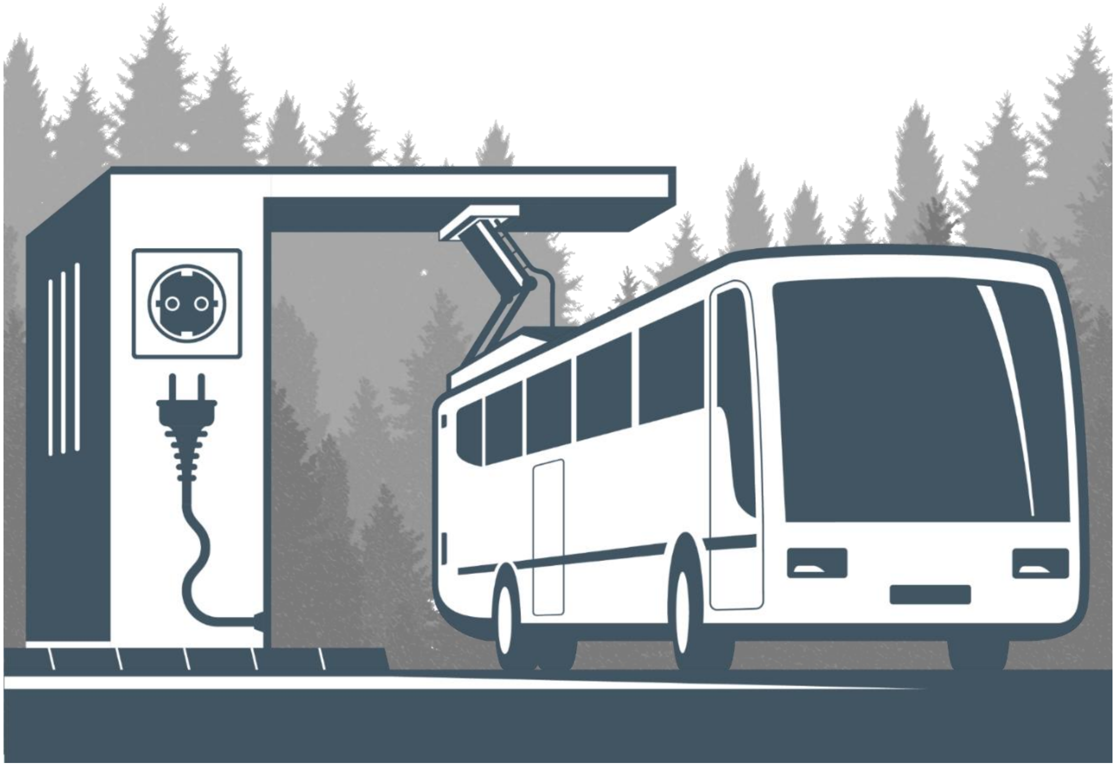
MaineDOT Low-No Grant Application

Attachment B

Transition Plans



Bus Electrification Transition Plan for Bangor Community Connector

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1. Executive Summary

Bangor Community Connector (Bangor CC) is currently considering transitioning its bus fleet to battery electric and hybrid 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, Bangor CC has expressed a preference for fleet and infrastructure asset configurations that will provide a feasible transition to battery electric and hybrid drivetrain technologies while supporting the agency's operational requirements. The selected configuration transitions the agency's current 22 diesel buses to a mixed fleet of 14 battery electric and 8 hybrid buses. To support the battery electric buses, the agency also plans to procure, install and commission four charging systems that will have the capacity to support charging of up to 12 buses simultaneously. The maintenance facility and utilities will also require upgrades to properly charge and maintain the proposed bus fleet.

One of the primary motivations behind Bangor CC's transition to battery electric and hybrid 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 hybrid and battery electric fleet. The results of this emissions projection estimate that the new fleet will provide up to a 60% reduction in emissions compared to Bangor CC's existing diesel operations.

The conclusion of the analysis is that hybrid and battery electric buses can feasibly support Bangor CC's operations. Furthermore, these drivetrain technologies offer the potential for the agency to greatly reduce emissions, though significant upfront capital spending will be required. Therefore, Bangor CC 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, Bangor Community Connector (Bangor CC), 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 Bangor CC's future route plans, vehicle technology options, building electrical capacity, emissions impacts, resiliency, and financial implications.

3. Existing Conditions

Bangor CC is a small transit agency providing service to the Bangor Maine area. The agency currently owns and operates a fleet of 22 transit buses, all of which are diesel powered:

Section Summary

- Bangor CC operates 11 routes with a 22-bus fleet, all of which are diesel powered
- The hub of the system is at Pickering Square in downtown Bangor

Table 1 Current Vehicle Roster

Bus Type/Roster Number	Fuel Efficiency (MPG)	Number of Buses	Procurement Date/Age
GILLIG *35'/1049-1050*	5	2	2011
GILLIG *35'/1048*	5	1	2011
GILLIG *35'/1046-1047*	5	2	2011
GILLIG 30'*/1743-1744*	5	2	2017
GILLIG 30'*/1858-1859*	5	2	2018
GILLIG 30'*/1960-1962, 1985-1989*	5	8	2019
GILLIG 35'*/2102-2105*	5	4	2021
GILLIG 30'*/2106*	5	1	2021

Though a shift to fixed stops is planned in the near future, Community Connector currently operates its routes with flag stops. This lets passengers be picked up and dropped off at any safe location along the route. Except as noted below, buses generally remain on the same route all day. The routes are shown in Figure 1 and described below (as adapted from the Bangor Area Comprehensive Transportation System (BACTS)). Although Bangor CC temporarily discontinued Saturday service from June 2022 until further notice due to an on-going driver shortage, these descriptions (and the analyses in this report) include the previously scheduled Saturday service to reflect typical operating conditions.

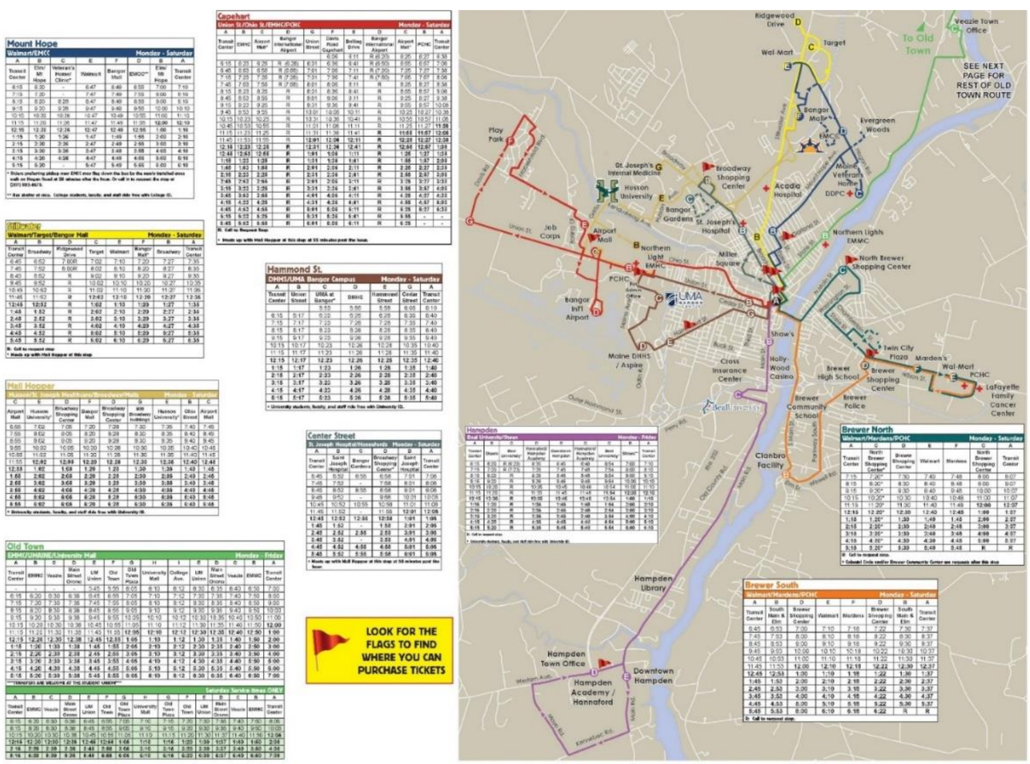


Figure 1 Bangor CC Route Map

1. The Hammond Street Route serves the Union Street-Hammond Street area by a one-way loop via Union Street, Vermont Avenue, Maine Avenue, Texas Avenue, Hammond Street, Cedar Street, and Main Street. The service is provided by a single bus operating on 60-minute headways on weekdays and Saturdays. This vehicle interlines with the Center Street Route. This route begins on weekdays and Saturdays at 5:53 a.m. at University College and ends at 5:40 p.m. at Pickering Square.
2. The Capehart Route serves the Ohio Street-Union Street Corridor, including Bangor International Airport and the Capehart housing complexes via Ohio Street and Union Street. The service is provided by two buses, giving 30-minute headways, on weekdays and Saturdays. This route begins at 6:06 a.m. at Capehart and ends at 6:25 p.m. at the Airport Mall.
3. The Center Street Route serves the Center Street Corridor via Center Street, Broadway, and Kenduskeag Avenue. The service is provided by a single bus operating on 60-minute headways on weekdays and Saturdays. This vehicle interlines with the Hammond Street bus. This route begins at 6:45 a.m. at Pickering Square and ends at 6:08 p.m. at Pickering Square.
4. The Mount Hope Route serves the area of Mount Hope Avenue, Hogan Road, Eastern Maine Community College and the Bangor Mall. The service is provided by one bus, giving 60-minute headways on weekdays and Saturdays. This route begins at 6:15 a.m. at Pickering Square and ends at 6:10 p.m. at Pickering Square.
5. The Stillwater Avenue Route serves the area of Broadway, Stillwater Avenue, the Bangor Mall and Ridgewood Drive. The service is provided by one bus, giving 60-minute headways on weekdays and Saturdays. This route begins at 6:45 a.m. at Pickering Square and ends at 6:35 p.m. at Pickering Square.
6. The Mall Hopper Route provides a direct link between the Bangor Mall, the Airport Mall, and the Broadway Shopping Center. Service begins and ends at the Airport Mall but does not directly link to the downtown terminal. There are three routes that connect with the Mall Hopper at various locations: the Capehart route at Airport Mall, the Center Street route at Broadway Shopping Center, and the Stillwater Route at the Bangor Mall, giving 60-minute headways on weekdays and Saturdays. This route begins at 6:55 a.m. at the Airport Mall and ends at 6:45 p.m. at the Airport Mall.
7. The Brewer North Route serves the more urbanized areas of the City of Brewer via North Main Street, Wilson Street, Parkway North, and State Street. The service is provided by one bus giving 60-minute headways on weekdays and Saturdays. This route begins at 7:15 a.m. at Pickering Square and ends at 5:48 p.m. at Mardens. On request, the bus will also make a stop at North Brewer and/or at the transit center at Pickering Square following the last stop.
8. The Brewer South Route serves the more urbanized areas of the City of Brewer, via South Main Street, Parkway South, and Wilson Street. The service is provided by one

bus, giving 60-minute headways on weekdays and Saturdays. This route begins at 6:45 a.m. at Pickering Square and ends at 6:22 p.m. at the Brewer Shopping Center. On request, the bus will also make a stop at South Main and Elm and/or the transit center at Pickering Square following the last stop.

9. The VOOT (Veazie, Orono, Old Town) Route serves the U.S. Route 2 corridor to Orono, and the U.S. Route 2/ Stillwater Avenue/ College Avenue loop through Old Town and Orono. The service is provided by two buses on 60-minute headways on weekdays and by a single bus on 2-hour headways on Saturdays. This route begins weekdays at 5:45 a.m. at the University of Maine Union and ends at 7:00 p.m. at Pickering Square, and Saturdays begins at 6:15 a.m. at Pickering Square and ends at 7:05 p.m. at Pickering Square.
10. The Hampden Route serves the U.S. Route 1A corridor from Bangor to Hampden. The route is served by a single bus operating on 60-minute headways on weekdays. This route begins at 6:15 a.m. at Pickering Square and ends at 6:10 p.m. at Pickering Square. There is no service on Saturdays.
11. The Black Bear Orono Express Shuttle Route operates during the academic year and serves the University of Maine campus and areas of Mill Street and Orchard Trails housing. The route is served by a single bus operating on 30-minute headways on weekdays starting at 7:20 a.m. at Mill Street and ending at 5:50 p.m. at Mill Street. The Black Bear Orono Express Shuttle is funded jointly by the Town of Orono and the University of Maine and is offered to riders fare-free.

Each route operates as a single self-contained block, except for Hammond and Center Street (which share a bus), and Old Town and Capehart (which are currently assigned two buses each). These block schedules were introduced recently as a result of COVID-related driver shortages. The previous schedule included separate buses on the Hammond and Center Street routes, and three buses on the Capehart route. Although it is Bangor CC's aim to revert to the previous schedule once the current driver shortage abates, for consistency this analysis considered the current schedule.

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, Bangor CC's revenue service fleet is composed of 30' and 35' transit buses. In the hybrid and battery electric vehicle space, there is a variety of possible vehicles for Bangor CC 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 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. 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

Section Summary

- Centralized chargers are recommended, particularly for the bus barn, for maximum scalability and flexibility in charging speed

A decentralized charger is a self-contained unit that allows charging one vehicle per charger. The charging dispenser is typically built into the charging cabinet. These are typically suited to small-scale charging applications. 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. These are best applied to large charging stations, such as those that would be installed in a bus depot for overnight charging. Similarly, centralized systems can support high-powered pantograph chargers for layover charging at a location like Pickering Square. Examples of both configurations are shown in Figure 2.

Figure 2 Example Charging Systems:

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

Right – Overhead Pantograph Charger and 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 Bangor CC's future plug style charging systems would have 150 kW of power while any future pantograph chargers would have 450 kW of power. These charging system power values have become standard to the transit bus industry.

6. Route Planning

Bangor CC'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 Bangor CC'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

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
- Electrification of some blocks, with conversion of others to hybrid vehicles, is recommended to balance vehicle electrification with operational and infrastructure constraints

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. Even when diesel heaters are installed, as was assumed in this study, icy 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 Bangor CC'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 Bangor CC'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 Bangor CC'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 Bangor CC's operations, ranging from slower-speed in-city routes to higher-speed routes to the suburbs and neighboring cities. 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 Bangor CC-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 194.4 kWh and 388.8 kWh by 2032. The year 2032 was selected as a "litmus test" because it is towards the end of the fleet transition schedule specified in Section 8, ensuring that all feasibly electrifiable routes are accounted for without requiring future vehicle procurements to be delayed while battery technology catches up. Clearly, if battery electric bus technology advances faster than anticipated, or if the existing fleet proves reliable and can outlast its 14-year lifespan, a greater proportion of blocks will be feasible for electrification. Conversely, if technology develops more slowly or the existing fleet requires replacement sooner, fewer blocks will be electrifiable.

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 2032 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 Block

Block	Mileage	'Short-Range' Bus		'Long-Range' Bus	
		kWh Req'd	Mileage Shortage/Excess	kWh Req'd	Mileage Shortage/Excess
Black Bear	138.7	315.2	-51.6	332.9	+22.6
Brewer North	110.2	256.8	-26.7	271.1	+47.7
Brewer South	156.1	364.3	-72.6	384.5	+1.7
Capehart 1	198.1	368.4	-93.5	390.2	-0.7
Capehart 2	189.3	352.0	-84.7	372.8	+8.1
Hammond/Center	136.5	318.2	-52.9	335.9	+21.4
Hampden	212.3	394.9	-107.8	418.3	-14.9
Mall Hopper	180.4	392.6	-90.9	416.0	-11.8
Mount Hope	150.4	349.7	-66.4	369.2	+7.9
Old Town 1	215.0	399.8	-110.4	423.5	-17.6
Old Town 2	185.9	345.7	-81.3	366.1	+11.5
Stillwater	134.7	312.9	-50.7	330.4	+23.7

6b. Operational Alternatives

As shown in Table 2, no blocks can be accommodated with 'short-range' buses, and four blocks cannot be accommodated even with 'long-range' buses. To address the operational shortcomings of the battery electric buses a few options were considered. One option is to recharge vehicles over the course of the day. This would take one of two forms. In the first case, buses would deadhead from the downtown transit center to the garage, recharge, and then deadhead back to the transit center to reenter service (perhaps on a different route than the one they operated previously). Although this midday recharging would allow less expensive short-range buses to be purchased, one potential disadvantage of this approach is the additional mileage and operator hours that the new deadheading would introduce. Another option is for buses to recharge directly at the transit center, using layover chargers that would be installed there. This does not require deadheading as the first option does, but still requires additional layover time for charging.

In both cases, to ensure efficient 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 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 day, with meal and charging breaks happening at the same time). Careful selection of route interlines, and selection of route departure times from the transit center (i.e. which routes depart at 15 minutes past the hour, and which at 45), can help balance layover durations with the time required for charging. If the first option of garage-based recharging is selected, the Hammond Street route could be modified to start/end at the garage to allow buses to be rotated in and out of service without deadheading. A bus low on battery would operate the outbound trip and be replaced with a fresh bus, which would operate the inbound trip before resuming service on another route. In the meantime, another bus low on battery would operate the next outbound trip. Due to the operational and infrastructure complexities of these options, they are currently not preferred by Bangor CC.

The operationally simpler option, and the plan that is preferred by Bangor CC stakeholders, is to maintain the schedule in its present state. Bus blocks that can be operated with ‘long-range’ electric buses are electrified, shown in green in Table 2, and those that cannot are serviced with hybrid vehicles. This allows all buses to operate for the entirety of the day with all charging occurring overnight. In the proposed plan using the current (COVID-era) schedule a peak service requirement of 12 buses will be operated with eight electric buses and four hybrids. The hybrids will run on the Mall Hopper and Hampden routes, as well as one of the blocks of the Capehart and Old Town routes. The electric buses can be deployed across the rest of the system, with the least demanding (and therefore the best testbed) routes being Brewer North and Stillwater. A fleet size of 22 (the same as pre-COVID) allows for pre-COVID service levels and future expansion with some leeway for route extensions. The above proportion of electrics to hybrids will scale to fourteen electric buses and eight hybrid buses. The increased number of hybrid buses will allow for any complications with the electric fleet to be overcome with little impact to service, as only 28% of the electric buses would need to be available for the peak service requirement to be met with the current schedule.

Hatch recommends that the electric buses are operated across all of the routes, particularly in the beginning period, when Bangor CC 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. This experience will help Bangor CC 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 Bangor CC operations.

7. Charging Schedule and Utility Rates

Section Summary

- The local utility has proposed new rates for EV charging, including penalties for peak period charging
- A charging schedule was developed to help Bangor CC 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. The operational configuration and fleet composition selected by Bangor CC, and described in the previous section of this report, assumes that buses will only be charged at the garage outside of usual operating hours.

From a cost perspective, developing a charging schedule soon is important as the local utility, Versant, plans to adjust its rate schedules. The new rate structure will apply variable pricing depending on the time of day that power is supplied. Bangor CC's current electricity rates are determined by Versant Power's 'M-2' rate table, as shown in Table 3. Under this rate table Bangor CC pays a flat "customer charge" monthly, regardless of usage. Bangor CC also pays a single distribution charge of $10.51 per kW and a single transmission charge of $14.57 per kW for their single highest power draw (kW) that occurs during each month. This totals to a single charge of $25.08 per peak kW draw per month to maintain Versant's distribution and transmission systems. This peak charge is not related to Versant's grid peaks, and is local to Bangor CC's usage. Finally, Bangor CC is charged an 'energy delivery charge' of $0.00604 per kWh, and an 'energy cost' of $0.09952 per kWh. These costs are recurring and are dependent on the amount of energy used by Bangor CC throughout the month.

To encourage the adoption of electric vehicles (EV), Maine's Public Utilities Commission (PUC) requested that utilities, including Versant, propose new rate structures for vehicle charging. In response to this request, Versant proposed an 'EV Rate 5' utility schedule filed under Docket No. 2021-00325. As part of this proposed rate schedule, Versant would require customers like Bangor CC to install new meters and service to their charging equipment to accurately account for the power draw associated with charging.
Table 3 below outlines the other differences between the existing 'M-2' and the proposed 'EV Rate 5' rate structures. The new rate structure would provide Bangor CC with a reduced monthly 'customer charge', as well as a lower monthly 'distribution charge'. With the new rate structure, the agency can also avoid the monthly transmission service charges by not charging vehicles during periods when Versant's grid load is peaking, termed the 'coincidental peak'. The historic data indicates that the daily system peak for Versant happens between 3 PM and 7 PM. Therefore, it is advisable for Bangor CC to develop a charging plan which avoids charging buses during these hours.

Table 3 Utility Rates Structure Comparison

	Current M-2 Rates	Proposed EV Rate 5 for DCFC
Customer Charge	$56.21 per month	$47.83 per month
Distribution Charge	$10.51 per non-coincidental peak kW (calculated monthly)	$8.97 per non-coincidental peak kW (calculated monthly)
Transmission Charge	$14.57 per non-coincidental peak kW (calculated monthly)	$23.11 per coincidental peak kW (calculated monthly)
Energy Delivery Charge	$0.00604 per kWh	$0.00604 per kWh
Energy Cost	$0.09952 per kWh	$0.09952 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. It can be seen in the figure that the optimized charging schedule assumes buses will be charged overnight (between 9 PM and 5 AM), outside of the times when Bangor CC's buses are in-service. This charging schedule would also avoid charging during the Versant grid's 'coincidental peak' (between 3 PM and 7 PM), which would allow Bangor CC to avoid a monthly 'transmission charge', should Versant's proposed 'EV Rate 5' schedule take effect.

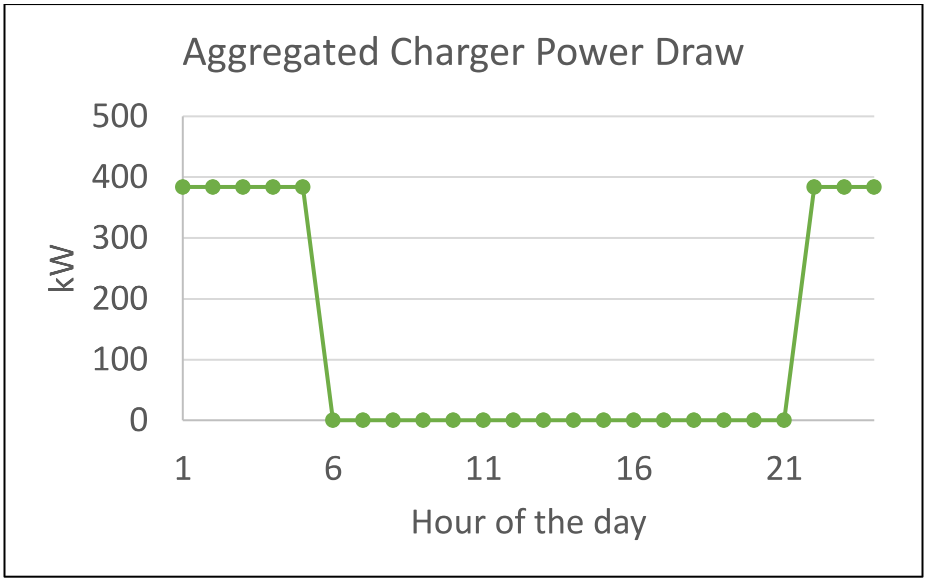


Figure 3 Proposed Charging Schedule for Bangor CC's Future Fleet

Below is an estimate of expected operational costs associated with the proposed charging schedule, based on both the existing 'M-2' and the proposed 'EV Rate 5'.

Daily kWh consumption = 3038 kWh
Monthly Non-coincidental peak = 384 kW
Monthly coincidental peak = 0 kW

<u>Under Current M-2 Rate Structure:</u>

$$Daily\ Charge = Daily\ kWh\ consumption\ \times (Energy\ Delivery\ Charge + Energy\ Cost)$$
$$= 3038\ kWh\ \times (\$0.00604 + \$0.09952)$$
$$= \$320.69$$

$$Monthly\ Charge = (Monthly\ Non - coincidental\ Peak\ \times Distribution\ Charge) + (Monthly\ Non - coincidental\ Peak\ \times Transmission\ Charge)$$
$$= (384\ kW\ \times \$10.51) + (384\ kW \times \$14.57)$$

$= \$9630.72$

Under New EV Rate 5 Structure:

$$Daily\ Charge = Daily\ kWh\ consumption\ \times (Energy\ Delivery\ Charge + Energy\ Cost)$$
$$= 3038\ kWh\ \times (\$0.00604 + \$0.09952)$$
$$= \$320.69$$

$$Monthly\ Charge$$
$$= (Monthly\ Non-coincidental\ Peak\ \times Distribution\ Charge) + (Monthly\ Coincidental\ Peak\ \times Transmission\ Charge)$$
$$= (384\ kW\ \times \$8.97) + (0\ kW \times \$23.11)$$
$$= \$3444.48$$

As this estimate shows, the proposed 'EV Rate 5' structure would save Bangor CC \$6,186.24 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 \$5,000 per month from a 'transmission charge'. Therefore, it is critical that Bangor CC 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 Bangor CC monitors changes in Versant'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 Bangor Community Connector's operation.

