- Upfront capital costs increase by approximately 47% and annual operating cost will decrease by approximately 7%, yielding a net 2% increase in total cost of ownership

Table 8: 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
		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, SPBS 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 FTA guidelines.
- 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 existing fueling infrastructure will not require replacement.

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

Table 9 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
DC Fast Charger – Plug-in Garage (de-centralized unit and 3 dispensers)	$270,000

Expense	Estimated Cost (2022 $'s)
Diesel and hybrid bus maintenance	$1.46 / mile
Electric bus maintenance	$1.10 / mile
Operator salary, benefits, overhead	$31.66 / hour
Diesel fuel	$2.75 / 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 (2035), 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 10 and Figure 16 summarize the NPV for both technologies by cost category.

Table 10: Net Present Value Summary

Category	Diesel Baseline	Future Fleet	Cost Differential (Future Fleet vs. Baseline)
Vehicle Capital Costs	$1,245,835	$1,742,758	+47%
Infrastructure Capital Costs	$0	$92,409	
Vehicle Maintenance Costs	$2,076,113	$1,629,462	-7%
Infrastructure Maintenance Costs	$0	$22,924	
Operational Cost	$4,175,593	$4,174,414	
Total Life Cycle Cost	**$7,497,542**	**$7,661,967**	**+2%**

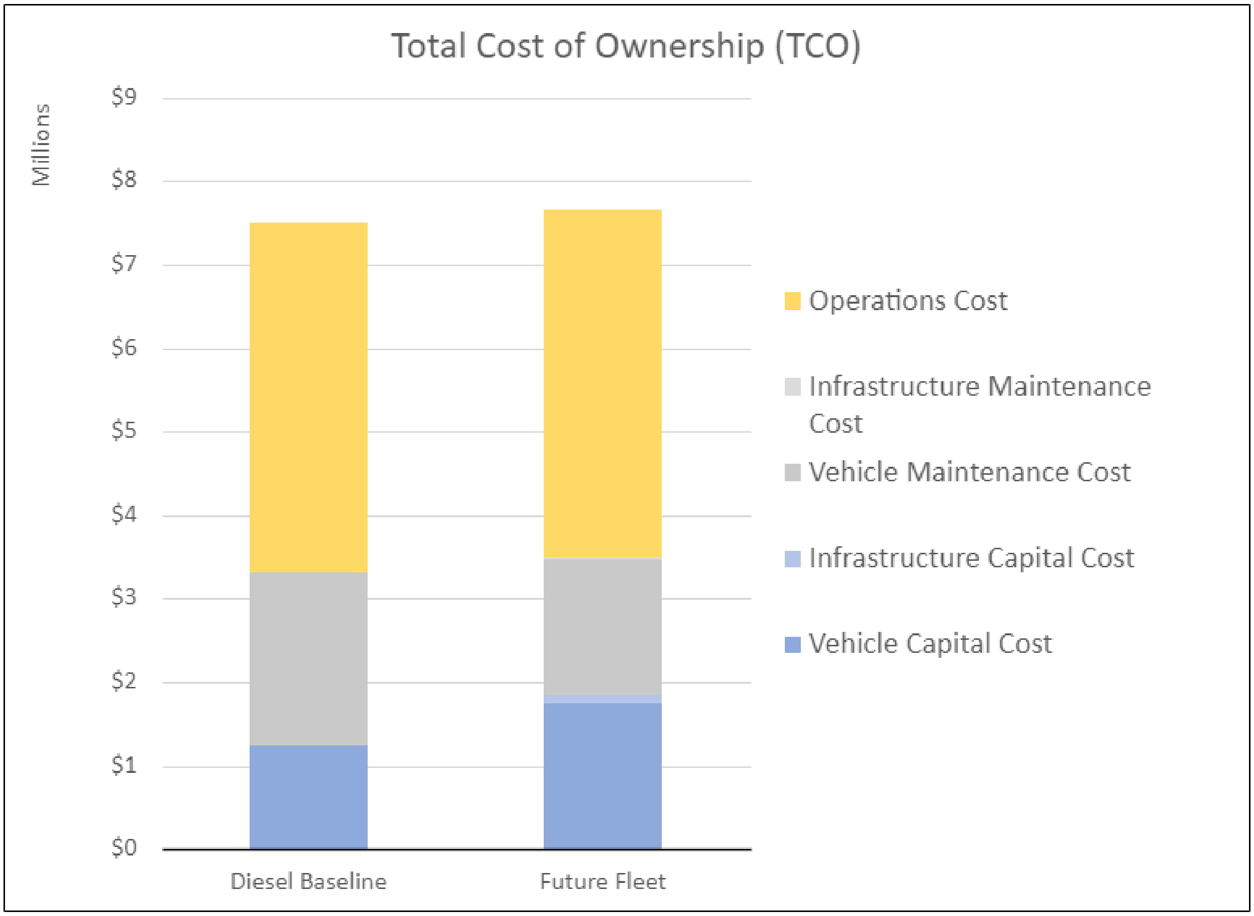

Figure 16 Life Cycle Cost Comparison

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 in the garage, the bulk of the extra capital spending is on the vehicles themselves. Electric buses are much simpler mechanically but command a cost premium due to their large battery systems. These factors yield a 47% 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 7% 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 almost entirely outweigh the initial extra capital spending, yielding a net-present-value increased cost of approximately 2%.