8. Asset Selection, Fleet Management and Transition Timeline

Section Summary

- Hatch recommends installing centralized charging at the bus barn
- Electric buses should be procured for the shorter blocks, with hybrid vehicles covering the longer ones

With operational and charging plans established, it was then possible to develop procurement timelines for infrastructure and vehicles to support those plans. Bangor CC, 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. Bangor CC 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.

As an additional complication, Bangor CC currently operates a mix of 30' and 35' buses. This is done to provide additional capacity on the busier routes (such as Old Town) while minimizing inefficient use of larger vehicles on the less ridden routes (such as Center Street). 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 a 30' bus, with the smallest available being 35'. The vendors that do (such as BYD) are likely to have more limited options, partly because of the smaller space available for batteries and partly because of the smaller market for 30' buses. Although the market is changing quickly, and within the next few years more 30' models are likely to be introduced, Hatch recommends that Bangor CC consider shifting to a higher proportion of 35' buses for greater flexibility in ordering. 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 length as operated now.

With respect to infrastructure procurements, the garage / main facility will eventually need to have enough chargers to accommodate all of Bangor CC's electric buses. In fact, Hatch recommends that plans be made for enough charging infrastructure to accommodate a future fleet of at least 22 battery electric buses; in the longer term beyond the scope of this report, it is possible that hybrids will be phased out entirely. In the short term, however, the garage will need sufficient chargers for the 14 electric buses prescribed in this transition plan by 2033. 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 Bus Barn. Centralized chargers will give Bangor CC 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. Bangor CC will require a minimum of 3 chargers with 3 dispensers each for a total of 9 dispensers to ensure there is a dedicated dispenser for each of its 8 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 charger as a spare for resiliency and for charging and maintaining spare vehicles, resulting in a requirement of 4 chargers with 3 dispensers each for a total of 12 dispensers for the fleet of 14 electric buses. 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
2024	Two Electric Transit Vans	Two level 2 chargers, design work for new Bus Barn	
2025	One (One Hybrid 35')	Construction of new Bus Barn	1048 (35', procured 2011)
2026	Two 450 kWh Electric 35'	One 150 kW centralized Bus Barn charger (two dispensers) + electrical upgrades and rough ins for future charger installations (conduit runs, concrete pads, transformers, switchgears etc.)	1046-1047 (35', procured 2011)
2027	Two 450 kWh Electric 30'	One 150 kW centralized Bus Barn charger (Three dispensers)	1743-1744 (30', procured 2017)
2028	Two (Two Hybrid 30')		1858-1859 (30', procured 2018)
2029	Eight (Three Hybrid 30', Five 450 kWh Electric 30')	Two 150 kW centralized Bus Barn chargers (Six dispensers)	1960-1962, 1985-1989 (all 30', procured 2019)
2030			
2031	One (One 450 kWh Electric 30')		2106 (30', procured 2021)
2032			
2033	Four (Four 450 kWh Electric 35')		2102-2105 (35', procured 2021)
2034			
2035			
2036			
2037	Two (Two Hybrid 35')		Pending replacements for 1049-1050 (30', to be procured 2023)

9. Building Spatial Capacity

Section Summary

- The existing bus barn has ample space for charging equipment and fleet storage.
- The Pickering Square transit hub has the ability to accommodate on-route charging if necessary

Bangor CC's main facilities are located at 475 Maine Avenue in Bangor, as shown in Figure 4. The primary structures on-site include a main office building, a motor pool building, and a Bus Barn.

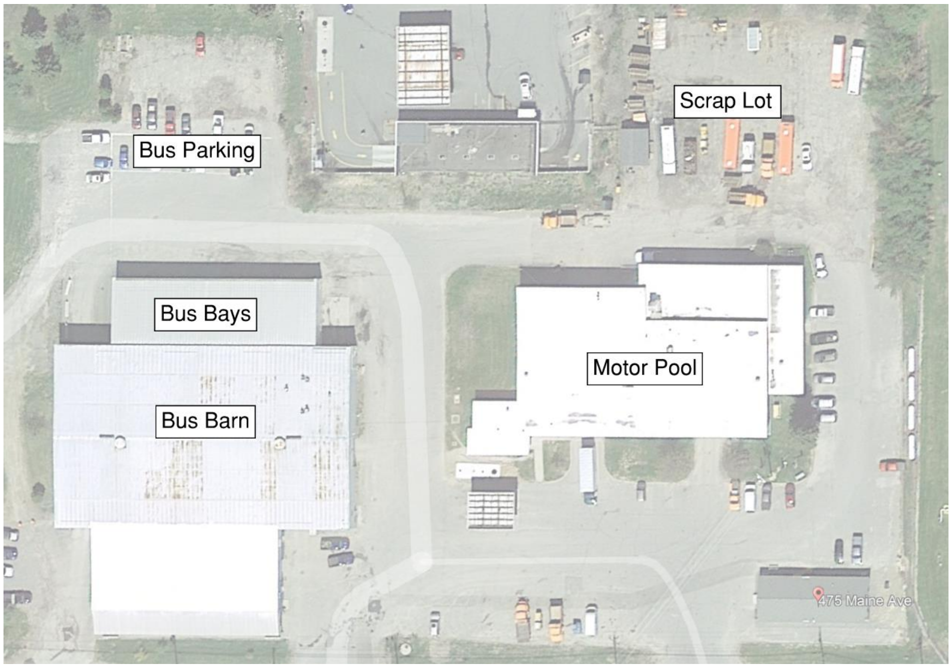


Figure 4 Bangor CC Main Facilities (475 Maine Avenue) (Source: Google Maps)

Buses and other municipal vehicles are maintained and serviced in the motor pool building, as shown in Figure 5. The motor pool building also has a storeroom which inventories parts for the fleets maintained at the facility. The motor pool facility will likely provide ample space for maintenance of electric and hybrid 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.

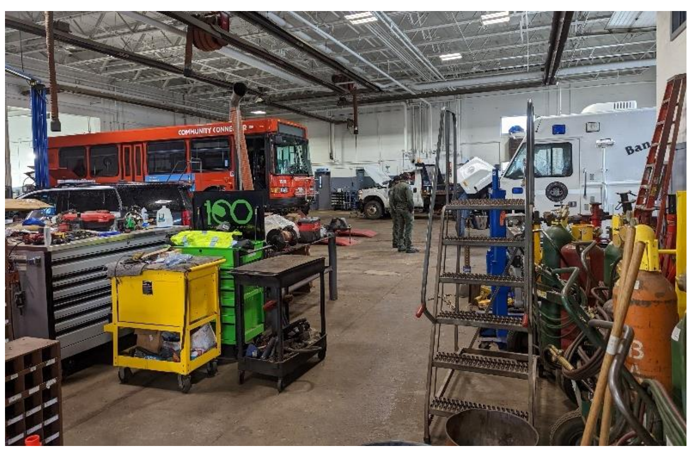


Figure 5 Motor Pool Maintenance Area

Currently buses are parked in the lot and bus bays, which are located at the north end of the property and shown in Figure 4. The bus bays are paved, insulated and conditioned providing "warm storage" for up to 10 buses, as shown in Figure 6.

Figure 6 Bus Bay "Warm Storage" Area

The Bus Barn, shown in Figure 7, is currently used to store buses during inclement weather and overnight. The parking space area, the bus bays, and the barn provide adequate space for storing the future hybrid and battery electric bus fleet proposed in this report, in addition to the fleets of other city departments sharing the facility. Furthermore, the bus bays and Bus Barn provide enough space to install the number of chargers and support systems for charging the future battery electric bus fleet.

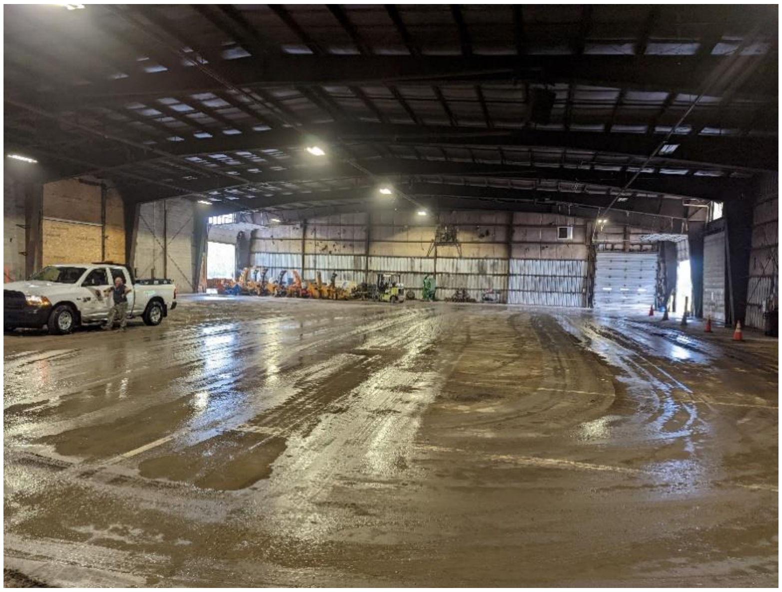


Figure 7 Bus Barn "Cold Storage" Area

Community Connector recently constructed a new Transit Center building at Pickering Square (Figure 8-9) in Bangor which will serve as the main hub and transfer point for its service. While this transition plan does not prescribe layover charging in the near-term, Bangor CC may decide in the future to implement it. If this occurs, the Transit Center would be the most logical location to place layover chargers to support operations. The Transit Center has seven sawtooth bus bays – three on the north side, three on the south side, and one on the west side. The west side space can accommodate a 40' bus and is intended to accommodate Downeast Transportation, Inc.'s (DTI) Bangor service. The space at the Transit Center will be sufficient for future electric and hybrid bus operations. The Transit Center has adequate space to install layover chargers, should Bangor CC decide to implement such a charging strategy in the future.

Figure 8 Pickering Square Location (Broad and Water Streets) (Source: Google Maps)

Figure 9 Pickering Square Transit Center Under Construction (June 2022)

10. Electrical, Infrastructure, and Utility Capacity

Section Summary

- A new electrical service to the bus barn will be required to serve the new chargers
- Separately metered service will allow the agency to take advantage of the DCFC specific utility rate structure

Versant Power is the utility provider for both of Bangor CC's primary building locations. As part of the development of this transition plan, Bangor CC has been partnering with Versant to communicate its projected future utility requirements to support battery electric buses. Also as part of this project, Versant and Bangor CC conducted field surveys of the two primary locations where charging infrastructure may be required:

+ Bus Barn – 475 Maine Avenue
+ Transit Center – Pickering Square

The Bus Barn has a 480V 3-phase service that is stepped down to 120/240V through a step-down transformer in the electrical room, as shown in Figure 10. This utility feed and transformer is not sufficient for the previously described charging needs at the Bus Barn which is estimated to be 384kW during the overnight charging period when all vehicles are charging simultaneously. As a result, a new dedicated 400kVA 480V 3-phase service with a separate meter is recommended for the charging infrastructure. A separate meter for charging operation is advisable to be able to qualify for the future proposed special EV charging rate structure.

Hatch has confirmed with Versant that it can accommodate a new 400kVA service at the Bus Barn for DC fast charging. Some upgrades might be required to the utility's protection systems, which should be under $20,000 according to Versant Power's initial estimates.

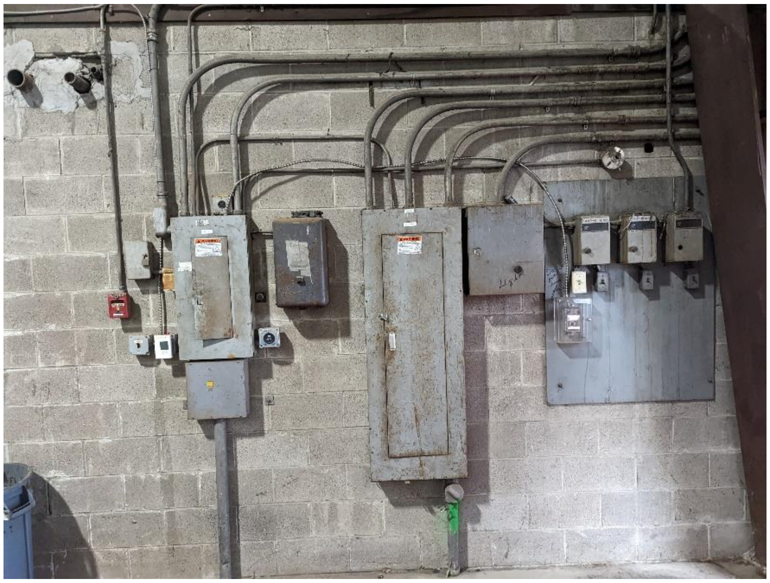


Figure 10 Bus Barn Electrical Room

While the operational analyses described in Section 6 of this report do not require layover charging at the Transit Center, a review of the utility capacity at that location was completed in case circumstances change in the future. To account for future agency growth, Hatch estimates that Bangor CC may require two overhead pantograph style chargers at the Transit Center in the future. According to the current estimate, 300kW of charging speed per charger should be sufficient to meet Bangor CC's operational needs. However, chargers of up to 450kW are available on the market today, and most agencies are choosing to install 450 kW layover chargers as a future-proofing investment. Even if today's buses cannot accommodate such a high charge rate and requires the charger to provide less power, such a decision minimizes any possible constraints on future fleets. It is therefore recommended that Bangor CC reevaluate the desired charger specifications before installing any layover charging at the Transit Center.

The new service recently installed for the Pickering Square terminal location as part of the construction is a 208V 3-phase service with the estimated peak load of 62kVA. This utility feed would not be sufficient for future charging at the new terminal, which is estimated to require roughly 1 MW based on two 450kW pantographs.

To accommodate this charging need, a new dedicated 480V 3-phase service would likely be required. A separate meter for charging operation is advisable to be able to qualify for the future proposed special EV charging rate structure. Hatch has confirmed with Versant that it can accommodate the new 1MVA service at the Transit Center for layover DC fast charging. Some upgrades might be required to the utility's protection systems, which should be under $20,000 according to Versant Power's initial estimates. The upgrade costs are based on the current utility feeder capacity at the Transit Center location. The feasibility and cost estimate for utility interconnection will need to be reevaluated when the layover charging stations at the Transit Center location are under consideration.

11. Resiliency

Electricity supply and energy resilience are important considerations for Bangor CC 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:

Section Summary

- 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

+ 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 Bangor CC 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.

11a. Existing Conditions

Bangor CC does not currently have resilient systems in place to support their future battery electric bus operations should there be an electrical service interruption. The agency does have a backup generator at the motor pool, as shown in Figure 11. The unit is used to provide power for lighting 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 Bus Barn or Bus Bays where vehicles are likely to be charged. There are also no battery backup or solar systems installed at Bangor CC's main complex, and no plans to install back-up power systems at the Transit Center.

Figure 11 Existing Diesel Generator Providing Lighting Power to Motor Pool During Outages

11b. Outage Data and Resiliency Options

After noting no viable resiliency systems in place currently, 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 the Community Connector's Bus Barn and at the Pickering Square Transit Center location to determine the requirements for backup power. Following is a summary of the outages at each of the locations in the last five years.

- Community Connector's Main Complex – There were only two outages at this location in the last five years. Out of the two outages, the one in 2018 lasted for slightly less than 2.5 hours. This outage was caused by a windstorm and was the longest one in the last five years. The second outage was in 2021 that was caused by equipment failure and lasted less than 30 minutes.
- Pickering Square Transit Center – The utility feed used by the new Transit Center saw 10 outages in the last five years. Most of the outages were minor and lasted no more than an hour. The longest two outages lasted for approximately 4 hours and 30 minutes in 2019 and 2021.

The outage data was compared with operational requirements to determine the appropriate sizing of the resiliency systems. Bangor CC 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 Bangor CC.

The battery storage requirements for the Bus Barn were calculated assuming a historical outage duration of 2.5 hours. The total energy requirement to charge five buses during that outage period would be 563 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 710 kWh. The power requirement for a generator at the Bus Barn was determined by the power draw of the minimum number of chargers required to simultaneously support the five vehicles. Assuming Bangor CC purchases the centralized chargers with three dispensers each, as specified in this report, two chargers would be required to support five buses. Assuming that all chargers Bangor CC 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.

While charging at the new Transit Center is currently not anticipated, requirements for resiliency systems were calculated to provide Bangor CC with information in case the agency's plans change in the future. The longest outage seen at the Transit Center site in the last five years is 4.5 hours. Hatch estimates that the largest energy draw that Bangor CC may require during any 4.5 hour period would be approximately 1092 kWh. Assuming a 20% spare capacity, the size of a battery backup system would need to be approximately 1.4 MWh.

The power requirement for a generator at the Transit Center was determined by the power draw of the two pantograph chargers operating simultaneously. The most common charging speed for layover charging application is 450kW. Assuming 90% efficiency for the chargers and 20% spare capacity, the resulting on-site generation capacity is determined to be approximately 1.3 MVA.

Hatch next generated cost estimates associated with the four resiliency system options for the two sites. 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 Cast Outage Scenarios

	Option 1 On-site Battery Storage		Option 2 On-site Diesel Generation	
	Size	**Capital Cost**	**Size**	**Capital Cost**
Bus Barn	710 kWh	$350,000	420 KVA	$195,000
Transit Center (for layover charging scenarios)	1.4 MWh	$675,000	1.3 MVA	$600,000

The above analysis and corresponding options are based on the historic outage data. 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 Bangor CC's electrification transition, the agency will have to choose an appropriate level of resiliency investment based on historical and anticipated needs.

11c. 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 Bangor CC'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 array would primarily be to offset energy from the grid and reduce utility costs.

On-site solar systems were only evaluated for the Bus Barn building for several reasons. First, the new Transit Center building will have a small footprint and little usable roof area to mount solar panels. At the main Bangor CC facilities, all the buildings are older, and the structures likely will not support solar systems. Bangor CC is, however, planning to renovate the Bus Barn, including improving the roof structure. This renovation provides an ideal opportunity to include a provision for rooftop solar at a minimal incremental cost. Table 7 outlines parameters for the solar power system that could be installed on the Bus Barn rooftop as well as the expected annual energy production and resulting cost savings from offsetting energy consumed from the grid.

Table 7 Bus Barn Rooftop Solar Analysis

Solar System Design Parameters	
Solar System Sizing Method:	Available Area
Solar Array Area Width	120 ft
Solar Array Area Length	200 ft
Solar Array Area	24,000 ft^2
Maximum Number of Panels	952 panels
Maximum System Power	405 kW
Annual Production Coefficient	1250 hours
Sunny Days Per Year	177 days
Annual Solar Energy Production	455,000 kWh
Annual Electric Usage	887,187 kWh
Maximum Percent of Electrical Usage Offset	51%
Electricity Rate	$0.1056 / kWh
System Cost	**$1,114,000**
Utility Bill Savings Per Year	**$48,000**
Simple Payback Period Without Grants	**23 years**
Payback Period with 80% Federal Grants	**4.6 years**

Based on the above parameters, daily production for sunny days is estimated to be 2.6 MWh. Since the energy requirement for 2.5 hour overnight charging at the Bus Barn is estimated to be 710 kWh, solar has the potential to provide enough energy to support the operation in the event of an outage on sunny days. In the event of a multiday outage, solar also has the potential to harvest enough energy during the daytime for full 8 hour charging operation (1.8 MWh) for 5 vehicles.

However, solar power generation is not recommended as a primary resiliency system as 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.

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 Bangor CC'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 rather than to only support outage scenarios. A more detailed study should be conducted to determine the battery energy requirements, which are likely to be more than 2.5 MWh for the Bus Barn based on the above solar estimates.

12. Conceptual Infrastructure Design

12a. Conceptual Layouts

To assist Bangor CC with visualizing the required infrastructure transition, conceptual plans were next developed based on the previous information established in this report.

Section Summary

- Hatch recommends installing chargers in the main area of the bus barn.
- Chargers at Pickering Square are feasible but not currently recommended
- The risk of a BEB fire is low but must be considered and mitigated

Bangor CC is already planning to renovate the Bus Barn in the near future. The agency recently received a quote to renovate the barn to meet code requirements, upgrade utilities, improve the structure, renovate the interior and provide warm storage for the remainder of the bus fleet. As part of this project, Hatch recommends that Bangor CC consider amending the quote to determine the costs of the following:

+ Upgrading the electrical utilities to support charging infrastructure.
+ Running conduit beneath the new paved surface or installing new overhead structure with conduits to support future charging system installation.
+ Upgrading the fire suppression system in consideration of housing battery and charging systems in the barn in accordance with Section 12b and a fire safety study (per standards UL9540, NFPA 70 and 230).
+ Expanding the server rack to support charge management systems.
+ Reinforcing the roof to support solar arrays.

Based on these recommendations, a conceptual infrastructure layout was developed for Bangor CC's Bus Barn, as shown in Figure 12.

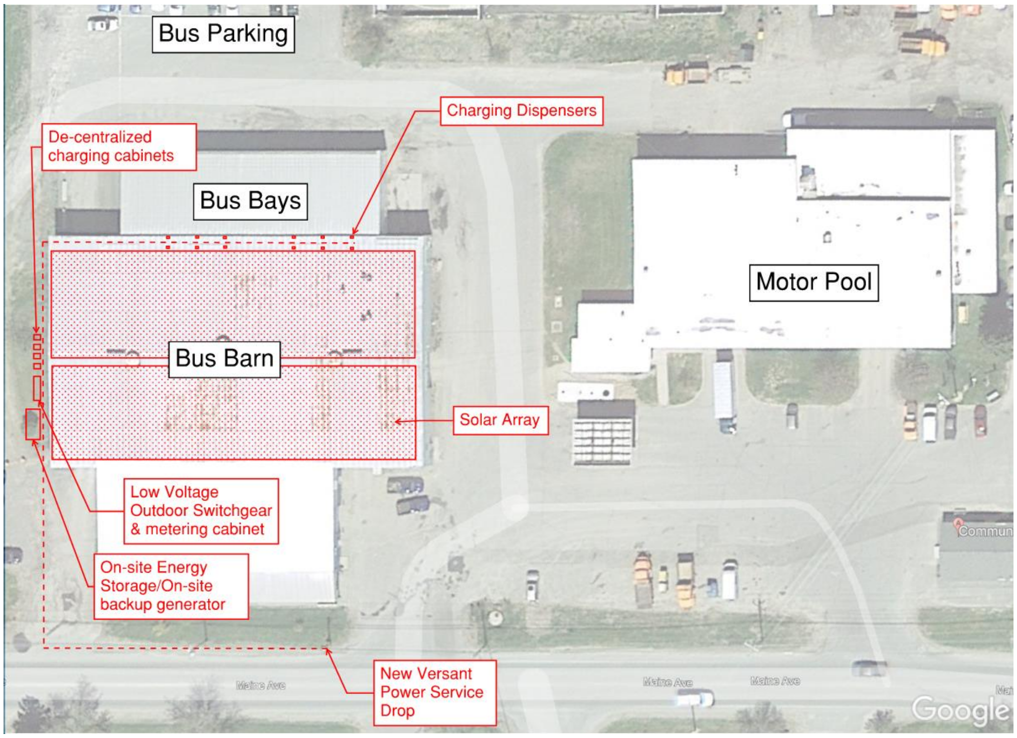


Figure 12 Bus Barn Infrastructure Conceptual Layout (Source: Google Maps)

While layover charging is currently not recommended at the Transit Center, Hatch recommends that conduit be run during construction in anticipation of any future charging needs, as shown in Figure 13.

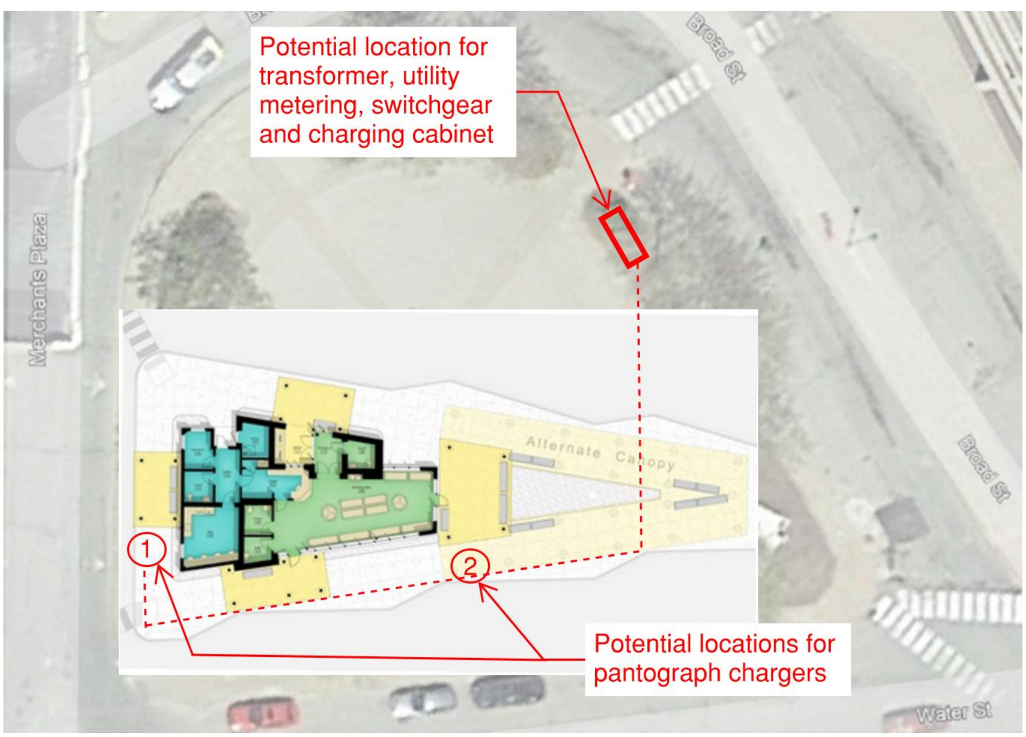


Figure 13 Pickering Square Transit Center Charger Location Concept (Source: Google Maps)

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 depot.

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. There are no current standards for fire suppression and mitigation of facilities housing battery electric vehicles. There are, however, relevant standards for the storage of high capacity batteries indoors for backup power systems, such as UL9540, NFPA 70, and NFPA 230. Despite there not being any standards developed specifically for electric vehicle operations, the primary components of any depot fire mitigation strategy are well understood: detectors for immediate discovery of a fire, sprinklers to extinguish it as much as possible, and barriers to prevent it from spreading to other buses or the building structure. Each of these requires specific consideration with respect to Bangor CC's facility and operations. Hatch recommends that Bangor CC commission a fire safety study as part of detailed design work for the Bus Barn upgrade to consider these factors.

13. Policy Considerations and Resource Analysis

Section Summary

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

Bangor CC's current operating budget is roughly $3.5 million per year. The agency's funding sources are summarized in Figure 14. As can be seen in the figure, Bangor CC'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.

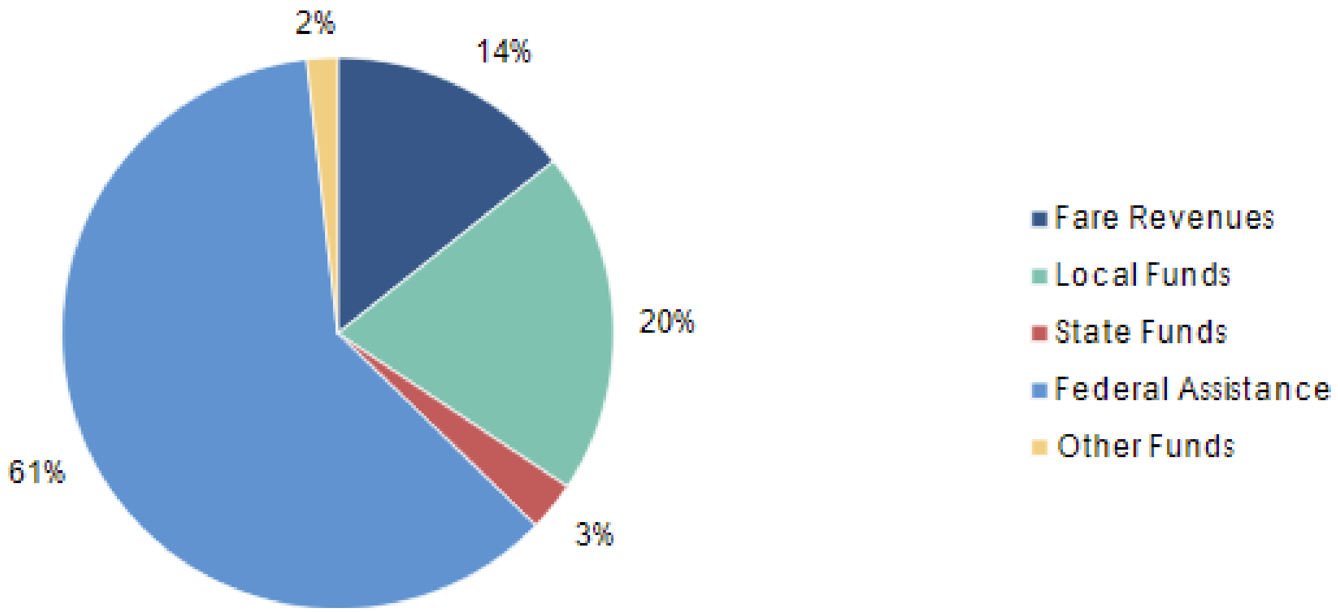


Figure 14 Current Agency Funding Summary (Source: MaineDOT)

As the agency transitions to hybrid and battery electric technology, additional policies and resources will become applicable to Bangor CC. Table 8 provides a summary of current policies, resources and legislation that are relevant to Bangor CC's fleet electrification transition.

Despite the large number of potential funding opportunities available to transit agencies seeking to transition to hybrid and battery electric technologies, these programs are competitive and do not provide Bangor CC with guaranteed funding sources. Therefore, this analysis assumes that Bangor CC will only receive funding through the largest grant programs that provide the highest likelihood of issuance to the agency. Specifically, this analysis assumed that Bangor CC 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 8 Policy and Resources Available to Bangor CC

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 hybrid or 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 at the Bus Barn. (*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 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. (*Formula funding)

14. Cost Considerations

Fleet electrification has significant financial impacts for the transit agency. Substantial capital cost increases are expected for both vehicles and infrastructure, compared to what is required for the agency's existing operations with fossil fuel vehicles. On the other hand, some savings on recurring expenses are likely, because electric vehicles require less maintenance and have cheaper energy costs.

Section Summary

- Bus electrification is expected to significantly increase capital cost
- However, reduced Bangor CC recurring expenses are expected, as electric vehicles cost less to maintain and fuel

The upfront purchase cost of battery electric and hybrid vehicles is much higher than for fossil fuel ones. For battery-electrics, this is largely due to the high cost of the propulsion batteries. Although the cost of batteries is declining each year it is still very high, particularly for heavy-duty transit vehicles. Because transit agencies prefer high-capacity batteries to extend vehicle range, the additional price of the batteries overshadows the cost savings from eliminating the engine and associated components on a diesel or gasoline vehicle. On the other hand, hybrid vehicles do not have large batteries; however, their drivetrains include a full set of components for fossil fuel operation, with electrical propulsion elements added on. This additional complexity increases the price of a hybrid vehicle above that of a fossil fuel one. The vehicle purchase cost increases are often significant, as shown below.

Electrifying a transit fleet often requires major infrastructure investment as well, to ensure that three separate items – the chargers themselves, the facility, and the utility connection – are suited for electric vehicles. Chargers are, of course, a prerequisite to EV operation; they must be purchased, installed, and commissioned. Particularly for heavy-duty applications like transit service, the required chargers are often high-powered and expensive. The facility itself must also be adapted for EV charging. In some cases, for modern facilities designed with spare electrical capacity, this will only require installation of additional conduit to connect to the electrical panel. For other, older facilities with outdated electrical and fire detection systems (such as Bangor's Bus Barn), this could involve a multimillion-dollar upgrade before the first charger can be installed. Finally, the facility's utility connection often requires upgrades as well, as detailed in Section 10. Although bus depots are industrial facilities, their existing electrical systems are usually unsuited for the heavy power demands of EV charging. Although the cost of utility and facility upgrades varies on a case-by-case basis, the price of chargers themselves is relatively consistent and is presented below.

These upfront capital costs are expected to be balanced out by recurring savings on operations and maintenance cost. For operations, EVs are cheaper to recharge than fossil fuel vehicles are to refuel. This is especially true if a charge management system is used to avoid electricity demand charges. Even hybrids, which still require fueling, use approximately 20% less fuel than non-hybrid vehicles, decreasing operations costs accordingly. In addition to operations spending, maintenance costs are expected to decline as well. EVs have many fewer drivetrain parts, especially moving parts, than fossil fuel vehicles. Therefore, components will wear out less often, meaning that less time has to be spent maintaining them and spare parts can be bought less frequently. For hybrid vehicles, maintenance costs are expected to remain largely unchanged compared to diesel or gasoline vehicles. Although hybrids have more complicated drivetrains, the electric propulsion means that regenerative braking can be used – prolonging the life of components like brake pads – and the fossil fuel engine does not need to handle as intense a duty cycle as it otherwise would.

Table 9 lists the operating and capital costs that Hatch assumed for this study. These are based on Bangor CC's figures and general industry trends and have been escalated to 2023 dollars where necessary.

Table 9 Cost Assumptions

Asset	Estimated Cost Per Unit (2023 $'s)
Electric Van	$200,000
30' Diesel Transit Bus	$580,000
30' Hybrid Transit Bus	$875,000
30' Battery Electric Transit Bus (450 kWh)	$1,100,000
35' Diesel Transit Bus	$600,000
35' Hybrid Transit Bus	$821,000
35' Battery Electric Transit Bus (450 kWh)	$1,115,000
DC Fast Charger – Plug-in Garage (centralized unit and 3 dispensers)	$270,000

Expense	Estimated Cost (2023 $'s)
Diesel and hybrid bus maintenance	$1.11 / mile
Electric bus maintenance	$0.83 / mile

The proposed fleet transition requires initial capital spending to reduce recurring cost and achieve other strategic goals. This need 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 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 Bangor CC 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 Bangor CC to change the speed of its electrification transition or change the desired end-state altogether.

15. Emissions Impacts

Section Summary

- Bus electrification will be key to meeting emission goals
- Forecasted grid conversion to clean energy will maximize the benefit of bus electrification
- The transition is expected to reduce emissions by 55-60%

One of the drivers behind Bangor CC's transition towards hybrid and battery electric buses was the State of Maine's goals to reduce emissions across the state. 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 Bangor CC.

Hatch calculated the anticipated emissions reductions from Bangor CC'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 Bangor CC'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.

The tank-to-wheel emissions baseline was compared against the vehicle types prescribed in Bangor CC's transition plan: hybrid and battery electric. For hybrid buses, emissions reductions are achieved through an improvement in fuel economy. This emissions calculation assumed that hybrid buses achieve a 6.3 mpg fuel economy, a 1.3 mpg improvement over the baseline diesel fleet.

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 hybrid and 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 Bangor CC. 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, Versant, 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 10 and Figure 15 summarize the results of the emissions calculations. These results demonstrate that the transition plan will achieve 55% reduction emissions assuming the grid mix that existed in 2020, or a 60% emissions reduction assuming that Versant is able to meet the state's goals to reduce grid emissions by the year 2030. In either case, Bangor CC's transition plan will achieve a reduction in emissions in excess of the 45% goal established by the State of Maine.

Table 10 CO_2 Emissions Estimate Results

Scenario	Well-to-Tank (kg)	Tank-to-Wheel (kg)	Grid (kg)	Total (kg)	Reduction over Baseline
Diesel Baseline	693,351	1,193,349		1,886,700	----------
Future Fleet (Assuming 2020 grid mix)	254,633	438,258	161,371	854,262	55%
Future Fleet (Assuming 2030 grid mix)	254,633	438,258	53,252	746,143	60%

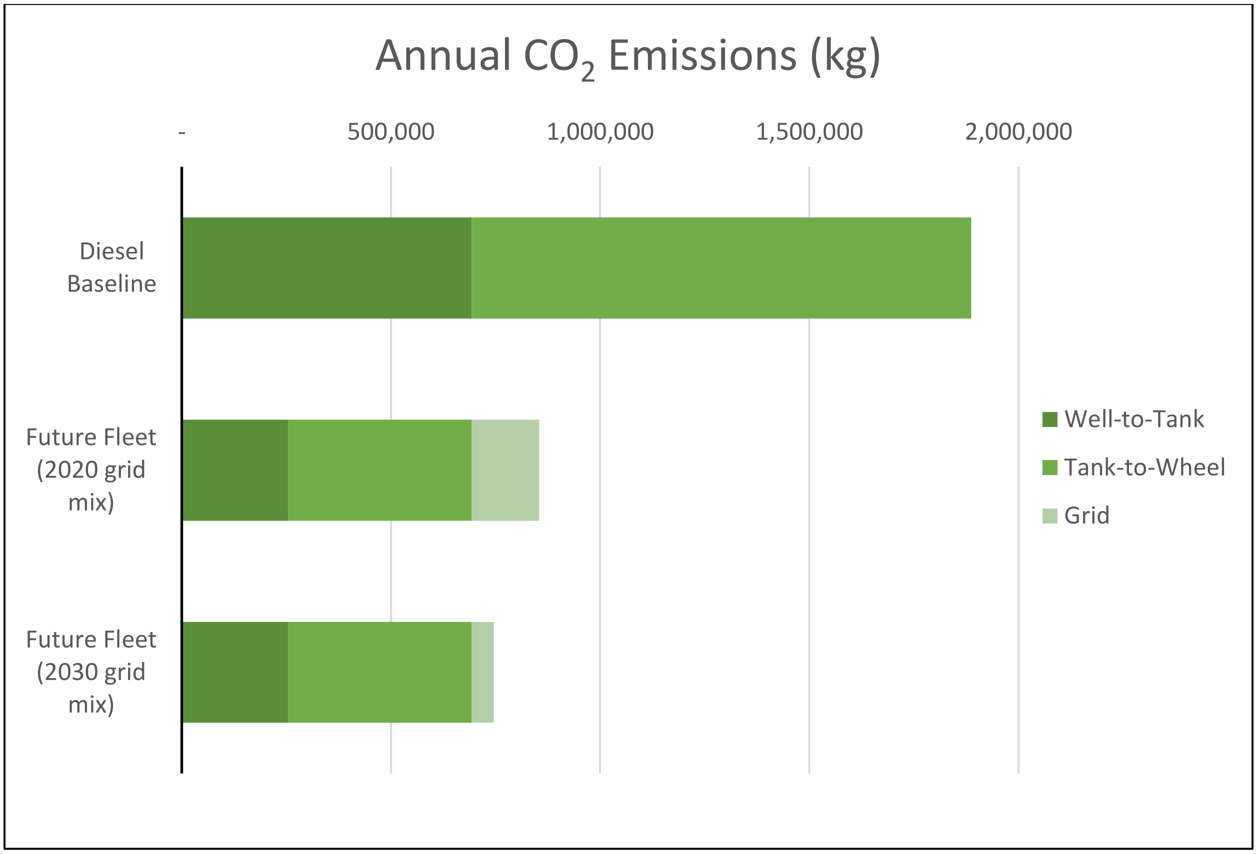


Figure 15 Graph of CO_2 Emissions Estimate Results

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

+ Transition the entire fleet to battery electric buses rather than a mix of hybrids and battery electrics.
+ Purchase green energy agreements through energy retailers to reduce or eliminate the emissions associated with grid production.

16. Workforce Assessment

> ***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

Bangor CC's staff currently operate a revenue fleet composed entirely of diesel vehicles. As a result, the staff have skill gaps related to hybrid and electric vehicle and charging infrastructure technologies that will be operated in the future. To ensure that both existing and future staff members can operate Bangor CC's future system a workforce assessment was conducted. Table 11 details skills gaps for the workforce groups within the agency and outlines training requirements to properly prepare the staff for future operations.

Table 11 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 Bangor CC 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 hybrid and battery electric buses to learn about the technology.
+ Coordinate with local vocational and community colleges to learn about education programs applicable to battery electric and hybrid 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.

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

17. Alternative Transition Scenarios

As part of this study, Bangor CC 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, Bangor CC currently favors the transition plan presented in this report. Should Bangor CC'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 Bangor CC review this transition plan on an annual basis to reevaluate the assumptions and decisions made at the time this report was authored.

Section Summary

- Hatch recommends reviewing this report annually for comparison with technology development and Bangor CC's operations

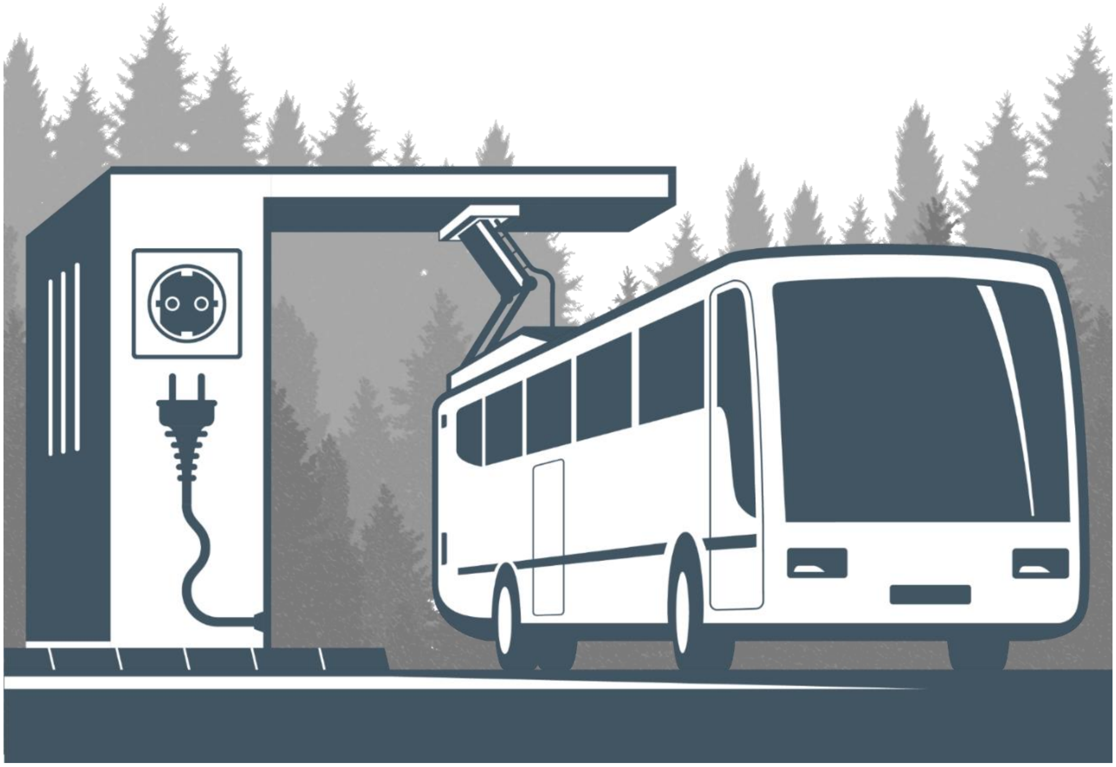
18. Recommendations and Next Steps

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 Bangor CC 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 MaineDOT, other transit agencies in Maine, as well as other key stakeholders, Bangor CC 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 Bangor CC 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.
  - Consider ordering buses as part of larger orders or partnering with other agencies or the DOT to form large joint procurements.
  - Consider shifting to a higher proportion of 35' buses to increase competition on future vehicle procurements.
  - Consider transitioning to a 100% battery electric fleet, should early procurements and operations perform acceptably.
- 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.
- Develop specifications for battery electric and hybrid buses.
- Develop specifications for required infrastructure.
- Commence training programs for all Bangor CC staff, as described in Section 16 of this report.

- As part of the Bus Barn renovation consider the following:
  - Upgrading the electrical utilities to support charging infrastructure.
  - Running conduit beneath the new paved surface or installing new overhead structure with conduits to support future charging system installation.
  - Upgrading the fire suppression system in consideration of housing battery and charging systems in the barn in accordance with Section 12b and a fire safety study (Per standards UL9540, NFPA 70 and 230).
  - Expanding the server rack to support charge management systems.
  - Reinforcing the roof to support solar arrays.
- Complete a full solar survey of the Bangor CC main facility area, including all buildings and parking lot areas. Consider covering parking areas to maximize solar potential. Adjust resiliency plans accordingly to fully capture any solar power generated.
- Coordinate transition efforts with peer transit agencies, Versant and Maine DOT.
- Continually monitor utility structures and peak charge rates and adjust charging schedules accordingly.
- Review this transition plan annually to update based on current assumptions, plans, and conditions.



Bus Electrification Transition Plan for BSOOB

Transit
Biddeford | Saco | Old Orchard Beach

Prepared by:
HATCH

Version: 1.2
3/17/2023

Table of Contents

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.

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, though significant upfront capital spending will be required. 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.

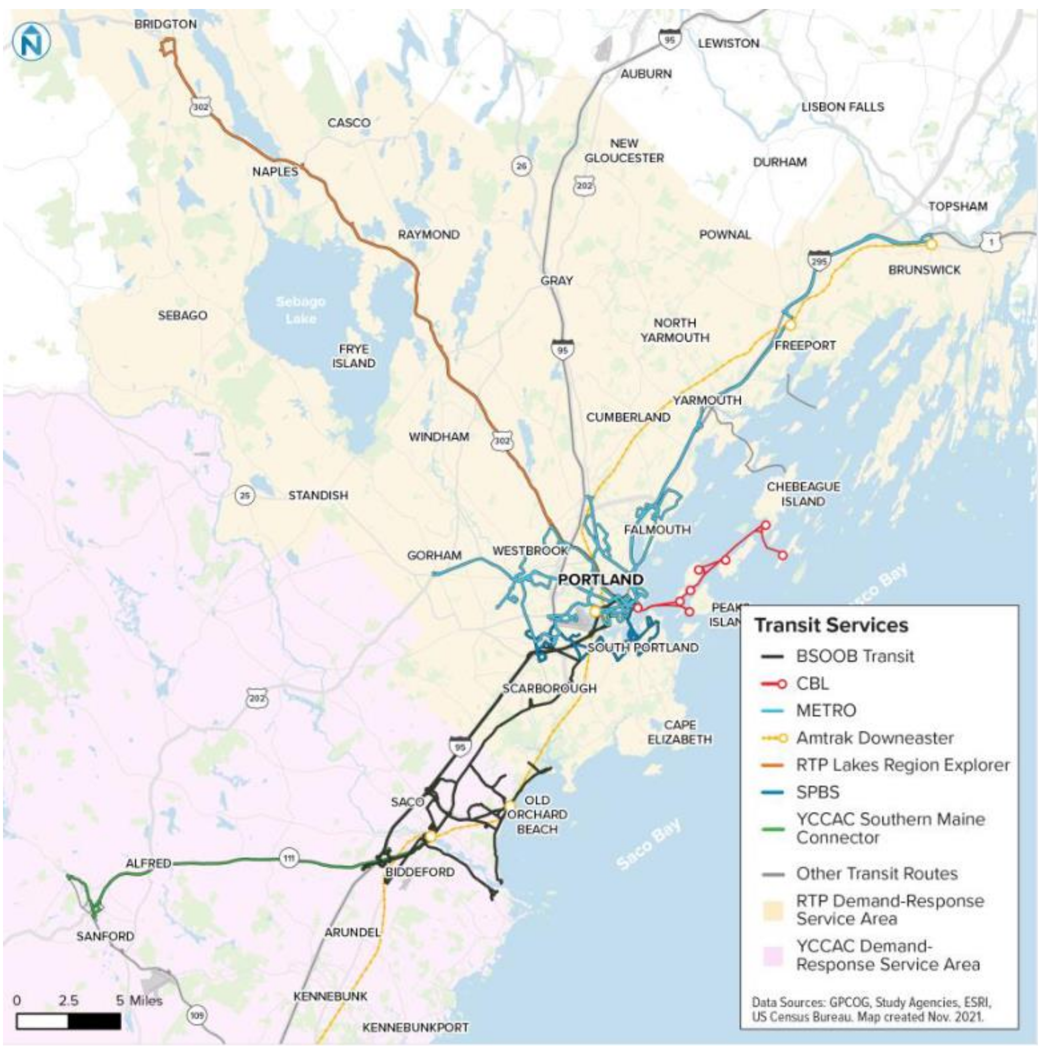


Figure 1 Map of BSOOB and Other Regional Transit Services (Source: GPCOG/Transit Together)

- **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. In the hybrid and battery electric vehicle space, 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.