The proposed fleet transition requires initial capital spending to reduce operating 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 47% 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 SPBS 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 SPBS to change the speed of its electrification transition or change the desired end-state altogether.

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

15. Emissions Impacts

One of the motivations behind SPBS'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 SPBS.

Hatch calculated the anticipated emissions reductions from SPBS'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:

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 77-87%

+ Tank-to-wheel
+ Well-to-wheel
+ Grid

Tank-to-wheel emission impact considers the emissions reduction in the communities, where the buses are operated. As a tank-to-wheel baseline, the ‘tailpipe’ emissions associated with SPBS’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. This is comparable to, and assumes gradual fuel economy improvement over, SPBS’s currently achieved 4.8 miles per gallon.

The tank-to-wheel emission baseline was compared against the battery-electric vehicles in SPBS’s transition plan. 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 emission estimate used industry averages for the well-to-wheel emissions associated with the delivery of diesel fuel to SPBS. 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 emission 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 EPA and EIA data average grid mix data 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 emission 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 11 and Figure 17 summarize the results of the emissions calculations. These results demonstrate that the transition plan will achieve 77% reduction emissions assuming the grid mix that existed in 2020, or a 87% 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, SPBS’s transition plan will achieve a reduction in emissions in excess of the 45% goal established by the Governor’s office.

Table 11 CO2 Emissions Estimate Results

Scenario	Well-to-Tank (kg)	Tank-to-Wheel (kg)	Grid (kg)	Total (kg)	Reduction over Baseline
Diesel Baseline	281,217	484,012	---	765,229	---
Future Fleet (Assuming 2020 grid mix)	21,411	36,852	121,319	179,582	77%
Future Fleet (Assuming 2030 grid mix)	21,411	36,852	40,035	98,298	87%