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. 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
- 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.

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.

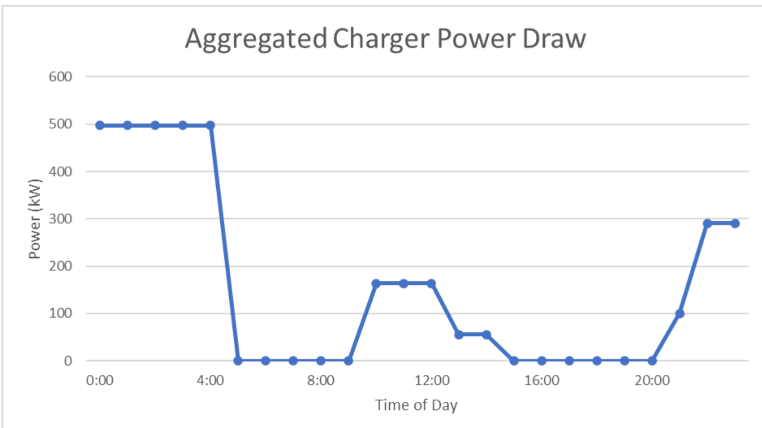


Figure 3 Proposed Depot Charging Schedule for BSOOB's Future Fleet

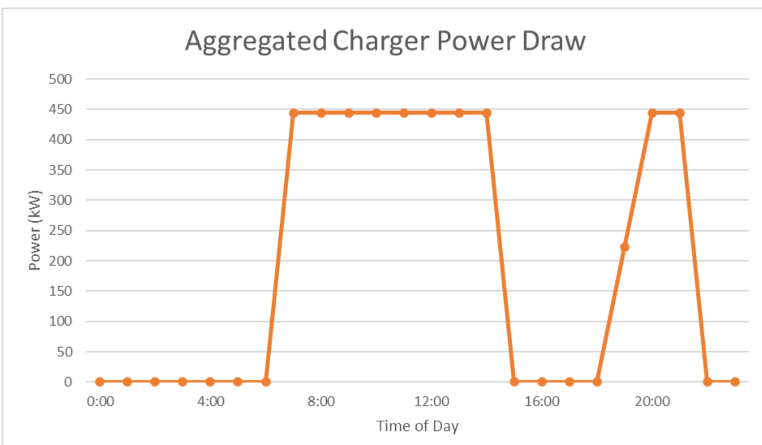


Figure 4 Proposed On-route Charging Schedule for BSOOB's Future Fleet

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:

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

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

Under New B-DCFC Rate Structure:

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

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

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.

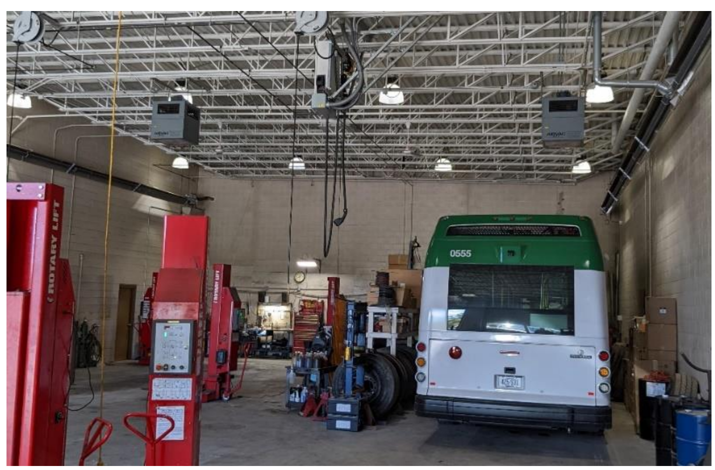


Figure 5 13 Pomerleau St Facility with DC Fast Chargers

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

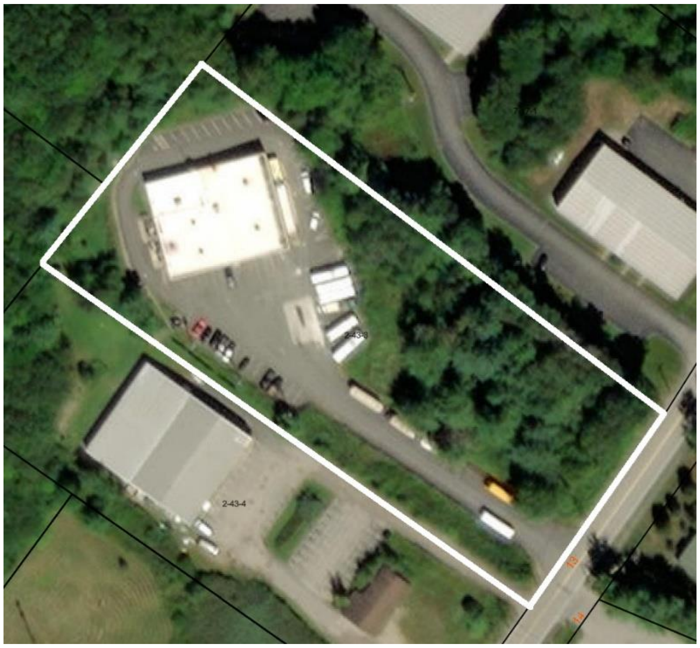


Figure 6 Aerial View Showing 13 Pomerleau St. Property Lines (Source: BiddGIS)

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.

- 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.

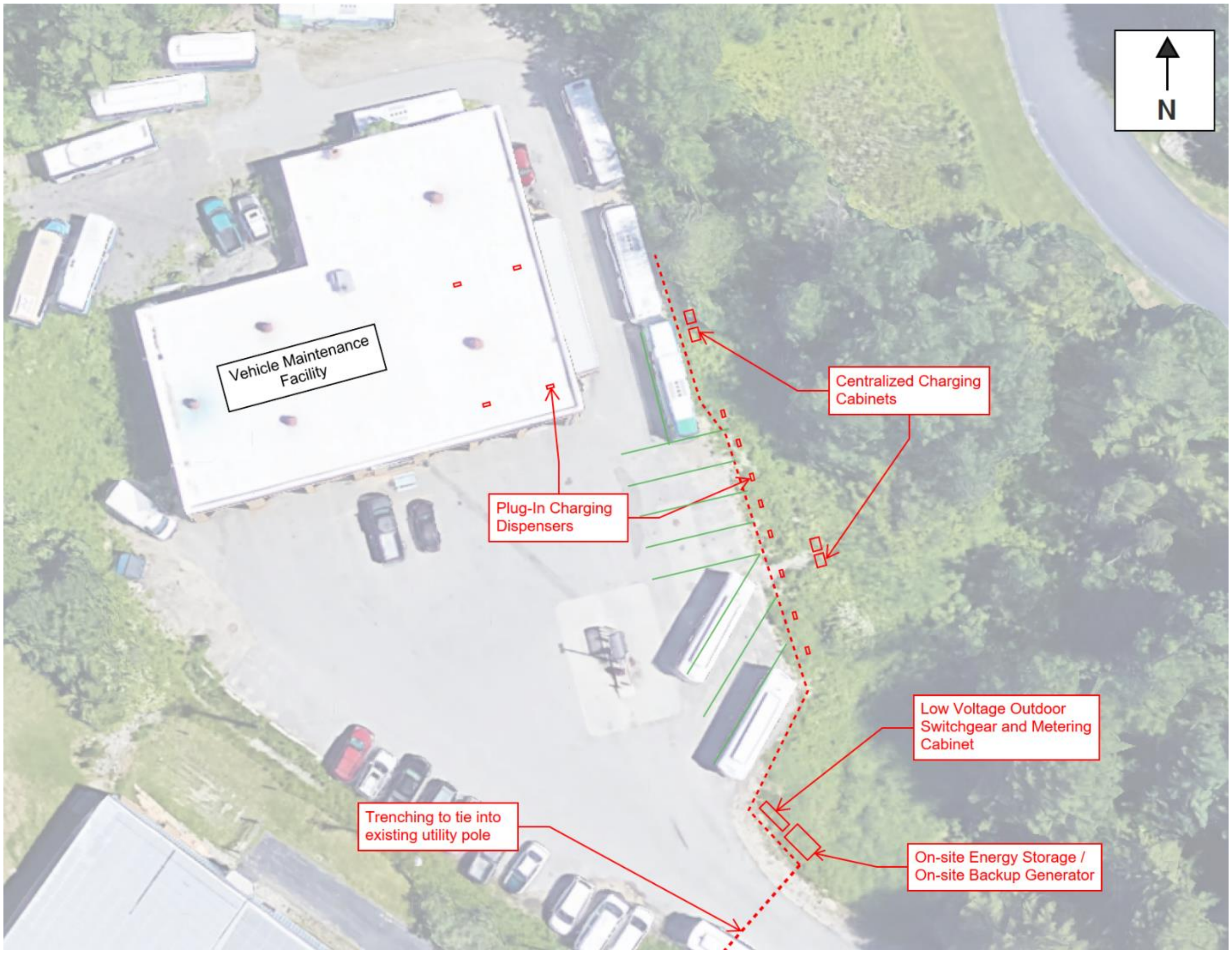


Figure 13 13 Pomerleau St. Overnight Charger Layout Option

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.

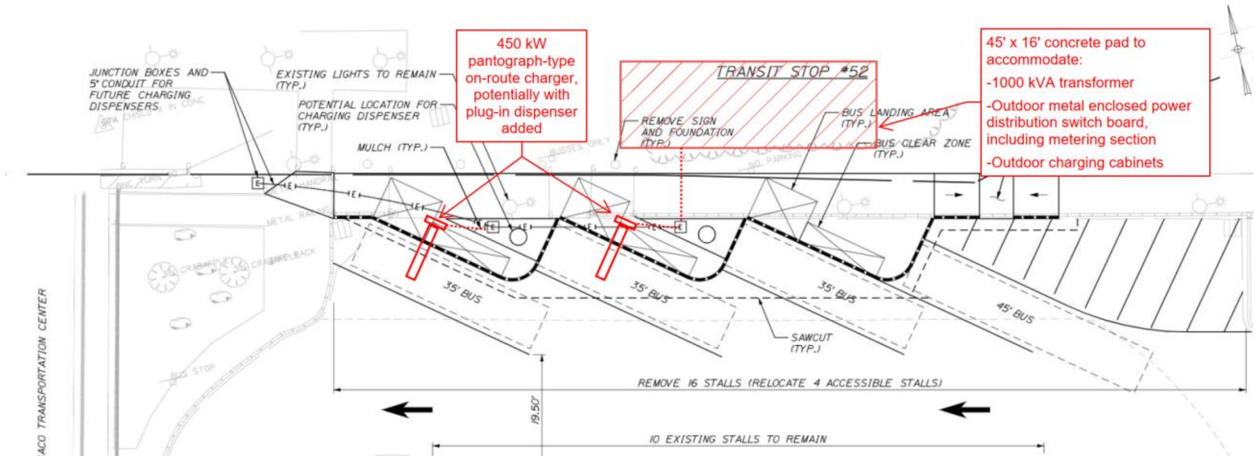


Figure 14 Saco Transportation Center On-Charger Layout Option (Source: GPCOG)

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.

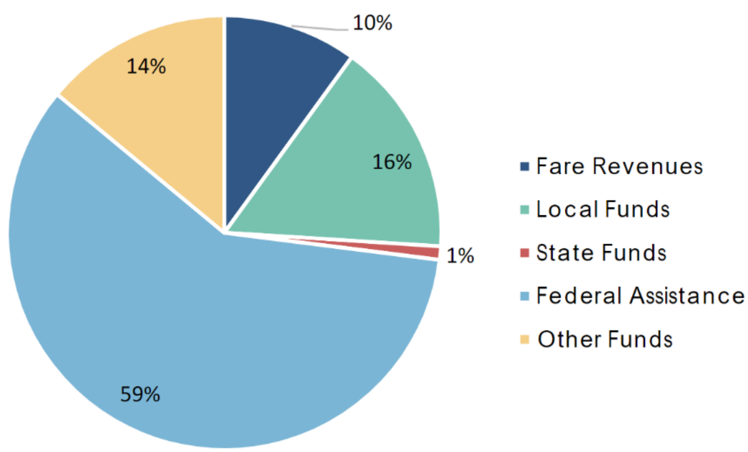


Figure 15 Current Agency Funding Summary (Source: Maine DOT)

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 Considerations

Section Summary

- Bus electrification is expected to significantly increase capital cost
- However, reduced BSOOB recurring expenses are expected, as electric vehicles cost less to maintain and fuel

Fleet electrification has significant financial impacts for the transit agency. Substantial capital cost increases are expected for both vehicles and infrastructure, compared to what is required for the agency's existing operations with fossil fuel vehicles. On the other hand, some savings on recurring expenses are likely, because electric vehicles require less maintenance and have cheaper energy costs.

The upfront purchase cost of battery electric and hybrid vehicles is much higher than for fossil fuel ones. For battery-electrics, this is largely due to the high cost of the propulsion batteries. Although the cost of batteries is declining each year it is still very high, particularly for heavy-duty transit vehicles. Because transit agencies prefer high-capacity batteries to extend vehicle range, the additional price of the batteries overshadows the cost savings from eliminating the engine and associated components on a diesel or gasoline vehicle. On the other hand, hybrid vehicles do not have large batteries; however, their drivetrains include a full set of components for fossil fuel operation, with electrical propulsion elements added on. This additional complexity increases the price of a hybrid vehicle above that of a fossil fuel one. The vehicle purchase cost increases are often significant, as shown below.

Electrifying a transit fleet often requires major infrastructure investment as well, to ensure that three separate items – the chargers themselves, the facility, and the utility connection – are suited for electric vehicles. Chargers are, of course, a prerequisite to EV operation; they must be purchased, installed, and commissioned. Particularly for heavy-duty applications like transit service, the required chargers are often high-powered and expensive. The facility itself must also be adapted for EV charging. In some cases, for modern facilities designed with spare electrical capacity, this will only require installation of additional conduit to connect to the electrical panel. For other, older facilities with outdated electrical and fire detection, this could involve a multimillion-dollar upgrade before the first charger can be installed. Finally, the facility's utility connection often requires upgrades as well, as detailed in Section 10. Although bus depots are industrial facilities, their existing electrical systems are usually unsuited for the heavy power demands of EV charging. Although the cost of utility and facility upgrades varies on a case-by-case basis, the price of chargers themselves is relatively consistent and is presented below.

These upfront capital costs are expected to be balanced out by recurring savings on operations and maintenance cost. For operations, EVs are cheaper to recharge than fossil fuel vehicles are to refuel. This is especially true if a charge management system is used to avoid electricity demand charges. Even hybrids, which still require fueling, use approximately 20% less fuel than non-hybrid vehicles, decreasing operations costs accordingly. In addition to operations spending, maintenance costs are expected to decline as well. EVs have many fewer drivetrain parts,

especially moving parts, than fossil fuel vehicles. Therefore, components will wear out less often, meaning that less time has to be spent maintaining them and spare parts can be bought less frequently. For hybrid vehicles, maintenance costs are expected to remain largely unchanged compared to diesel or gasoline vehicles. Although hybrids have more complicated drivetrains, the electric propulsion means that regenerative braking can be used – prolonging the life of components like brake pads – and the fossil fuel engine does not need to handle as intense a duty cycle as it otherwise would.

Table 10 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 2023 dollars where necessary.

Table 10 Cost Assumptions

Asset	Estimated Cost Per Unit (2023 $'s)
35' Diesel Transit Bus	$600,000
35' Battery Electric Transit Bus (225 kWh)	$950,000
35' Battery Electric Transit Bus (450 kWh)	$1,115,000
45' Diesel Commuter Coach	$650,000
45' Battery Electric Commuter Coach (541 kWh)	$1,250,000
Diesel Trolley-Style Bus	$325,000
Battery Electric Trolley-Style Bus (458 kWh)	$725,000
DC Fast Charger – Plug-in Garage (centralized unit and 3 dispensers)	$270,000
DC Fast Charger – Pantograph Overhead	$630,000

Expense	Estimated Cost (2023 $'s)
Diesel bus maintenance	$1.13 / mile
Electric bus maintenance	$0.85 / mile

The proposed fleet transition requires initial capital spending to reduce recurring cost and achieve other strategic goals. This need 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 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 change the speed of its electrification transition or change the desired end-state altogether.

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 11 and Figure 16 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 11 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%

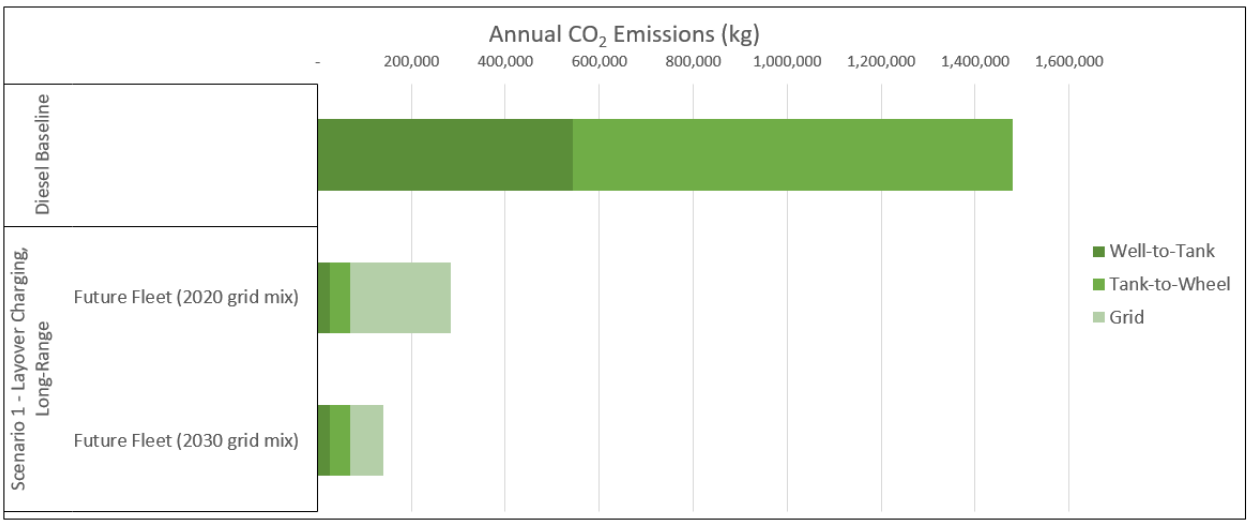


Figure 16 Graph of CO_2 Emissions Estimate Results

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 12 details the key skills that BSOOB's workforce groups will need to maintain for safe and effective electric bus operation.

Table 12 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. 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.

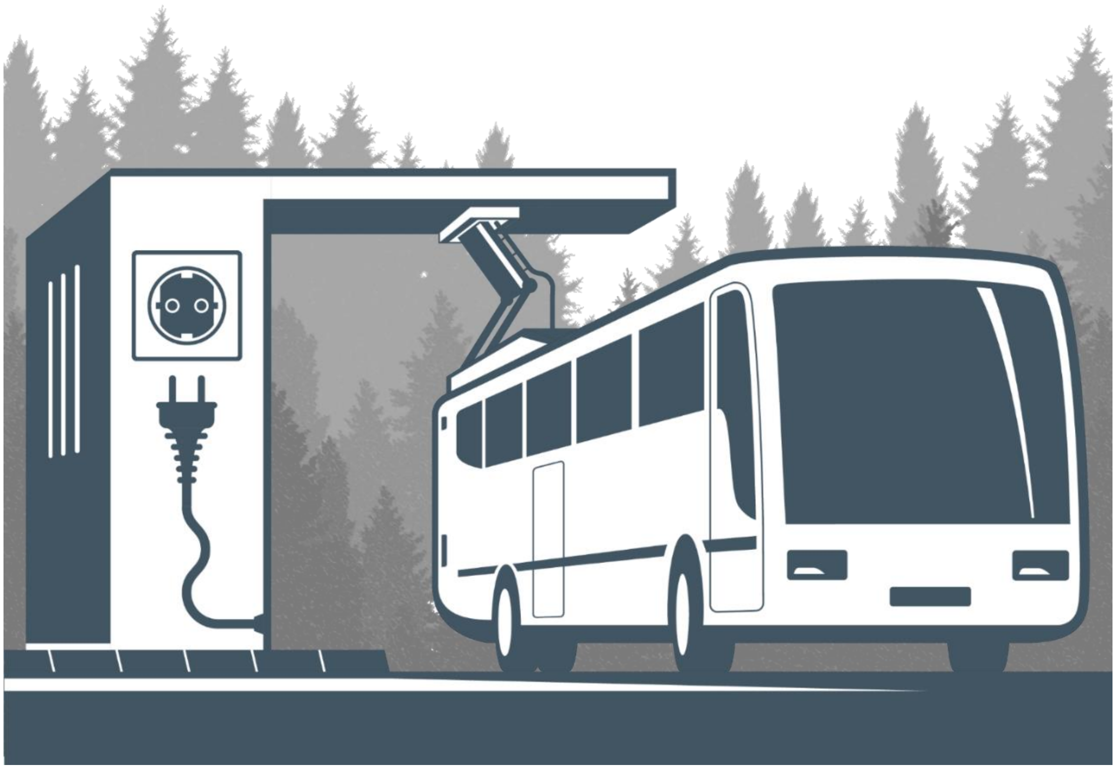
18. Recommendations and Next Steps

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.
  - Review this transition plan annually to update based on current assumptions, plans, and conditions.



Bus Electrification Transition Plan for Lewiston-Auburn Citylink

citylink

Prepared by:

HATCH

Version: 1.2
3/17/2023

Table of Contents

1. Executive Summary

Citylink, the bus agency serving the Lewiston-Auburn area in Maine, is currently considering transitioning its bus fleet to battery electric and hybrid 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, Citylink 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 maintains the agency's current fleet size of nine buses by replacing them with nine battery electric buses. To support the battery electric buses, the agency also plans to procure, install, and commission three charging systems at the Oak St. parking lot in downtown Lewiston that will have the capacity to support overnight charging of up to nine buses simultaneously, as well as potentially a pantograph-style charger for use during service hours.

One of the primary motivations behind Citylink'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 projection estimate that the new fleet will provide up to an 88% reduction in emissions compared to Citylink's existing diesel operations.

The conclusion of the analysis is that battery electric buses can feasibly support Citylink's operations. Furthermore, these buses offer the potential for the agency to greatly reduce emissions, though significant upfront capital spending will be required. Therefore, Citylink 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, the Androscoggin Valley Council of Governments (AVCOG, the body overseeing Citylink), 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 Citylink's future route plans, vehicle technology options, building electrical capacity, emissions impacts, resiliency, and financial implications.

3. Existing Conditions

Citylink is a small transit agency providing service to the Lewiston-Auburn, Maine area. The agency currently owns and operates a fleet of nine vehicles, all of which are diesel powered. There is currently one cutaway shuttle in the fleet, but this is planned to be replaced by a transit bus in 2023.

Section Summary

- Citylink operates ten routes with a nine-bus fleet
- Peak service requires six buses (six blocks)
- LATC, which is staffed by AVCOG, contracts out Citylink operations to WMTS

Table 1 Current Vehicle Roster

Bus Type/Roster Number	Fuel Efficiency (MPG)	Number of Buses	Procurement Date/Age	Projected Retirement Date
GILLIG 35' (1101 – 1102)	4.3	2	2011	2023
F-550 Cutaway (1401)	4.3	1	2014	2023
GILLIG 35' (1901 – 1902)	4.3	2	2019	2031
***GILLIG 29'* (1904)**	4.3	1	2019	2031
GILLIG 29' (2201 – 2202)	4.3	2	2022	2034
GILLIG 35' (2203)	4.3	1	2022	2034

Citylink has ten fixed routes that operate with 30 to 120-minute headways. All Citylink routes except Route 8 - the Mall Shuttle, serve either the Oak Street Bus Station in Lewiston or the Downtown Auburn Transportation Center (Great Falls Plaza) in Auburn. The routes are shown in Figure 1 below.

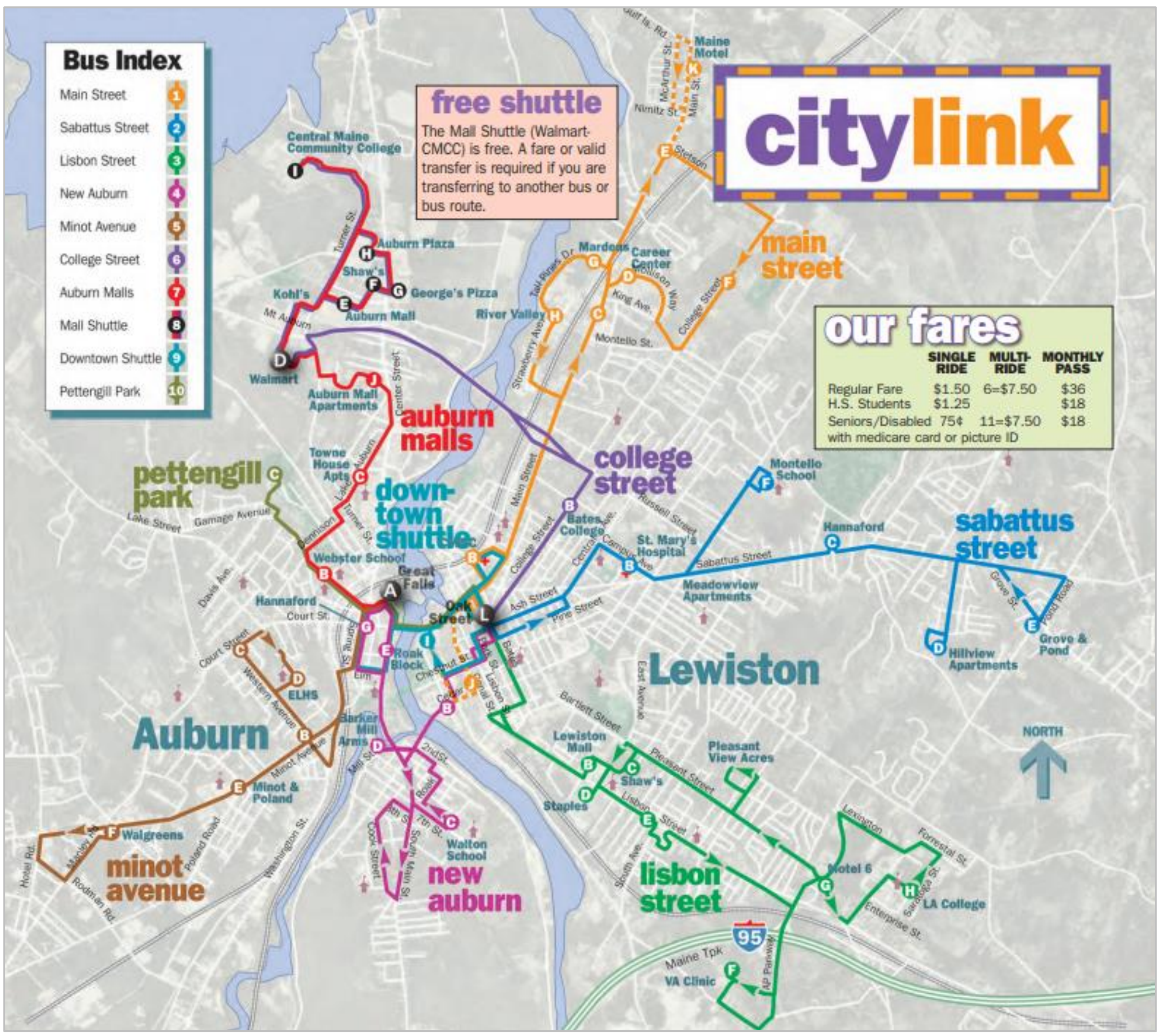


Figure 1 Citylink Route Map

- **Route 1 - Main Street**
  Operates every hour Monday to Friday.
  Operates every two hours on Saturday.
- **Route 2 - Sabattus Street**
  Operates every hour Monday to Friday.
  Operates every two hours on Saturday.
- **Route 3 - Lisbon Street**
  Operates every hour Monday to Friday.
  Operates every two hours on Saturday.
  Serves University of Southern Maine (USM)
- **Route 4 - New Auburn**
  Operates every two hours Monday to Saturday.
- **Route 5 - Minot Avenue**
  Operates every two hours Monday to Friday.
- **Route 6 - College Street**
  Operates every hour Monday to Saturday.
  Serves Central Maine Community College (CMCC) Campus
- **Route 7 - Auburn Malls/Mall Shuttle**
  Operates every hour Monday to Saturday.
  Serves Central Maine Community College (CMCC) Campus
- **Route 8 - Mall Shuttle**
  Operates every half hour Monday to Saturday.
  No fare required.
  Serves Central Maine Community College (CMCC) Campus
  Not a distinct route; formed by overlap of Routes 6 and 7.
- **Route 9 - Downtown Shuttle**
  Operates every two hours Monday to Friday.
- **Route 10 - Pettengill Park**
  Operates every hour Monday to Friday.

Most routes operate as self-contained blocks, with the following exceptions: Routes 1 and 10 share a vehicle, as do Routes 4, 5, and 9. In addition, as noted above, Route 8 (the Mall Shuttle) is not a distinct route but is formed by the overlap of Routes 6 and 7. These block schedules were introduced recently as a result of COVID-related driver shortages. The previous schedule included a peak fleet requirement of seven buses, rather than six today, and higher frequencies on some routes than those shown here. Although it is Citylink's aim to revert to the previous schedule once the current driver shortage abates, for consistency this analysis considered the current schedule, with one exception. Several past transit studies have recommended that Citylink service be extended later into the evening to accommodate second-shift workers and give passengers additional flexibility in travel times. This study assumed that this change is implemented whether or not bus electrification occurs, with last departures from Oak St. occurring at approximately 7:15pm rather than 5:15pm as they do now.

3a. Stakeholder Environment

Citylink operations occur through a complex interaction between multiple stakeholders. The local Metropolitan Planning Organization (MPO) is the Androscoggin Valley Council of Governments (AVCOG), which receives federal funding on Citylink's behalf. AVCOG also provides the entire staff pool for the Lewiston-Auburn Transit Committee (LATC). As described on the AVCOG website, LATC's primary responsibility is "providing the buses, radios, fare boxes, bus stop signs and shelters, [as well as] overseeing system marketing, setting fares, planning and scheduling, and most other policy matters." Neither of these entities operates or maintains the buses, however – this is the responsibility of Western Maine Transportation Services (WMTS), which is a private company that performs these services under contract. WMTS also operates other services throughout the Lewiston-Auburn region, which serve the same transit hubs downtown but are otherwise independent of Citylink.

This arrangement makes any large-scale transition, like fleet electrification, more complex to implement. The primary complication as compared with a "typical" fleet electrification program is the location of the overnight charging infrastructure. At most transit agencies, the garage where maintenance and overnight storage takes place is the most intuitive location for electric vehicle charging. At Citylink, however, doing so would require multi-million-dollar investment into a garage owned by WMTS, a private company with an operating contract much shorter than the life of the charging assets. This would pose difficulties with obtaining federal grant support for the electrification process and would likely preclude competitive bidding by other companies on future operating contracts. For this reason, this study assumed that overnight charging will not occur at the WMTS depot, and that only a small charger for maintenance use would be installed there. Overnight charging location options are discussed further in Section 9.

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, Citylink's revenue service fleet is composed of 29' and 35' transit buses. In the hybrid and battery electric vehicle space, there is a variety of possible vehicles for Citylink 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 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. 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. <u>Infrastructure Technology Options</u>

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 de-centralized 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 Citylink's future plug style charging systems would have 150 kW of power 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.

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 to provide access to enroute chargers and extra layover time to allow for charging
- Long-range electric buses can cover four of Citylink's six blocks without layover charging

Citylink'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 or set of routes) for the entire day, and then returns to the garage once service has concluded in the evening. Although Citylink'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. Even when diesel heaters are installed, as was assumed in this study, icy 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 Citylink'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 Citylink'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 Citylink'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 Citylink's operations, ranging from slower-speed in-city routes to higher-speed routes to 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 Citylink-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 yielded usable battery energy of 194.4 kWh and 388.8 kWh by 2032. The year 2032 was selected as a "litmus test" because it is near the beginning of the fleet transition schedule specified in Section 8, ensuring that all feasibly electrifiable routes are accounted for without requiring future vehicle procurements to be delayed while battery technology catches up. Clearly, if battery electric bus technology advances faster than anticipated, or if the existing fleet proves reliable and can outlast its 12-year lifespan, there will be a higher operating margin in bus electrification, allowing more service expansion. Conversely, if technology develops more slowly or the existing fleet requires replacement sooner, less service expansion will be possible.

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 2032 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 Block

Block	Mileage	'Short-Range' Bus		'Long-Range' Bus	
		kWh Required	Mileage Shortage/Excess	kWh Required	Mileage Shortage/Excess
Routes 1/10	170.5	362.6	-82.9	385.3	1.7
Route 2	152.5	356.6	-69.3	378.0	4.6
Route 3	181.7	425.1	-98.6	450.5	-26.4
Routes 4/5/9	154.9	384.9	-70.0	406.0	-6.3
Route 6	155.2	363.0	-72.1	384.7	1.7
Route 7	140.7	348.7	-61.7	368.3	8.2

6b. Operational Alternatives

As shown in Table 2, no blocks can be accommodated with 'short-range' buses, and two blocks cannot be accommodated even with 'long-range' buses. To address the operational shortcomings of the battery electric buses a few options were considered. One option – to adopt a split fleet with hybrid buses covering the two longest blocks – was dropped from consideration because of the difficulties inherent in operating a mixed fleet.

Another possibility is to purchase short-range buses and recharge them over the course of the day. This would require additional layover time for charging; as the time between runs is not sufficient for one charger to replenish all six operating buses, particularly with short-range buses which require more frequent charging. In other words, the peak service requirement would increase, with a seventh bus inserted into the rotation to ensure that one bus is always able to charge.

If layover charging were conducted, the operations the schedule (and perhaps even the route structure) would need to be optimized for the needs of the buses. For example, 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 day, with meal and charging breaks happening at the same time). Careful selection of route interlines and route departure times from the hubs can help balance layover durations with the time required for charging. For example, routes that do not serve the layover charger location can be interlined with routes that do serve it, ensuring that all buses can cycle through the layover charger over the course of the day. Due to the increase in fleet size that this alternative would entail, it is currently not preferred by Citylink.

The operationally simpler option, and the plan that is preferred by Citylink stakeholders, is to procure long-range buses and maintain the present fleet size. Although long-range buses could operate today's service pattern (without evening service) without requiring layover charging, the extension of the service into the evening hours increases the required range beyond the expected capability of long-range buses. If the operating performance and battery development forecasts are accurate, this will require a layover charger to be installed. However, because long-range buses can go farther than short-range buses, the available layover time in the schedule will be sufficient to recharge the buses without requiring the addition of another bus for peak service. Even if service is extended later into the evening or expanded with an additional route, the layover charger will be able to support service with the existing fleet size.

For the chosen alternative, there is a close relationship between span of service, battery technology advancement, and layover charging requirements. If the expansion of service into the evening hours does not occur, or if buses have longer range by 2032 than this study has assumed, it is likely that a layover charger will not be required.

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 Citylink 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 introduces operational complexity by requiring a minimum duration for certain layovers. The operational configuration and fleet composition selected by Citylink, 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.

Citylink's current electricity rates are determined by Central Maine Power's 'MGS-S' rate table, as shown in Table 3. Under this rate table Citylink pays a flat "customer charge" monthly, regardless of usage. Citylink 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 peak and is local to Citylink's usage. Finally, Citylink 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 Citylink 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 the customers like Citylink install 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 Citylink 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 Citylink 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 3. It can be seen in the figure that the optimized charging schedule assumes buses will be charged overnight (between 9 PM and 5 AM), outside of the times when Citylink's buses are in-service, using the plug-in chargers. The optimized charging schedule also includes midday charging (at an assumed 200 kW power draw) using overhead fast chargers between 6 AM and 10 AM. This charging schedule avoids charging during the Central Maine Power grid's 'coincidental peak' (between 3 PM and 7 PM), which would allow Citylink 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.

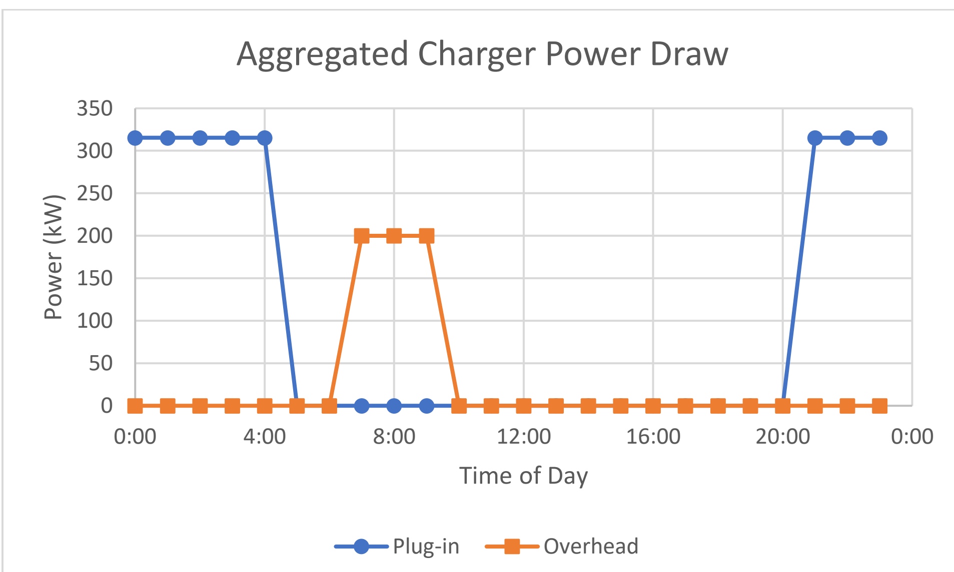


Figure 3 Proposed Charging Schedule for Citylink's Future Fleet

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

Daily kWh consumption = 2613 kWh

Monthly Non-coincidental peak = 315 kW
Monthly coincidental peak = 0 kW

Under Current MGS-S Rate Structure:

$$Daily\ Charge = Daily\ kWh\ consumption \times (Energy\ Delivery\ Charge + Energy\ Cost)$$
$$= 2613\ kWh \times (\$0.001745 + \$0.12954)$$
$$= \$343.05$$

$$Monthly\ Charge = (Monthly\ Non - coincidental\ Peak \times Distribution\ Charge) + (Monthly\ Non - coincidental\ Peak \times Transmission\ Charge)$$
$$= 315\ kW \times \$16.64$$
$$= \$5241.60$$

Under New B-DCFC Rate Structure:

$$Daily\ Charge = Daily\ kWh\ consumption \times (Energy\ Delivery\ Charge + Energy\ Cost)$$
$$= 2613\ kWh \times (\$0.001745 + \$0.12954)$$
$$= \$343.05$$

$$Monthly\ Charge = (Monthly\ Non - coincidental\ Peak \times Distribution\ Charge) + (Monthly\ Coincidental\ Peak \times Transmission\ Charge)$$
$$= (315\ kW \times \$4.39) + (0\ kW \times \$19.35)$$
$$= \$1382.85$$

As this estimate shows, the optional ‘B-DCFC’ rate structure would save Citylink $3,858.75 per month. These savings are, again, achieved by avoiding charging during the coincidental peak between 3 PM and 7 PM, and the reduced monthly ‘distribution’ 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 $6,095 per month from a ‘transmission charge’. Therefore, it is critical that Citylink only charges the buses, whether using plug-in or overhead pantograph, 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 Citylink 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 Citylink’s operation.

8. Asset Selection, Fleet Management and Transition Timeline

Section Summary

- Hatch recommends ordering more 35' buses to allow greater vendor competition
- Hatch recommends installing centralized chargers at the Oak St hub

With operational and charging plans established, it was then possible to develop procurement timelines for infrastructure and vehicles to support those plans. Citylink, 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. Citylink 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.

As an additional complication, Citylink currently operates a mix of 29' and 35' buses. This is done to provide additional capacity on the busier routes (such as College Street) while minimizing inefficient use of larger vehicles on the less ridden routes (such as Minot Avenue). 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 a 29' or 30' bus, with the smallest available being 35'. The vendors that do (such as BYD) are likely to have more limited options, partly because of the smaller space available for batteries and partly because of the smaller market for 29' / 30' buses. Although the market is changing quickly, and within the next few years more 30' models are likely to be introduced, Hatch recommends that Citylink consider shifting to a higher proportion of 35' buses for greater flexibility in ordering. 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 length as operated now.

With respect to infrastructure procurements, the Oak St. parking lot will eventually need to have enough chargers to accommodate all of Citylink'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.

To serve the charging requirements described in the previous section for the proposed electric fleet, a centralized charging architecture is recommended for the Oak St. parking lot. Centralized chargers will give Citylink 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, Citylink will require a minimum of three chargers (for a total of nine dispensers) to ensure there is a dedicated dispenser for each of its seven electric buses needed for pre-COVID 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 one or two spare dispensers to accommodate dispenser cable failures, “hot standby” buses, and possible future expansion. As discussed previously, this procurement schedule assumes that the pantograph charger at the Oak St. bus bays is procured several years after electric bus operation begins. As several Citylink blocks can be operated without layover charging, this delay will let Citylink staff gain operating experience and determine whether a layover charger is necessary or if, for example, battery technology has advanced quickly enough that it is no longer required. This procurement schedule also assumes that two vehicles are included in the first order although only one vehicle is scheduled for replacement; given the agency’s required knowledge acquisition, as well as the range and potential reliability challenges associated with a small fleet of BEBs, a 1:1 replacement ratio – yielding a single electric bus in the fleet – is impractical for supporting daily operation. 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
2024	Two 35’ 450kWh	One 150kW centralized charger (three dispensers) + electrical upgrades and rough-ins for future charger installations (conduit runs, concrete pads, transformers, switchgears, etc.) One 30kW charger at WMTS facility	1101
2031	Three (two 35’ 450kWh, one 30’ 450kWh)	Two 150kW centralized chargers + one pantograph charger at Oak St. transit hub (if warranted)	1901, 1902, 1904
2034	Three (one 35’ 450kWh, two 30’ 450kWh)		2201 – 2203
2035	Two 35’ 450kWh		Pending replacements for 1102, 1401

Hatch recommends that the first (2024) order of electric buses is operated across all the routes. This experience will help Citylink understand electric bus operations and make any scheduling or routing adjustments that may be needed. As discussed above, the experience Citylink will gain will inform the decision on whether an enroute charger is required. 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 city. 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 Citylink operations.

9. Building Spatial Capacity

Citylink's main storage and maintenance facility is the WMTS garage at 76 Merrow Road in Auburn. As discussed in Section 3a, this is a private facility, which makes it impractical for the heavy up-front capital investment that would be required for fleet electrification. In consultation with stakeholders from AVCOG and the cities of Lewiston and Auburn, the following two locations were identified as possible options for overnight charging locations:

- Auburn School Bus Depot, Industry Av, Auburn
- Oak St. Municipal Parking Lot, Lewiston

Section Summary

- The existing WMTS garage is a private facility, making large subsidized investment into it impractical
- Hatch recommends the Oak St. parking lot in downtown Lewiston as the overnight charging location for Citylink

The School Bus Depot is a city-owned facility that already operates a fleet of several dozen school buses. This would ensure a smooth transition, as the only requirements would be charging equipment and a parking area for the Citylink fleet, and would have the potential for future synergies with any school bus electrification projects. However, Auburn stakeholders noted that the Depot is a tightly constrained site, with the existing school bus fleet already filling up the entire parking lot and little room available for expansion. This would mean that any Citylink vehicles relocated to the Depot would displace school buses, which was not practical. In addition, the School Bus Depot would introduce an additional operating location – separate from anywhere used for revenue operations or maintenance – requiring additional deadheading and administration. Therefore, the School Bus Depot was eliminated from consideration.

The Oak St. Municipal Parking Lot in downtown Lewiston, shown in Figure 4, is located directly adjacent to the nearby Oak St. transit hub. Because its primary use is by office workers employed in downtown Lewiston, it is approximately 80% full during the day but only 10% occupied at night. This usage pattern would complement Citylink's expected charging schedule. The parking spaces near the chargers would be marked as daytime-only, with cars parking there (potentially using the chargers and thereby providing revenue to the city) during Citylink service hours and buses taking over the same parking spaces at night. Although Citylink would have to determine a daytime parking arrangement for a spare bus if one is stationed at Oak St., there should otherwise be no interference between Citylink and other users of the parking lot. Further details on the proposed layout of the parking lot are provided in Section 12.

Figure 4 Oak St. Parking Lot, View from Bates St. (Source: Google Maps)

The transit hub area of Oak St. (shown in Figure 5) might, as mentioned earlier, require an enroute charger to ensure service robustness and allow evening service. The hub is well-positioned to allow this, as there are lengthy bus-only areas, with wide setbacks to the adjacent building, along both the Oak St. and Bates St sides of the station. As detailed in Section 12, providing a layover charger here is feasible.

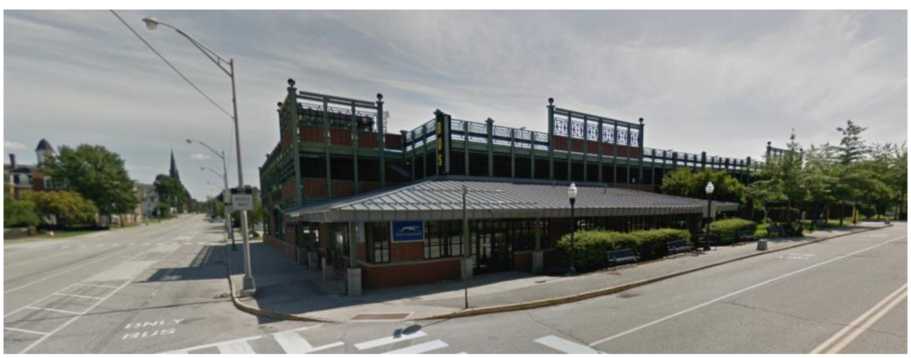


Figure 5 Oak St. Transit Hub (Source: Google Maps)

The Oak St. location will only accommodate vehicle charging; maintenance will continue to occur at the WMTS garage or another similar facility. To ensure that an electric bus can be properly maintained and tested there, a charger (even if a low-powered one) will need to be installed in the maintenance bay. In addition, a dedicated back-shop area will need to be identified to maintain components related to electric drivetrains. As shown in Figure 6, Figure 7, and Figure 8, the WMTS garage should have sufficient space to accommodate these needs.