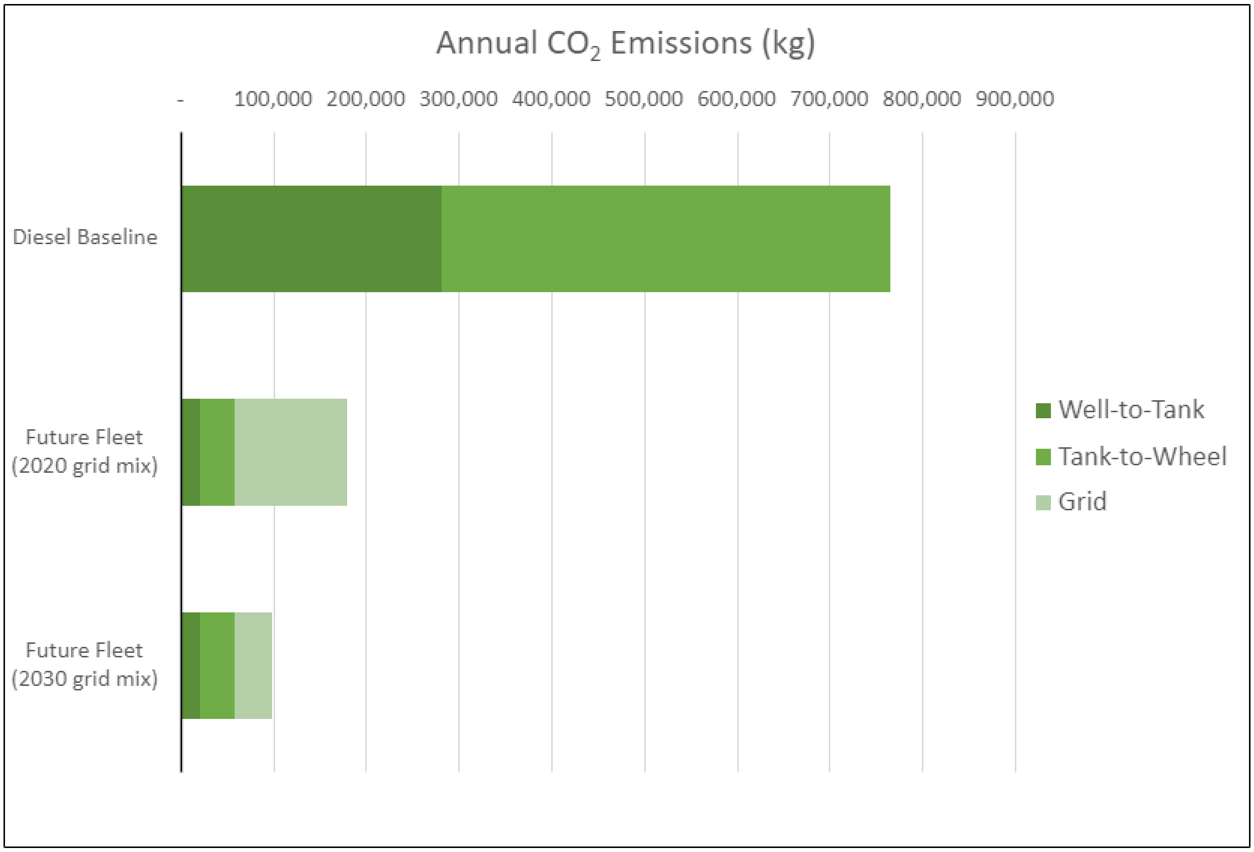

Figure 17 Graph of CO2 Emissions Estimate Results

Should SPBS 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 on-site energy storage (potentially including spare buses) for "peak shaving" – feeding power back to the grid during periods of high demand.

16. Workforce Assessment

SPBS's staff currently operate a fleet primarily composed of diesel vehicles. As a result, the staff have skill gaps related to electric vehicle and charging infrastructure technologies that will be operated in the future. To ensure that the existing workforce is retained and able to successfully operate South Portland's future system a workforce assessment was conducted. Table 12 details skills gaps for the workforce groups within the agency and outlines training requirements to properly prepare the staff for future operations.

Section Summary

- Staff and stakeholder training will be critical to BEB success
- Hatch recommends partnering with local colleges and other transit agencies to share skills

Table 12 Workforce Skill Gaps and Required Training

Workforce Group	Skill Gaps and Required 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 SPBS consider the following training strategies:

+ Add requirements to vehicle and infrastructure specifications to require contractors to deliver training programs to meet identified skill gaps as part of capital projects.
+ Coordinate with other peer transit agencies, especially within the state of Maine, to transfer 'lessons learned'. Send staff to transit agency properties that have already deployed battery electric buses to learn about the 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.

It is recommended that SPBS begin training staff and other stakeholders on these technologies ahead of the delivery of the first vehicles and charging systems.

17. Alternative Transition Scenarios

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

As part of this study, SPBS 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, the use of layover chargers, and different operational plans. Through discussions, however, SPBS elected to proceed with the transition plan presented in this report. Details on the alternative plans are presented in Appendix B, D, and E. Should South Portland'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 SPBS 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 facilitating this study SPBS 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, SPBS will be able to reduce emissions, noise, operating cost, and other negative factors associated with diesel operations, while complying with the Governor's Roadmap and operating sustainably for years to come.

For SPBS 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. In particular, consider revising the procurement schedule to receive multiple electric buses as part of the first order in 2026.
  - Before or as part of the first electric bus order, conduct a pilot program with a small number of electric buses to test the technology and validate the results of the analyses presented in this transition plan. During this pilot program, operate the electric buses on all routes.

  - Require 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.
  - Develop specifications for battery electric buses.
  - Reach a "mutual aid" agreement with Metro, or another urban transit agency in Maine, that would let SPBS borrow spare buses in case of difficulties with its fleet.
  - Retain diesel buses for at least two years after they are retired to ensure they can substitute for electric buses if any incidents or weather conditions require it.
- For the infrastructure at 929 Highland Avenue, consider the following:
  - Installing new ductwork from the building to the proposed cabinet location, and from there to the charger location.
  - Upgrading the fire suppression system in consideration of housing battery and charging systems in the depot (Per standards UL9540, NFPA 70 and 230).
  - Expanding the server rack to support charge management systems.
  - Determine battery storage system requirements that would complement existing solar arrays and coordinate with municipality to ascertain the feasibility of diverting some solar power into battery storage for resilience. Also, consider generation options for resiliency against longer outages.
  - Develop specifications for required infrastructure.
- For other components of the transition:
  - Commence training programs for all SPBS staff, as described in Section 16 of this report. Coordinate transition efforts with peer transit agencies, Central Maine Power, and Maine DOT.
  - Continually monitor utility structures and peak charge rates and adjust charging schedules accordingly.
  - Develop a funding strategy to account for the 47% 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 Simulations Presentation
C. Utility Outage Data
D. Life Cycle Costing Models
E. Alternative Transition Strategy Presentation