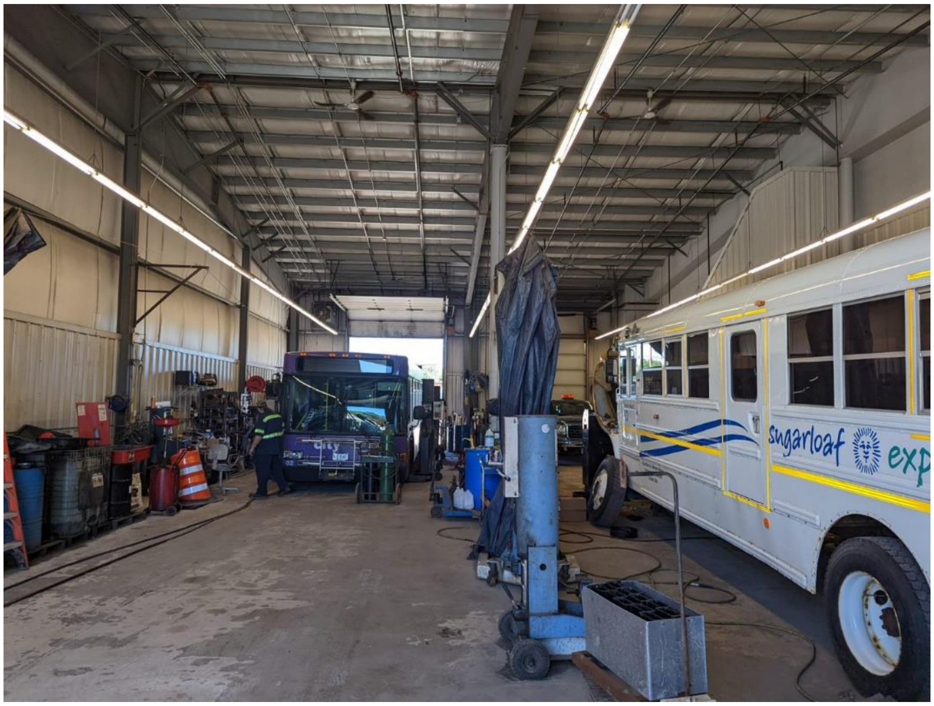


Figure 6 WMTS Facility Existing Maintenance Bay

Figure 7 WMTS Facility Parking Area and New Maintenance Bays Under Construction

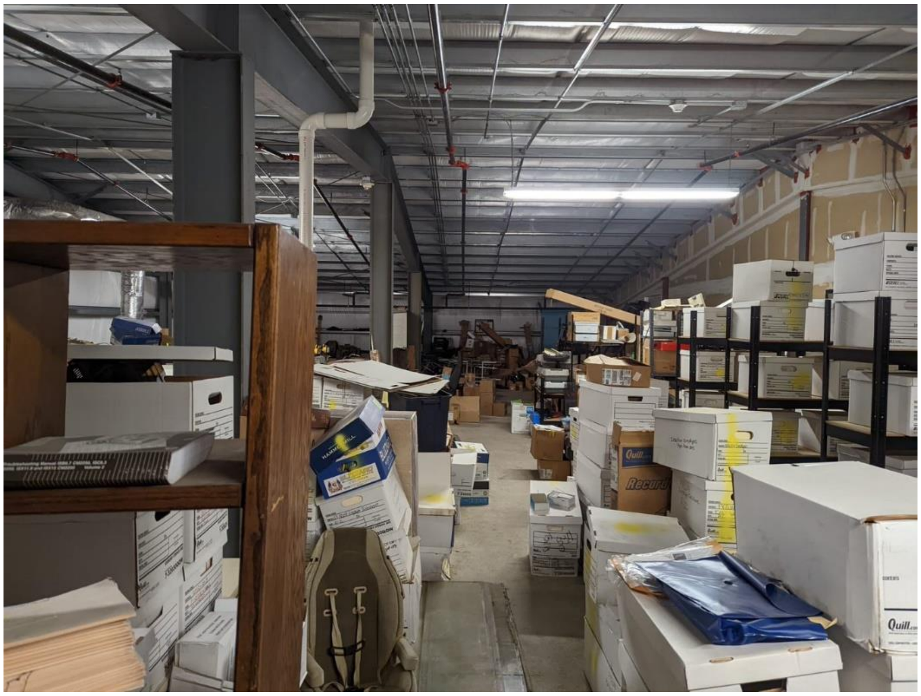


Figure 8 WMTS Facility Upstairs Storage Area (Potential Location for Backshop)

10. Electrical, Infrastructure, and Utility Capacity

Section Summary

- The existing service at the garage is not sufficient to support the charging infrastructure
- Separately metered service will allow the agency to take advantage of the DCFC specific utility rate structure in the future

Central Maine Power is the utility provider for Citylink's primary charging location which proposed to be at the Oak St. Municipal Parking lot. As part of the development of this transition plan, Citylink has been partnering with Central Maine Power to communicate its projected future utility requirements at this location.

The Oak St. Municipal Parking Lot has a 480V 3-phase service that is stepped down to 120/208V through a 75 kVA step-down transformer located outdoors, as shown in Figure 9. This utility feed and transformer are not sufficient for the previously described charging needs at Oak St. which is estimated to be 315kW during the overnight charging period when all vehicles are charging simultaneously. As a result, a new dedicated 350 kVA 480V 3-phase service with a separate meter is recommended for the charging infrastructure. A separate meter for charging operation is also advisable to be able to qualify for the future proposed special EV charging rate structure.

Hatch has confirmed with Central Maine Power that it can accommodate a new 350 kVA service at the Oak St. Municipal Parking Lot. Central Maine Power has provided initial estimate for the new transformers and service feed to be approximately $50,000.

Figure 9 Oak St. Municipal Parking Lot Electrical Distribution Assets

The above capacity estimates include three centralized plug-in charging systems with three dispensers each totaling nine dispensers for overnight charging as well as one overhead pantograph charger for midday rapid charging.

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 must 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. 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. Citylink is in a good position in this regard, as its fleet replacement timeline allows it to wait for the technology to mature before placing an order. Nevertheless, it will be prudent for Citylink 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 WMTS, or another urban transit agency in Maine, that would let Citylink 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
- Work with the city of Lewiston to develop contingency plans in case the layover charger fails and midday use of the plug-in chargers is required (see Section 12).

11b. Electrical Resiliency

Electricity supply and energy resilience are important considerations for Citylink 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 Citylink 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

The Oak St. 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. This would mean that a prolonged power outage would deprive Citylink of the ability to operate service once it has transitioned 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 the Oak St. Parking lot to determine the requirements for backup power. There were only two outages at this location in the last five years (2017 and 2018). Of the two outages, the one in 2017 was insignificant and only lasted for two mins. The second outage that occurred in 2018 lasted for an hour and ten minutes.

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 365 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 460 kWh. 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 six vehicle. Assuming Citylink purchases the centralized chargers with three dispensers each, as recommended in this report, two chargers would be required to charge the fleet. Assuming that all chargers Citylink would purchase would be rated at a minimum 150kW, would have an efficiency of 90%, and a 20% spare capacity, the resulting on-site generation capacity required would be approximately 420 kVA.

Hatch next generated cost estimates associated with the two resiliency system options for the Oak St. Parking lot. Table 6 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 6 Resiliency Options for Worst Cast Outage Scenarios

	Size	Capital Cost
Option 1 On-site Battery Storage	460 kWh	$290,000
Option 2 On-site Diesel Generation	420 kVA	$250,000

The above analysis and corresponding options are based on the historic outage data. 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 Citylink'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 Citylink'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 array would primarily be to offset energy from the grid and reduce utility costs.

An on-site solar system was evaluated for the Oak St. Municipal Parking lot because the top floor of the garage structure provides a large surface area that could be utilized for a solar array as illustrated in Figure 10 below. The solar array could potentially be installed in either of two ways:

1. Install the panels on racks directly on the current parking surface, similar to a roof installation. This method would no longer allow vehicles to park on the top floor of the garage.
2. Build an additional elevated structure over the parking surface allowing cars to park underneath and for the panels to serve as a canopy for the top floor parking.

The city will need to conduct a parking utilization analysis for option 1 or a structural analysis for option 2 to determine the feasibility of installing solar panels on the Oak St. Municipal garage's top floor using the proposed methods.

Figure 10 Oak St. Municipal Garage Proposed Solar Array

Table 7 outlines parameters for the solar power system that could be installed on the top floor of the garage structure as well as the expected annual energy production and resulting cost savings from offsetting energy consumed from the grid.

Table 7 Oak Street Station Parking Garage

Solar System Design Parameters	
Solar System Sizing Method:	Available Area
Solar Array Area Width	90 ft
Solar Array Area Length	200 ft
Solar Array Area	18,000 ft^2
Maximum Number of Panels	598 panels
Maximum System Power	254 kW
Annual Production Coefficient	1,277 hours
Sunny Days Per Year	197 days
Annual Solar Energy Production	292,100 kWh
Annual Electric Usage	711,998 kWh
Maximum Percent of Electrical Usage Offset	41%
Electricity Rate	$0.12954 / kwh
System Cost	**$700,000**
Utility Bill Savings Per Year	**$37,850**
Simple Payback Period Without Grants	**18.5 years**
Payback Period with 80% Federal Grants	**3.7 years**

Based on the above parameters, the maximum daily production for sunny days is estimated to be approximately 1.5 MWh. Since the energy requirement for charging during the outage scenario of 1 hour and 10 minutes is estimated to be 365 kWh, solar has the potential to provide enough energy to support the operation in the event of an outages on a sunny day. In the event of a multiday outage, solar does not have the potential to harvest enough energy during the daytime for full 24 hour charging operation (2.6 MWh).

Solar power generation is not recommended as a primary resiliency system as 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.

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 Citylink'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 rather than to only support outage scenarios. A more detailed study should be conducted to determine the battery energy requirements, which are likely to be more than 365 kWh based on the above solar estimates.

12. Conceptual Infrastructure Design

12a. Conceptual Layouts

Section Summary

- Hatch recommends installing wall-mounted chargers in the Oak St. parking lot, and a layover charger (if needed) on the Oak St. side of the bus bays

To assist Citylink 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 the charging infrastructure – for both enroute and overnight charging – be placed at the Oak St. transit hub / municipal parking lot in downtown Lewiston. As this is the property of the city of Lewiston rather than LATC / Citylink, municipal approval would be required.

The Oak St. parking lot is virtually empty overnight; this leaves sufficient space for overnight bus storage and charging, even considering the additional parking and maneuvering space that buses require. As the buses are too tall to follow the existing parking lot access route through the adjacent parking garage, a new curb cut would likely need to be constructed facing Bates St., resulting in a loss of approximately three parking spaces. The bus layover area would be best placed adjacent to the curb cut to ensure easier bus access. Approximately 45 parking spaces would need to be reserved for daytime parking only, ensuring that the buses would have sufficient room for parking and maneuvering. There are three primary methods for installing the overnight chargers:

+ Mounted on the garage wall
+ Mounted on mid-lot islands
+ Suspended from an overhead structure

Of these options, the overhead structure would allow the most layout flexibility, but would also be the most expensive, maintenance-intensive, and difficult to adapt for daytime use. The two ground-level alternatives would offer comparable utility; buses would be able to park adjacent to the dispensers to charge overnight, and cars would be able to use the same spaces to charge during the daytime (generating revenue for the city). Figure 11 and Figure 12 illustrate possible layouts for these two alternatives. Hatch recommends that the city of Lewiston selects the wall-mounted alternative, to minimize the capital and operational impacts of charger installation. Aside from the charging infrastructure itself, the city of Lewiston 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.

At the transit hub, the Bates St. side is occasionally used by Greyhound buses. As these buses are taller than transit buses and are not compatible with pantograph chargers, to avoid interference it is most practical to install the charger on the Oak St. side. The specific location would need to be determined during detailed engineering; key considerations include bus maneuverability, sidewalk space, proximity to charging cabinets, nearby underground utilities, sight lines around parked buses, snow clearance, and security. The figures below show a charger location that would probably best accommodate bus maneuverability to and from the charger.

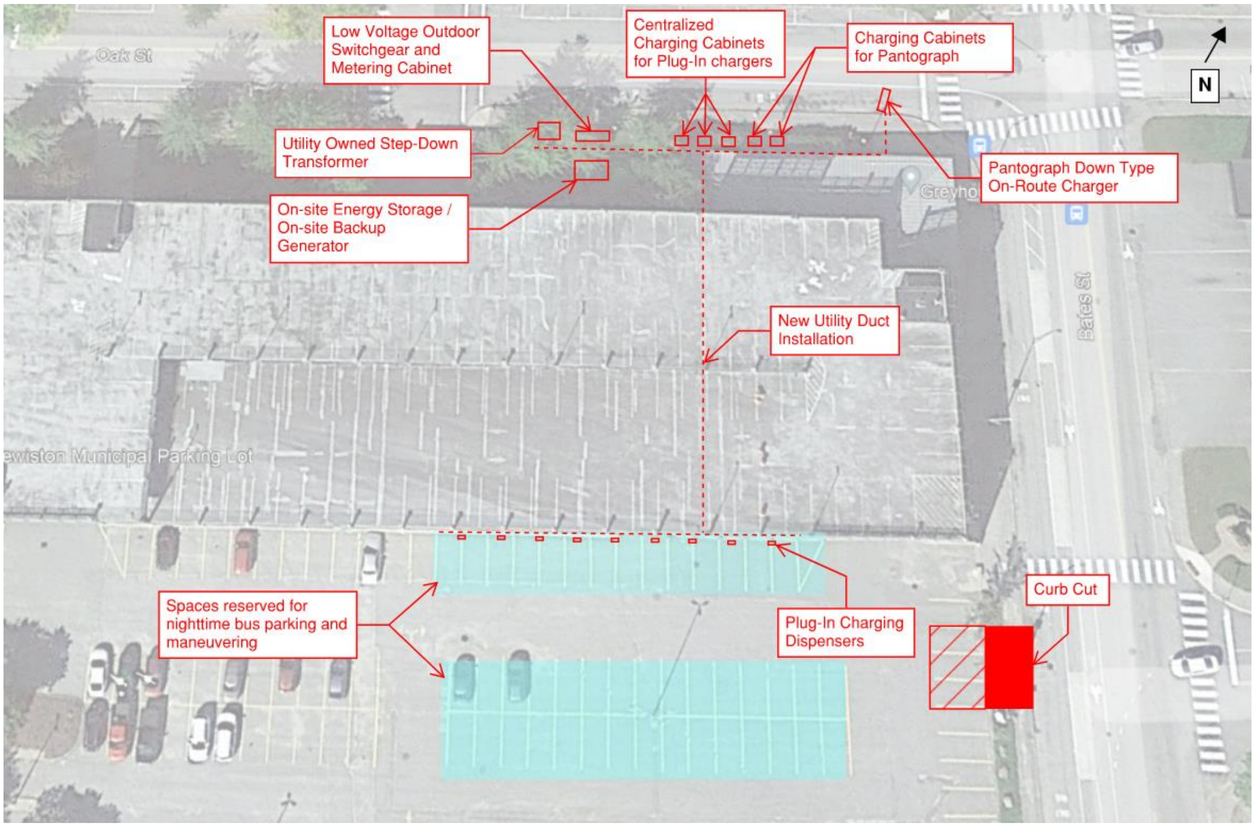


Figure 11 Wall-Mounted Charger Layout Option

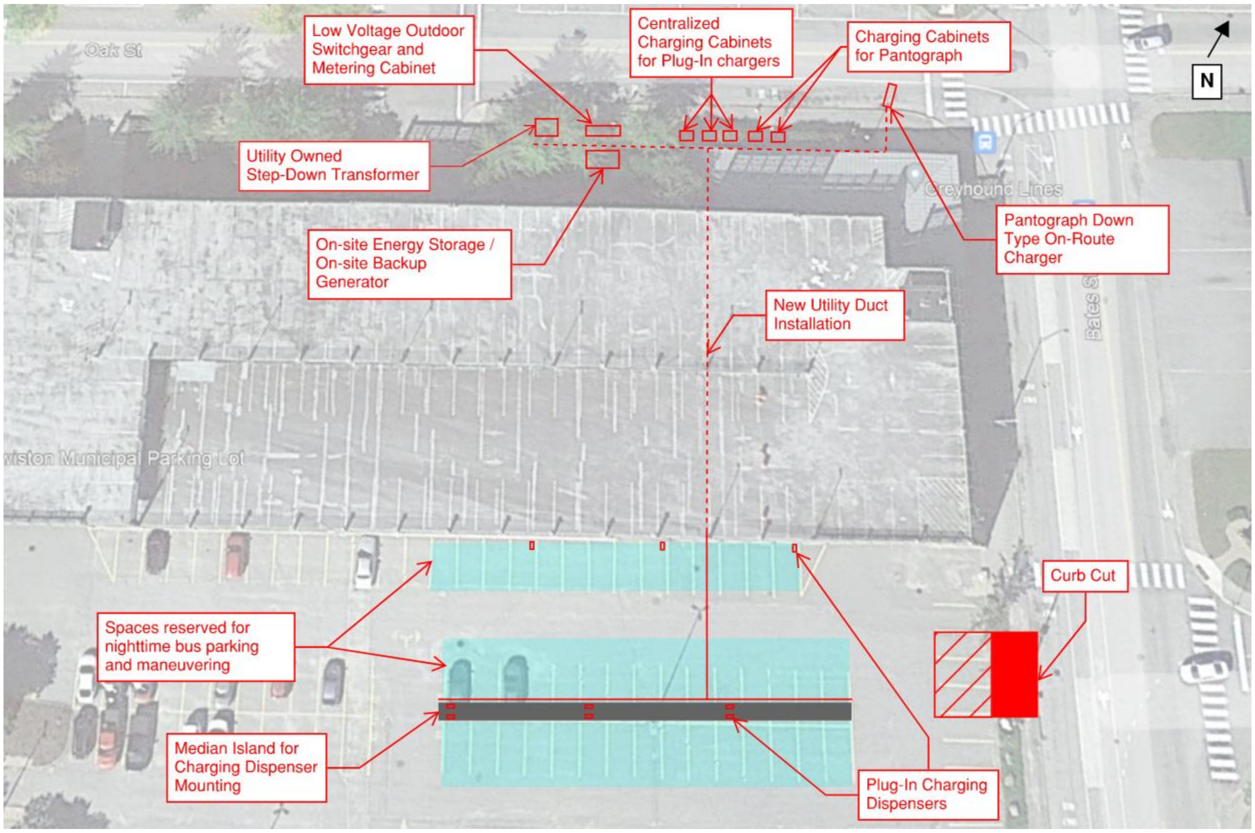


Figure 12 Mid-Lot Island Charger Layout Option

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 Citylink's risk is partially mitigated because the buses will be stored outdoors while charging, Hatch still recommends that Citylink 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 adjacent 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. Each of these requires specific consideration with respect to Citylink's operations; for example, the staff presence can likely be provided by appropriately trained personnel at the fire station across the street from Oak St. Hatch recommends that Citylink 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

Section Summary

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

Citylink's current operating budget is roughly $2.0 million per year. The agency's funding sources are summarized in Figure 13. As can be seen in the figure, Citylink'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.

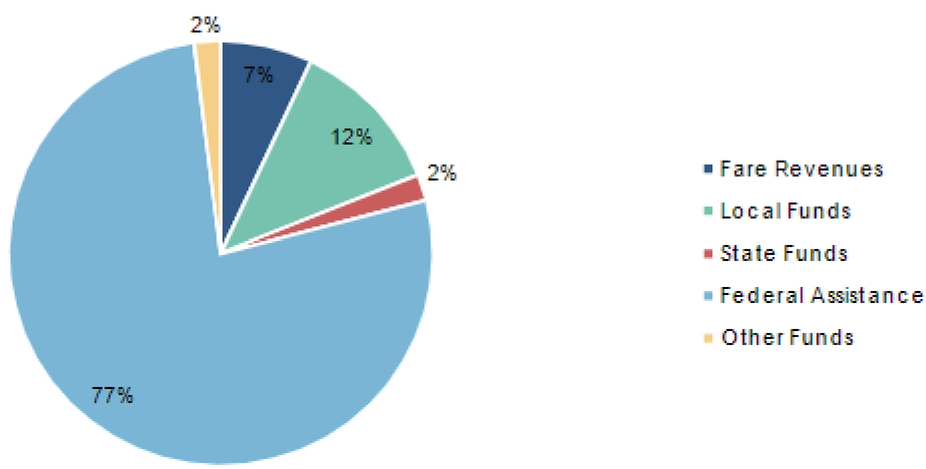


Figure 13 Current Agency Funding Summary (Source: MaineDOT)

As the agency transitions to battery electric technology, additional policies and resources will become applicable to Citylink. Table 8 provides a summary of current policies, resources and legislation that are relevant to Citylink'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 Citylink with guaranteed funding sources. Therefore, this analysis assumes that Citylink will only receive funding through the largest grant programs that provide the highest likelihood of issuance to the agency. Specifically, this analysis assumed that Citylink 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 8 Policy and Resources Available to Citylink

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 at Oak St. (*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 Considerations

Section Summary

- Bus electrification is expected to significantly increase capital cost
- However, reduced Citylink recurring expenses are expected, as electric vehicles cost less to maintain and fuel

Fleet electrification has significant financial impacts for the transit agency. Substantial capital cost increases are expected for both vehicles and infrastructure, compared to what is required for the agency's existing operations with fossil fuel vehicles. On the other hand, some savings on recurring expenses are likely, because electric vehicles require less maintenance and have cheaper energy costs.

The upfront purchase cost of battery electric and hybrid vehicles is much higher than for fossil fuel ones. For battery-electrics, this is largely due to the high cost of the propulsion batteries. Although the cost of batteries is declining each year it is still very high, particularly for heavy-duty transit vehicles. Because transit agencies prefer high-capacity batteries to extend vehicle range, the additional price of the batteries overshadows the cost savings from eliminating the engine and associated components on a diesel or gasoline vehicle. On the other hand, hybrid vehicles do not have large batteries; however, their drivetrains include a full set of components for fossil fuel operation, with electrical propulsion elements added on. This additional complexity increases the price of a hybrid vehicle above that of a fossil fuel one. The vehicle purchase cost increases are often significant, as shown below.

Electrifying a transit fleet often requires major infrastructure investment as well, to ensure that three separate items – the chargers themselves, the facility, and the utility connection – are suited for electric vehicles. Chargers are, of course, a prerequisite to EV operation; they must be purchased, installed, and commissioned. Particularly for heavy-duty applications like transit service, the required chargers are often high-powered and expensive. The facility itself must also be adapted for EV charging. In some cases, for modern facilities designed with spare electrical capacity, this will only require installation of additional conduit to connect to the electrical panel. For other, older facilities with outdated electrical and fire detection systems this could involve a multimillion-dollar upgrade before the first charger can be installed. Finally, the facility's utility connection often requires upgrades as well, as detailed in Section 10. Although bus depots are industrial facilities, their existing electrical systems are usually unsuited for the heavy power demands of EV charging. Although the cost of utility and facility upgrades varies on a case-by-case basis, the price of chargers themselves is relatively consistent and is presented below.

These upfront capital costs are expected to be balanced out by recurring savings on operations and maintenance cost. For operations, EVs are cheaper to recharge than fossil fuel vehicles are to refuel. This is especially true if a charge management system is used to avoid electricity demand charges. Even hybrids, which still require fueling, use approximately 20% less fuel than non-hybrid vehicles, decreasing operations costs accordingly. In addition to operations spending, maintenance costs are expected to decline as well. EVs have many fewer drivetrain parts,

especially moving parts, than fossil fuel vehicles. Therefore, components will wear out less often, meaning that less time has to be spent maintaining them and spare parts can be bought less frequently. For hybrid vehicles, maintenance costs are expected to remain largely unchanged compared to diesel or gasoline vehicles. Although hybrids have more complicated drivetrains, the electric propulsion means that regenerative braking can be used – prolonging the life of components like brake pads – and the fossil fuel engine does not need to handle as intense a duty cycle as it otherwise would.

Table 10 lists the operating and capital costs that Hatch assumed for this study. These are based on Citylink's figures and general industry trends and have been escalated to 2023 dollars where necessary.

Table 9 Cost Assumptions

Asset	Estimated Cost Per Unit (2023 $'s)
30' Diesel Transit Bus	$580,000
30' Battery Electric Transit Bus (225 kWh)	$900,000
30' Battery Electric Transit Bus (450 kWh)	$1,100,000
35' Diesel Transit Bus	$600,000
35' Battery Electric Transit Bus (225 kWh)	$950,000
35' Battery Electric Transit Bus (450 kWh)	$1,115,000
DC Fast Charger – Plug-in Garage (centralized unit and 3 dispensers)	$270,000
DC Fast Charger – Pantograph Overhead	$630,000

Expense	Estimated Cost (2023 $'s)
Diesel bus maintenance	$1.57 / mile
Electric bus maintenance	$1.18 / mile

The proposed fleet transition requires initial capital spending to reduce recurring cost and achieve other strategic goals. This need 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 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 Citylink 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 Citylink to change the speed of its electrification transition or change the desired end-state altogether.

15. Emissions Impacts

One of the motivations behind Citylink'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 Citylink.

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 77-88%

Hatch calculated the anticipated emissions reductions from Citylink'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 Citylink'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 Citylink. 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 10 and Figure 14 summarize the results of the emissions calculations. These results demonstrate that the transition plan will achieve 77% emissions reduction assuming the grid mix that existed in 2020, or 88% 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, Citylink's transition plan will achieve a reduction in emissions in excess of the 45% goal established by the State of Maine.

Table 10 CO_2 Emissions Estimate Results

Scenario	Well-to-Tank (kg)	Tank-to-Wheel (kg)	Grid (kg)	Total (kg)	Reduction over Baseline
Diesel Baseline	307,769	529,711	-----	837,480	----------
Future Fleet (Assuming 2020 grid mix)	21,411	36,852	129,506	187,769	77%
Future Fleet (Assuming 2030 grid mix)	21,411	36,852	42,737	101,000	88%

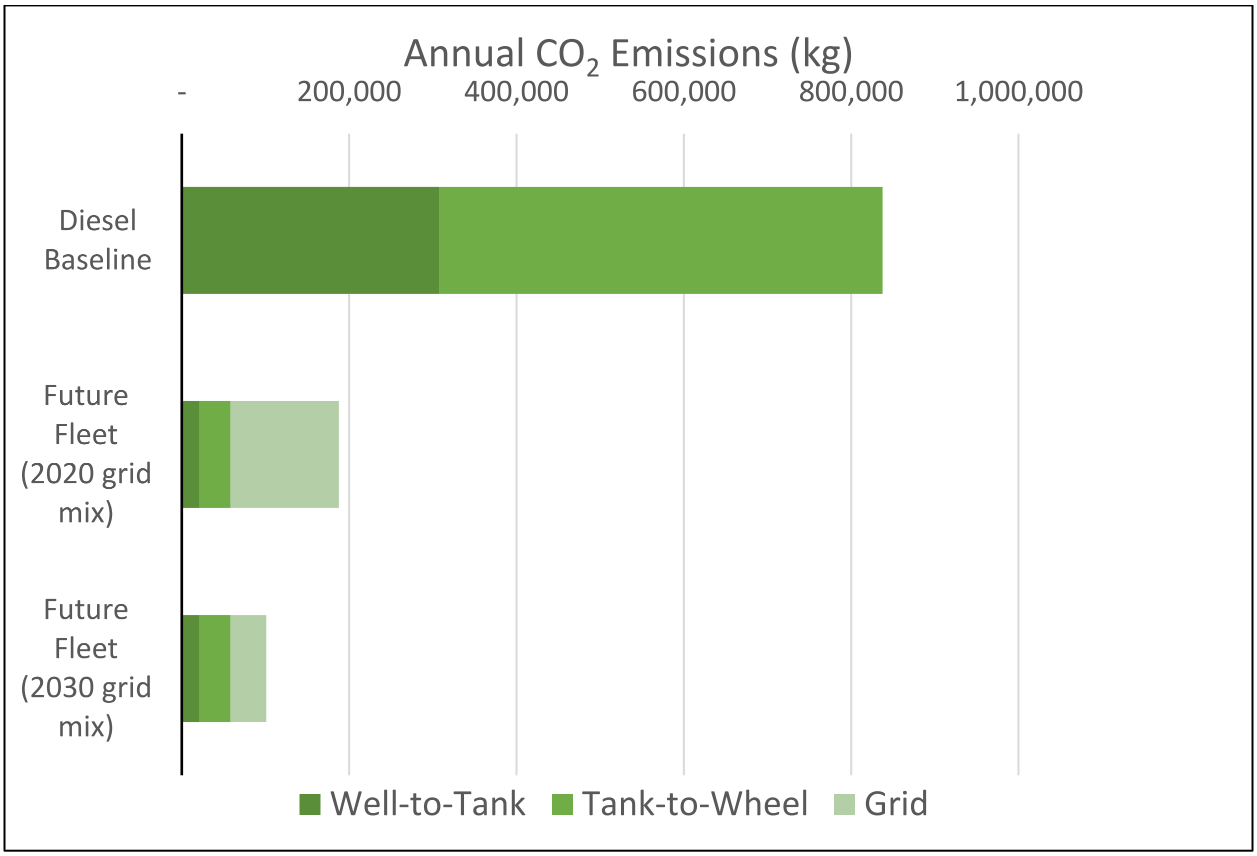


Figure 14 Graph of CO_2 Emissions Estimate Results

Should Citylink 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 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

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

WMTS staff currently operate a revenue fleet composed entirely of diesel vehicles. As a result, the staff have skill gaps related to battery electric vehicle and charging infrastructure technologies that will be operated in the future. To ensure that both existing and future staff members (whether at WMTS or elsewhere) can operate Citylink's future system a workforce assessment was conducted. Table 11 details skills gaps for the workforce groups within the agency and outlines training requirements to properly prepare the staff for future operations.

Table 11 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 Citylink consider the following training strategies:

- Add requirements to the operations contract for the system operator to train its staff on the safe operation and maintenance of electric vehicles.
- 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. If no nearby programs are available, consider partnering with a school to develop a curriculum.

As electric vehicles become increasingly widespread, contracted operators such as WMTS will likely take the initiative to train their own personnel on the new technology, both for electrification of services operated in-house and for increased competitiveness on procurements.

In the long term, Hatch does not expect this new training requirement to limit LATC's ability to competitively bid out the Citylink operations and maintenance contract. As the electrification transition timeline approaches, it is recommended that Citylink partner with its contract operator at that time to 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 Citylink operations

As part of this study, Citylink 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, Citylink currently favors the transition plan presented in this report. Should Citylink'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 Citylink review this transition plan on an annual basis to reevaluate the assumptions and decisions made at the time this report was authored.

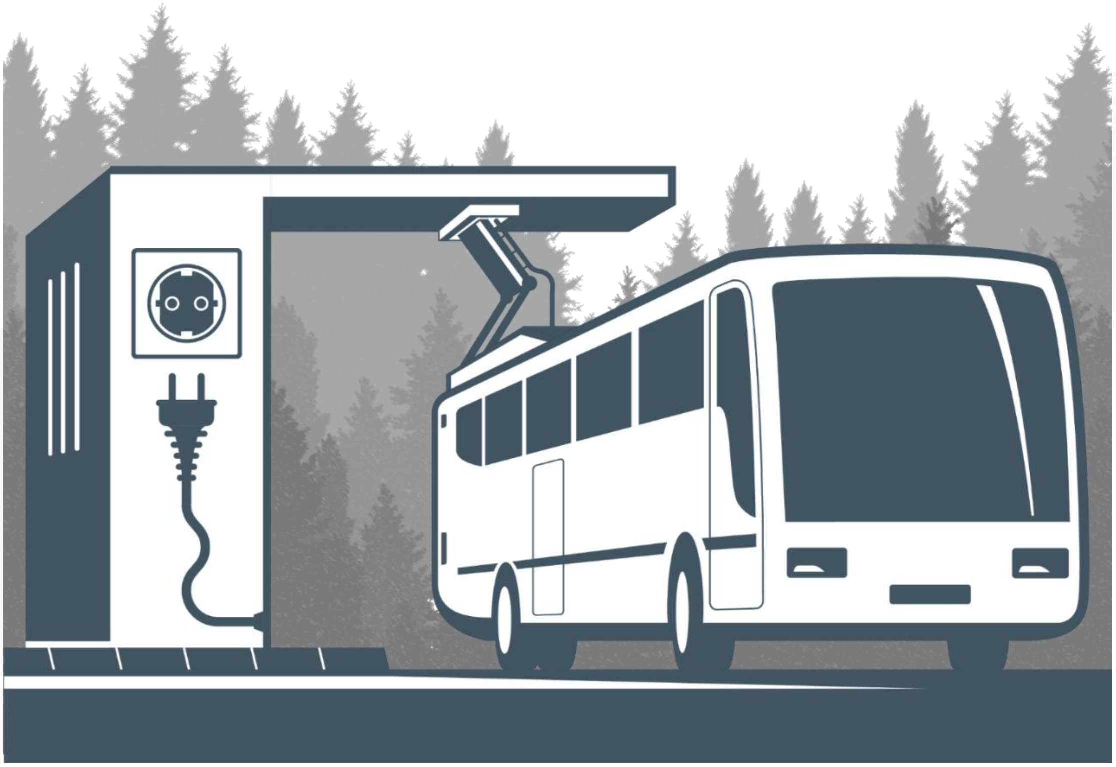
18. Recommendations and Next Steps

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 AVCOG and Citylink have taken the first step toward fleet electrification, and the agency stands well-positioned to continue this process in the coming years. In partnership with MaineDOT, other transit agencies in Maine, as well as other key stakeholders, Citylink 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 Citylink 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 shifting to a higher proportion of 35' buses to increase competition on future vehicle procurements.
    - 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 WMTS, or another urban transit agency in Maine, that would let Citylink 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 Oak St.:
    - Coordinate with the city of Lewiston on required upgrades to the Oak St. lot.
    - Upgrade the electrical utilities to support charging infrastructure.
    - Conduct a fire safety analysis in accordance with Section 12b and standards UL9540, NFPA 70 and 230.
    - Consider omitting the Oak St. layover charger, should early procurements and operations perform acceptably.
    - Develop specifications for chargers and other required infrastructure.
    - Work with the city of Lewiston to develop contingency plans in case the layover charger fails and midday use of the plug-in chargers is required (see Section 12).
    - Conduct a study with the city of Lewiston to predict revenue from public daytime use of the chargers at Oak St.
- For other components of the transition:
    - Work with WMTS to plan for staff training programs, as described in Section 16.
    - Coordinate transition efforts with peer transit agencies, CMP, and Maine DOT.
    - Continually monitor utility structures and peak charge rates and adjust charging schedules accordingly.
    - Review this transition plan annually to update based on current assumptions, plans, and conditions.



Bus Electrification Transition Plan for Greater Portland Metro

GREATER PORTLAND metro

Prepared by:

HATCH

Version: 1.2

3/17/2023

Table of Contents

1. Executive Summary

Greater Portland Metro, the bus agency serving the Portland area in Maine, is currently in the early stages of transitioning its diesel and CNG bus fleet to battery electric vehicles. To effectively plan the remaining stages of 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, Metro 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 maintains the agency's existing fleet size of 44 buses while ensuring viable operation for Metro's range of services. To support the battery electric buses, the agency also plans to procure, install, and commission nine additional charging systems that, together with additional dispensers on the existing chargers, will have the capacity to support overnight charging of up to 33 buses simultaneously.

One of the primary motivations behind Metro'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 an 87% reduction in emissions compared to Metro's pre-electrification operations.

The conclusion of the analysis is that battery electric buses can feasibly support Metro's operations. Furthermore, these buses offer the potential for the agency to greatly reduce emissions, though significant upfront capital spending will be required. Therefore, Metro 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, Metro, 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 Metro's future route plans, vehicle technology options, building electrical capacity, emissions impacts, resiliency, and financial implications.

3. Existing Conditions

Metro is a small transit agency providing service to the Greater Portland area of Maine. The agency currently owns and operates a revenue fleet of 32 diesel vehicles, 10 compressed natural gas (CNG) vehicles, and two battery-electric buses. These vehicles include standard low-floor transit buses (either 35' or 40' in length) and cutaway minibuses. The agency maintains an up-to-date fleet, procuring new buses on a rolling basis to replace old vehicles approaching the end of their useful life (7 years for cutaways and 14 years for transit buses).

Section Summary

- Metro operates ten routes with a 44-bus fleet, two of which are battery-electric buses

Table 1 Current Vehicle Roster

Bus Type/Roster Number	Fuel Type	Number of Buses	Procurement Date
Gillig Phantom Transit Bus (1101-1107)	Diesel	7	2011
Gillig Phantom Transit Bus (1401-1405)	CNG	5	2014
Arboc Cutaway (1606-1608)	Diesel	3	2015
Arboc Cutaway (1709)	Diesel	1	2016
New Flyer Transit Bus (1810-1814)	CNG	5	2018
New Flyer Transit Bus (1815-1820)	Diesel	6	2018
New Flyer Transit Bus (1921-1926)	Diesel	6	2019
New Flyer Transit Bus (2027-2033)	Diesel	7	2020
New Flyer Transit Bus (2134-2135)	Diesel	2	2021
Proterra 35' Transit Bus (2236-2237)	Electric	2	2022

Metro has ten fixed routes that operate on mostly 30-minute to 1-hour headways, including the BREEZ, a longer express route that provides service from Portland to Brunswick, ME. Most routes operate the same service pattern throughout the day. Nearly all routes serve the downtown Portland area, where connections are also available to other transit agencies, as shown in Figure 1 below.

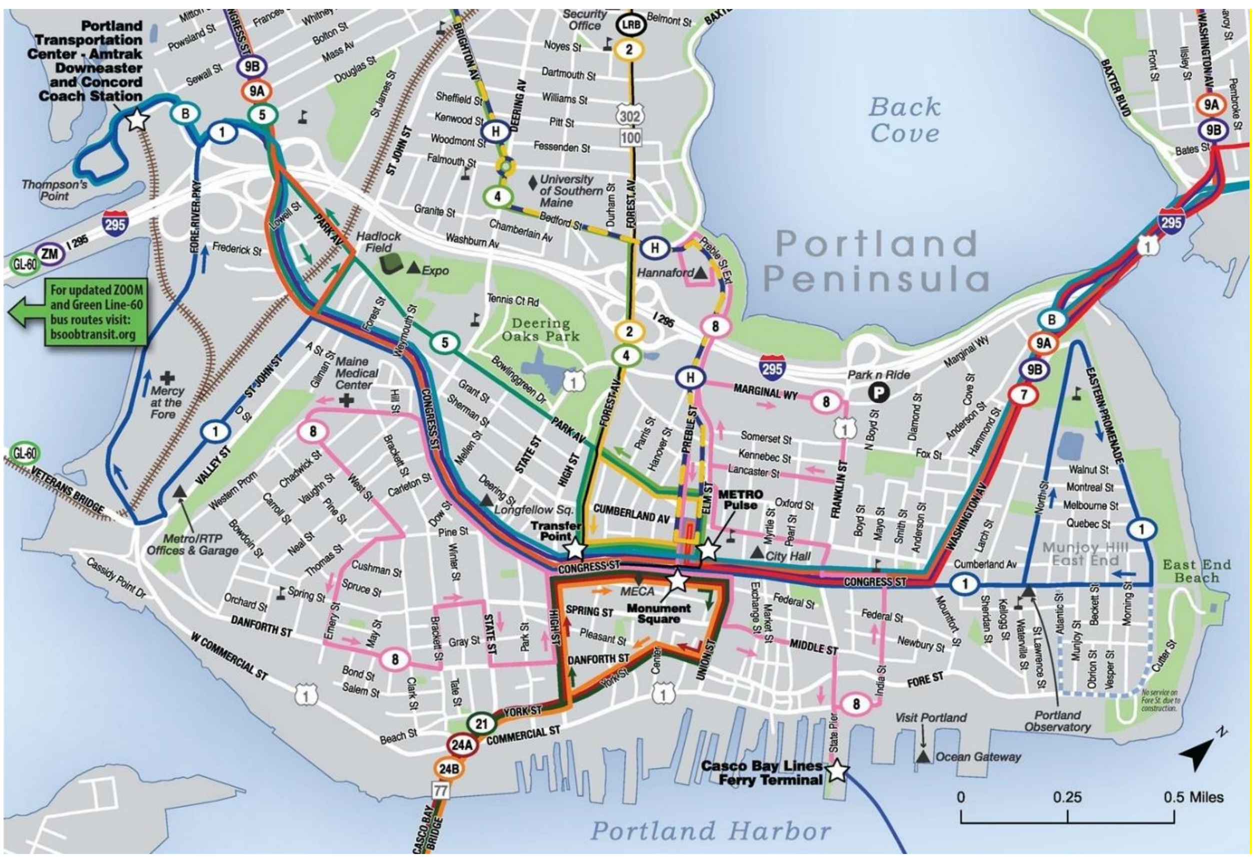


Figure 1 Map of Metro and Other Regional Transit Services in Downtown Portland

- **Route 1 – Congress Street**
  Serves Thompson's Point/Portland Transportation Center and Munjoy Hill/Eastern Prom, via Congress Street and Fore River Parkway.
  Operates mostly every 30 minutes on Mondays-Saturdays, from 5:00 AM to 11:00 PM.
  Operates every hour on Sundays from 8:00 AM to 6:00 PM.
- **Route 2 – Forest Avenue**
  Serves downtown Portland and Prides Corner, Westbrook via Forest Avenue.
  Operates mostly every 30 minutes on Mondays-Fridays, from 5:00 AM to 11:00 PM.
  Operates every hour on Saturdays from 6:30 AM to 10:00 PM.
  Operates every hour on Sundays from 8:30 AM to 3:30 PM.
- **Route 3 – Portland, Westbrook, South Portland**
  Serves Portland / Riverside, Westbrook, and South Portland / Maine Mall area.
  Most trips continue with connection to Route 5 service.
  Operates every 45-60 minutes on Mondays-Fridays, from 5:30 AM to 10:30 PM.
  Operates every hour on Saturdays from 8:00 AM to 10:00 PM.
  Operates every hour and a half on Sundays from 10:00 AM to 5:30 PM.
- **Route 4 – Westbrook**
  Serves Portland and Westbrook, via USM (Portland) and Brighton Avenue.
  Operates mostly every 30 minutes on Mondays-Fridays, from 6:00 AM to 11:00 PM.
  Operates mostly every 45-50 minutes on Saturdays from 6:00 AM to 10:30 PM.
  Operates every 45 minutes on Sundays from 8:00 AM to 7:00 PM.
- **Route 5 – Maine Mall**
  Serves downtown Portland and Maine Mall area.
  Operates mostly every 30 minutes on Mondays-Fridays, from 5:30 AM to 10:00 PM.
  Operates mostly every 45-50 minutes on Saturdays from 6:00 AM to 10:00 PM.
  Operates every 45 minutes on Sundays from 8:00 AM to 6:00 PM.
- **Route 7 – Falmouth**
  Serves downtown Portland and Falmouth.
  Operates every hour on Mondays-Saturdays, from 6:30 AM to 6:30 PM.
  Operates every hour on Sundays from 8:30 AM to 4:00 PM.
- **Route 8 – Peninsula Loop**
  Serves Portland Peninsula.
  Operates mostly every 30 minutes on Mondays-Fridays, from 7:00 AM to 6:00 PM.
  Operates every hour on Saturdays from 8:00 AM to 6:00 PM.
  Operates every hour on Sundays from 9:00 AM to 3:30 PM.
- **Route 9A / 9B – Deering / West Falmouth**
  Serves downtown Portland and North Deering in clockwise (9A) and counterclockwise (9B) directions, including all three Portland Public High Schools.
  Operates every 30-60 minutes on Mondays-Fridays from 5:30 AM to 10:00 PM.
  Operates every hour on Saturdays, from 7:30 AM to 10:00 PM.
  Operates every hour on Sundays from 8:30 AM to 3:30 PM.
- **Husky Line**
  Serves Portland, Westbrook, Gorham, and the two USM campuses.
  Operates mostly every 45 minutes on Mondays-Fridays, from 6:30 AM to 10:00 PM.

Operates mostly every 45 minutes on Saturdays from 8:00 AM to 10:00 PM.
Operates mostly every 45 minutes on Sundays from 8:00 AM to 6:30 PM.

+ **Metro BREEZ** (Express)
  Serves Portland, Yarmouth, Freeport, and Brunswick.
  Operates every 45-90 minutes on Mondays-Fridays, from 6:30 AM to 10:00 PM.
  Operates every 2-3 hours on Saturdays from 8:00 AM to 8:30 PM.
  Operates every 2-3 hours on Sundays from 9:00 AM to 7:30 PM.

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, Metro's revenue service fleet is composed primarily of 35'-40' transit buses, as well as several cutaways which are being replaced with transit buses. In the hybrid and battery electric vehicle space, there is a variety of possible vehicles for Metro 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. 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 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

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 Metro’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.

Metro’s electrification plan (discussed below) anticipates installing one pantograph-style charger at the Elm St Pulse, which is the hub of the network. These chargers are only compatible with transit-style buses, which have conductive bars on the roof. If Metro plans to share the charger with other transit agencies that operate different vehicle types – for example, RTP’s Lakes Region Explorer, which runs a cutaway vehicle, or BSOOB’s Zoom service, which operates a commuter coach – then the charger 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. To allow maximum futureproofing and regional coordination, Hatch recommends that Metro consider adding this to the Elm St Pulse charger specification as a priced option.

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
> - To avoid wasteful deadheading, on-route charging is required for Elm St routes

Metro's current operating model (for its diesel and CNG vehicles) is similar to that of many transit agencies across the country. Except for buses operating school trips or supplemental peak-hour service, most vehicles leave the garage at the appropriate time in the morning, operate (on the same route or pair of routes) for the entire day, and then return to the garage once service has concluded in the evening. Although Metro'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 diesel and CNG vehicles, but may not always be valid for electric vehicles, which have reduced range in comparison. Metro has operated its new electric buses accordingly, with a vehicle typically operating for as long as it is able and then being replaced with a diesel once its state of charge reaches 30-40%. Metro noted that the buses have not been able to operate for a full day, even given the comparatively mild weather experienced 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. Although practices like pre-conditioning the bus before leaving the garage are recommended to extend range, winter conditions will present challenges in electric bus operation.

6a. Operational Simulation

To assess how battery electric buses' range limitations may affect Metro'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 Metro's operations. As mentioned above, it was not necessary to simulate hybrid operations because the vehicles offer comparable range to diesel and CNG buses.

Hatch conducted a route-specific electric bus analysis by generating "drive cycles" for several routes that represented the typical modes of Metro'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 Metro-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. 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 Metro’s plans for fleet acquisition and depot reconstruction, battery capacity values as of 2032 were taken for analysis. (Buses procured before 2032 can be assigned to less energy-intensive blocks). Combined with the safety margins discussed in Section 4, this yielded usable battery energy of 194 kWh for short-range transit buses and 388 kWh for long-range transit buses. Clearly, if battery electric bus technology advances faster than anticipated, or if the existing fleet proves reliable and can outlast its 14-year lifespan, 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 potentially additional on-route chargers or buses may be required.

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.

Table 2 Energy Requirements by Block

Block	Mileage	‘Short-Range’ Bus		‘Long-Range’ Bus	
		kWh Required	Mileage Shortage/Excess	kWh Required	Mileage Shortage/Excess
Route 1	164.7	447.6	-93.1	472.3	-29.1
	130.1	353.3	-58.4	372.8	5.6
Route 2	174.5	407.1	-91.3	429.8	-16.7
	225.7	526.0	-142.3	555.3	-67.7
Route 3/5	250.9	551.6	-160.9	583.8	-83.0
	197.5	438.5	-110.0	464.0	-32.0
	220.9	491.4	-133.8	519.5	-55.6
	173.9	385.8	-86.2	407.7	-8.0
Route 4	177.2	418.5	-95.0	445.0	-22.4
	159.8	377.4	-77.5	401.3	-5.0
	243.1	574.1	-160.9	610.4	-88.3
Route 7	200.4	406.2	-104.9	430.3	-19.4
Route 8	89.7	243.5	-18.1	257.0	45.9
	88.1	239.6	-16.6	252.8	47.4

Block	Mileage	'Short-Range' Bus kWh Required	'Short-Range' Bus Mileage Shortage/Excess	'Long-Range' Bus kWh Required	'Long-Range' Bus Mileage Shortage/Excess
Route 9A / 9B	173.8	383.0	-85.7	410.8	-9.3
	108.2	238.7	-20.1	256.0	56.3
	147.5	325.3	-59.5	348.9	16.9
	186.9	411.9	-98.9	441.8	-22.5
Route 9 (Schools)	30.0	66.0	58.4	70.9	134.7
	36.5	80.4	51.8	86.2	128.2
	30.3	66.7	58.0	71.6	134.4
	40.8	89.8	47.5	96.4	123.9
Husky Line	230.2	424.5	-125.1	454.5	-33.4
	254.7	470.5	-150.1	503.6	-58.3
Metro BREEZ	362.8	631.2	-251.0	663.9	-150.3
	243.5	425.0	-132.5	447.0	-31.8
	305.7	534.3	-195.3	562.0	-94.6

6b. Operational Alternatives

As shown in Table 2, short-range buses can only accommodate the four school-trip blocks, 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.

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 Metro to continue operations without being impacted by vehicle range constraints. This is feasible for the school trip services, which have a lengthy midday layover period that can be used for charging. For the other services, however, adopting hybrids would not correspond with Metro's existing and planned 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, Metro 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, Metro is currently considering this option only for blocks with lengthy midday scheduled layovers (such as some Breez and Route 9 blocks) and for routes terminating at Thompson's Point (where no on-route charger is planned) but not for the bulk of its routes.

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 and recharge less quickly than long-range buses. Operationally, this has an impact on infrastructure and fleet size requirements. As short-range buses require more charging time per hour of operation, a greater number of buses must be charging at any given time, requiring a larger number of chargers and buses. This is compounded by the need to avoid charging during system-peak times to reduce electricity costs (discussed below), which increases the need for charging in the hours leading up to the beginning of the system peak. Therefore, three additional buses would be required for peak service, as well as two chargers at the Elm St Pulse; the extra charging time would also require more driver hours and operating cost. Operation with long-range buses, on the other hand, would allow Metro to continue operations with its existing fleet size and only one charger; a bus currently unused during the midday (for example, a Breez bus or school trip vehicle) would operate in place of the vehicle being charged. These fleet and infrastructure cost savings exceed the additional upfront expense of purchasing more expensive long-range buses. For this reason, Metro stakeholders have chosen to proceed with the latter option of purchasing long-range buses and recharging them throughout the day.

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, 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 Route 7 does not provide any layover time, with buses arriving at Elm St on the half-hour and departing immediately thereafter. However, Route 7 operates on a 60-minute frequency, and one hour is too long of a charge window for a single bus to allow all buses access to the charger throughout the day. Therefore, interlining vehicles between Route 7 and another route would be prudent to give all vehicles adequate charging time. A final option is to revise a route to start and end near the depot, to allow buses low on charge to be swapped out for fresh buses without requiring deadheading. A bus low on battery would operate the outbound trip and be replaced with a fresh bus, which would operate the inbound trip before resuming service on another route. In the meantime, another bus low on battery would operate the next outbound trip. This would reduce reliance on the on-route charger and may (assuming sufficient frequency on that route) eliminate the need for the charger entirely. As Metro 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.

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 Metro 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 introduces operational complexity by requiring a minimum duration for certain layovers. The operational configuration and fleet composition selected by Metro, 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.

Metro's current electricity rates are determined by Central Maine Power's 'MGS-S' rate. However, this rate structure is only applicable for services with peak load of 400kW or less. As discussed further down in this section, the peak load for Metro's depot charging location will exceed 1000 kW, requiring Metro to adopt the 'LGS-S-TOU' rate structure. Hence, the 'LGS-S-TOU' rate structure, as shown in Table 3, is assumed to estimate the utility cost under the "current" rate structure. Under this 'LGS-S-TOU' rate structure, Metro will pay a flat "customer charge" monthly, regardless of usage. Metro will also pay 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 Table 3 below. This peak charge is not related to Central Maine Power's grid peak and is local to Metro's usage. Finally, Metro is charged an 'energy delivery charge' of $0.001654 per kWh, and an 'energy cost' at a statewide average rate of $0.12954 per kWh. These costs are recurring and are dependent on the amount of energy used by Metro throughout the month.

The on-route charging load is under 400 kW so the on-route charging location will be eligible for the current 'MGS-S' rate structure, under which Metro pays a flat "customer charge" monthly, regardless of usage. As shown in Table 4, Metro 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 peak and is local to Metro's usage. Finally, Metro is charged an 'energy delivery charge' of $0.001745 per kWh, and an 'energy cost' at a statewide average rate of $0.12954 per kWh. These costs are recurring and are dependent on the amount of energy used by Metro 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 the customers like Metro install a new meter and dedicated service for their charging equipment to accurately account for the power draw associated with charging.

The new rate structures would provide Metro 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 Metro to develop a charging plan which avoids charging buses during these hours.

Table 3 Utility Rates Structure Comparison (depot)

	Current Rates (LGS-S-TOU)	Future Rates (B-DCFC)
Customer Charge	$734.28 per month	$147.19 per month
Peak Demand Charge	$17.73 per non-coincidental peak kW (calculated monthly)	$2.60 per non-coincidental peak kW (calculated monthly)
Shoulder Demand Charge	$3.34 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	$0.001654 per kWh	$0.003747 per kWh
Energy Cost	$0.12954 per kWh	$0.12954 per kWh

Table 4 Utility Rates Structure Comparison (on-route)

	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 3 for the depot charging at 114 Valley Street facility and Figure 4 for on-route charging at the Elm St Pulse. It can be seen in the figures that the optimized charging schedule assumes buses will be charged overnight (between 7 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 the overhead fast charger at Elm St between 9 AM and 3 PM and again between 7 PM and 8 PM. (Although the overhead fast charger is capable of power levels up to 450 kW, as discussed previously, this analysis assumes a maximum power level of 300 kW plus a safety margin; this helps reduce power costs and provides operational resilience by allowing charging speed to be increased where needed in case of traffic delays). This charging schedule avoids charging during the Central Maine Power grid's 'coincidental peak' (between 3 PM and 7 PM), which would allow Metro 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.

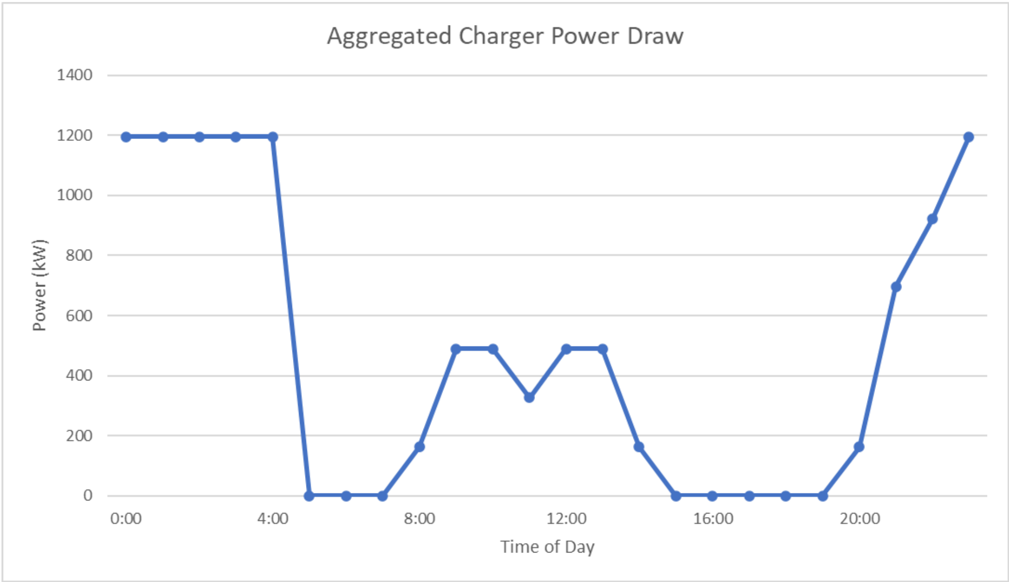


Figure 3 Proposed Depot Charging Schedule for Metro's Future Fleet

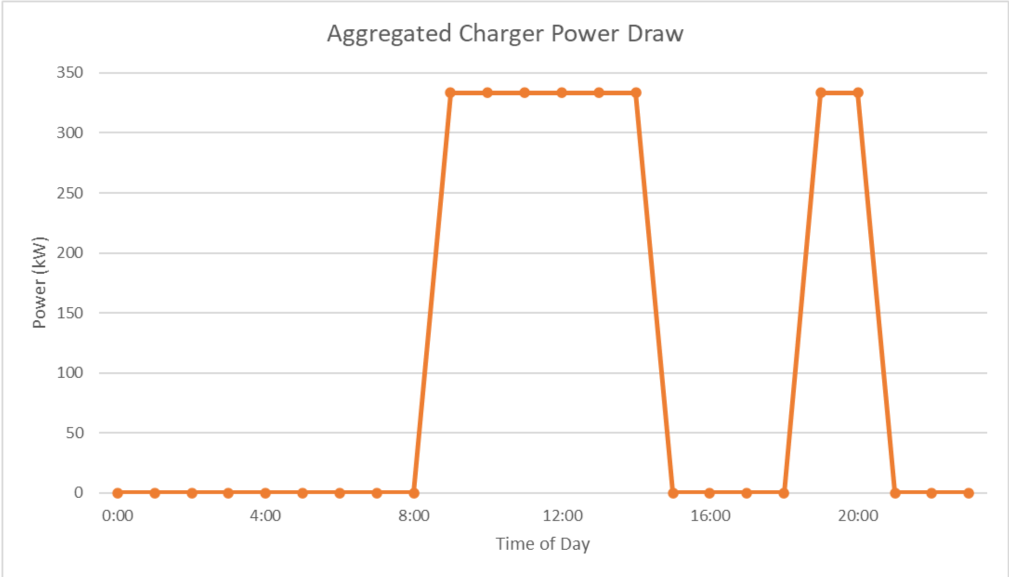


Figure 4 Proposed On-route Charging Schedule for Metro's Future Fleet

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

Depot - 114 Valley St Facility

Daily kWh consumption = 9,807 kWh
Monthly Non-coincidental peak = 1196 kW
Monthly coincidental peak = 0 kW

Under Current LGS-S-TOU Rate Structure:

$$Daily\ Charge = Daily\ kWh\ consumption\ \times (Energy\ Delivery\ Charge + Energy\ Cost)$$
$$= 9{,}807\ kWh\ \times (\$0.001654 + \$0.12954)$$
$$= \$1286.61$$

$$Monthly\ Charge = Max\ ((Highest\ Power\ during\ Peak\ Period \times Peak\ Demand\ Charge), (Highest\ Power\ during\ Shoulder\ Period \times Shoulder\ Demand\ Charge), (Highest\ Power\ during\ Off - Peak\ Period\ \times Off - Peak\ Demand\ Charge))$$
$$= Max\ \big((490\ kW \times 17.73), (490\ kW \times \$3.34), (1{,}196\ kW \times \$0)\big)$$
$$= Max\ (\$8{,}687.70, \$1636.60, \$0)$$
$$= \$8{,}687.70$$

Under New B-DCFC Rate Structure:

$$Daily\ Charge = Daily\ kWh\ consumption\ \times (Energy\ Delivery\ Charge + Energy\ Cost)$$
$$= 9{,}807\ kWh\ \times (\$0.001654 + \$0.12954)$$
$$= \$1286.61$$

$$Monthly\ Charge = Max\ ((Highest\ Power\ during\ Peak\ Period \times Peak\ Demand\ Charge), (Highest\ Power\ during\ Shoulder\ Period \times Shoulder\ Demand\ Charge), (Highest\ Power\ during\ Off - Peak\ Period\ \times Off - Peak\ Demand\ Charge)) + (Monthly\ coincidental\ Peak\ \times Transmission\ Charge)$$
$$= Max\ \big((490\ kW \times 3.34), (490\ kW \times \$3.34), (1196 \times \$0)\big) + (0\ kW\ \$19.35)$$
$$= Max\ (\$1{,}636.60, \$1{,}636.60, \$0)) + (\$0)$$
$$= \$1{,}636.60$$

On-Route – Elm St Pulse

Daily kWh consumption = 2,613 kWh

Monthly Non-coincidental peak = 315 kW
Monthly coincidental peak = 0 kW

Under Current MGS-S Rate Structure:

$$Daily\ Charge = Daily\ kWh\ consumption\ \times (Energy\ Delivery\ Charge + Energy\ Cost)$$
$$= 1{,}222\ kWh\ \times (\$0.001745 + \$0.12954)$$
$$= \$160.43$$

$$Monthly\ Charge = (Monthly\ Non-coincidental\ Peak\ \times Distribution\ Charge) + (Monthly\ Non-coincidental\ Peak\ \times Transmission\ Charge)$$
$$= 333\ kW\ \times \$16.64$$
$$= \$5{,}546.67$$

Under New B-DCFC Rate Structure:

$$Daily\ Charge = Daily\ kWh\ consumption\ \times (Energy\ Delivery\ Charge + Energy\ Cost)$$
$$= 1{,}222\ kWh\ \times (\$0.001745 + \$0.06580)$$
$$= \$160.43$$

$$Monthly\ Charge = (Monthly\ Non-coincidental\ Peak\ \times Distribution\ Charge) + (Monthly\ Coincidental\ Peak\ \times Transmission\ Charge)$$
$$= (333\ kW\ \times \$4.39) + (0\ kW \times \$19.35)$$
$$= \$1{,}463.33$$

As this estimate shows, the optional 'B-DCFC' rate structure would save Metro $7,051.10 per month at the depot location and $4,083.34 per month at the on-route charging location. These savings are, again, achieved by avoiding charging during the coincidental peak between 3 PM and 7 PM, and the reduced monthly 'distribution' 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 $19,554.60 per month at the depot location and $6,443.55 at the on-route charging location from a 'transmission charge'. Therefore, it is critical that Metro only charges the buses, whether using plug-in or overhead pantograph, 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 Metro 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 Metro's operation.

8. Asset Selection, Fleet Management and Transition Timeline

Section Summary

- Hatch recommends consolidating smaller orders into larger procurements to gain economies of scale
- Hatch recommends purchasing, rather than leasing, BEB batteries
- Hatch recommends installing a centralized charger at Elm St Pulse
- Hatch agrees with Metro's plan to coordinate fleet electrification with depot reconstruction

With operational and charging plans established, it was then possible to develop procurement timelines for infrastructure and vehicles to support those plans. Metro, like almost all transit agencies, acquires buses on a rolling schedule. This helps lower average fleet age, maintain stakeholder competency with procurements and new vehicles, and minimize scheduling risks. However, this also yields a high number of small orders. For any bus procurement – and especially for a newer technology like electric buses – there are advantages to larger orders, such as lower cost and more efficient vendor support. Metro 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.

Another key decision to consider when developing a transition plan is battery ownership. Some BEB vendors, such as Proterra, 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 especially demanding duty cycles, which are most likely to accelerate battery degradation and warrant midlife battery replacement.

These programs, however, 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, particularly if electricity or maintenance costs are higher than expected. 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 Metro will be unable to operate the bus for the typical 14-year period, and will not be able to reuse the battery in any second-life applications. (Although second-life technology is in the 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 14-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 Metro 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 Metro’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. Metro’s next order of electric buses can be accommodated by installing additional dispensers on the existing chargers; subsequent orders will arrive after Metro’s depot is expected to be rebuilt. Hatch recommends that the depot be designed for a fully electric fleet, with dedicated space and power provision for all required chargers, with any support infrastructure for the remaining diesel/CNG fleet constructed in a temporary configuration for eventual removal.

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 Metro 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, Metro will require a minimum of nine additional chargers, plus four additional dispensers on the existing chargers (for a total of 33 dispensers) to ensure there is a dedicated dispenser for each of the 27 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. 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 provides a summary of the proposed vehicle and infrastructure procurement schedule. This schedule excludes the diesel vehicles to be procured in 2025; those vehicles are accounted for during their following replacement cycle in 2039, when the fleet will become fully electrified.

Table 5 Proposed Fleet and Charging System Transition Schedule

Year	Buses Procured	Infrastructure Procured	Buses Replaced
2024	3 (3 450 kWh 35’)	4 additional dispensers on existing chargers	1101-3

2025			
2026			
2027			
2028	5 (5 450 kWh 35’)	Two additional charger with 6 dispensers	1401-5
2029			
2030			
2031		New depot; 7 new chargers with 21 dispensers, including transformers, switchgear, and utility feed Relocate existing transformer, chargers, dispensers	
2032	11 (11 450 kWh 40’)		1810-20
2033	6 (6 450 kWh 35’)		1921-6
2034	7 (7 450 kWh 35’)		2027-33
2035	2 (2 450 kWh 35’)		2134-5
2036	6 (6 450 kWh 35’)		2236-7, replacements for 1606-8, 1709
2037			
2038			
2039	4 (4 450 kWh 35’)		Replacements for 1104-7

Hatch recommends that Metro continue to operate its electric buses across all the routes, as it is doing now. This will help Metro continue to gain experience with electric bus operations and make any scheduling or routing adjustments that may be needed. Also, 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 city. 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 Metro operations.

9. Building Spatial Capacity

Section Summary

- The 114 Valley St facility has sufficient space for required infrastructure and may undergo a proposed expansion.
- The Elm St Pulse is a feasible location for on-route charging.

Metro’s main storage and maintenance facility is located at 114 Valley Street in Portland, Maine. The current depot has space for 48 buses, with most vehicles housed in the storage area shown in Figure 5. The garage is currently equipped with two 150kW DCFC charging cabinets for the agency’s new Proterra buses. As shown in Figure 5, these are located along the eastern wall of the storage area. Though the present chargers ensure that the existing electric fleet can be properly charged and maintained, additional dispensers will need to be installed with upcoming bus orders. In addition, a dedicated back-shop area will need to be identified to maintain components related to electric drivetrains. If Metro’s plans change and the existing facility needs to be retained for the long-term future, there should be sufficient space to accommodate these needs. The open, unobstructed design of the vehicle storage facility makes installation of overhead charging equipment comparatively simple (though a structural upgrade will likely be required), and shop space formerly used by RTP (which moved to its own facility in 2019) could be repurposed for BEB component storage and repair.

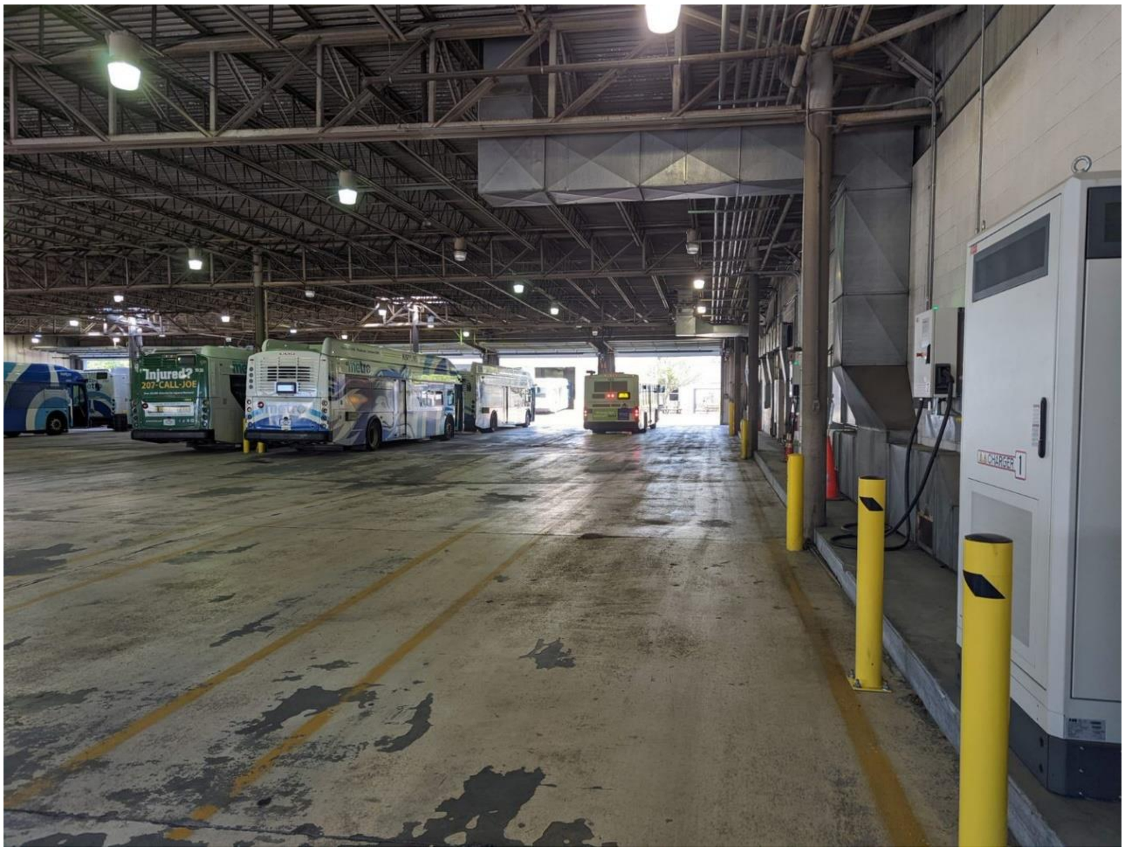


Figure 5 Existing DC Fast Chargers at 114 Valley St Facility

Metro is, however, in the process of designing a new facility that will replace the existing one. It is expected to occupy the same footprint as the existing facility, as well as the nearby parcel at 151 St John Street, and have space for up to 100 buses. Though this plan is in the very early stages, Metro expects to design the new facility specifically to serve BEBs, with diesel and CNG infrastructure provided on a temporary basis until the fleet is fully electrified. As a BEB-specific facility, it is expected to have sufficient space for all required chargers, dispensers, transformers, fire protection measures, and other items. Figure 6 shows the extents of the existing (in solid) and expanded (in dashed) property.

Figure 6 Existing and Proposed Footprint of Maintenance and Storage Facility

The Elm St Pulse, located at 21 Elm St in central Portland, is served by nearly all of Metro's routes. Downtown Portland is a regional transit hub, with service from Metro, BSOOB, RTP, and SPBS all converging at its center. As the primary transit hub and terminal for the greatest number of routes, the Elm St Pulse makes intuitive sense as a charging location. However, it has limited sidewalk space, as shown in Figure 7; discussions with other transit agencies and city and state governments would be needed to find land for, build, and operate a charging station. In addition, it may not remain the primary hub in the long term, as Metro is in discussions through the Transit Together study to potentially through-route more services across downtown Portland, or potentially have multiple new hubs. As shown in Figure 8, there is ample city-owned land available in downtown Portland, with other land owned by state or federal entities. As the city, state, and federal governments strongly support vehicle electrification, Metro is encouraged to consider partnering with government entities to find an optimal location for a future transit hub and potential on-route charging facility. As any such discussions are in the very early stages, this study assumed a charger at Elm St; spatial constraints at that site are discussed in Section 12.

Figure 7 Elm St Pulse (21 Elm St)

Figure 8 City-Owned Land near the Elm St Pulse in Downtown Portland (Source: City of Portland GIS)

10. Electrical, Infrastructure, and Utility Capacity

Section Summary

- The existing service at the garage can accommodate Metro's next BEB order, but not subsequent orders
- Separately metered service at Elm St Pulse will let Metro take advantage of the DCFC specific utility rate structure in the future

Central Maine Power is the utility provider for Metro's primary charging location at 114 Valley St. As part of its electrification efforts, Metro has been partnering with Central Maine Power to install the required electrical infrastructure.

As part of Metro'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 500 kVA on-site transformer, shown in Figure 9. This transformer can support one additional charger which, together with additional dispensers on the existing chargers, will be sufficient to support nine buses. However, the entire electric fleet will require a peak charging rate of 1.2 MW. As a result, when Metro procures its next set of new chargers in 2031, Hatch recommends that the transformer be upgraded as a part of the installation. This will allow the infrastructure to be fully installed and configured at one time without requiring expensive piecemeal upgrades as electrification advances. In addition, Metro plans to design its new depot for an eventual fleet size of 100 buses; Hatch recommends including provisions (such as spare conduits and transformer pads) to reduce the cost of future electrical infrastructure once the fleet expands beyond its current size.

Figure 9 Dedicated Transformer for BEB Chargers at 114 Valley St

The Elm St Pulse, on the other hand, does not yet have dedicated electrical infrastructure for vehicle charging, so installation of a separately metered service will likely be required. If the current location adjacent to the Elm St Parking Garage is maintained, this service could also potentially be used to install publicly accessible EV chargers in the garage. Coordination with city government, the utility, local stakeholders, and other transit agencies is recommended before determining a final location for the charger.

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 must 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 and CNG 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 Metro 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 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 and CNG 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 accessible 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. Metro 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 Metro'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 Metro borrow spare buses in case of difficulties with its fleet.
+ Retain a small diesel or CNG backup fleet to ensure they can substitute for electric buses if any incidents or weather conditions require it.
+ Develop contingency plans in case the on-route charger fails and midday depot swapping is required.

11b. Electrical Resiliency

Electricity supply and energy resilience are important considerations for Metro when transitioning from diesel/CNG 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 Metro will need to be determined based on a cost benefit analysis.

Table 6 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

The 114 Valley St 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. Metro has a generator that can accommodate low-power building loads (e.g. lighting) during an outage but is not suited for high-power bus charging. Similarly, the Elm St Pulse does not have any high-power generation capacity or other backup systems. This means that a prolonged power outage at both locations would deprive Metro 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 Metro'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.

+ 114 Valley St Bus Storage/Maintenance Facility – This facility has seen one outage in the last 5 years, which lasted for about 2 hours. Metro noted that because this facility is near two major medical complexes, power outages are rare and usually resolved quickly.
+ Elm St Pulse – This location had no recorded outages over the time period analyzed.

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 2.4 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 3 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. Assuming Metro purchases the centralized chargers with three dispensers each, as recommended in this report, 9 chargers would be required to charge the fleet. Assuming that all chargers Metro would purchase would be rated at a minimum 150kW, would have an efficiency of 90%, and a 20% spare capacity, the resulting on-site generation capacity required would be approximately 1.8 MVA.

Hatch next generated cost estimates associated with the two resiliency system options for the 114 Valley St 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	3 MWh	$1.9 M
Option 2 On-site Diesel Generation	1.8 MVA	$1.1 M

The above analysis and corresponding options are based on the historic outage data, and an assumption that service is not reduced as a result of the outage. This assumption is targeted towards short-term, localized outages of the type that would cut off electricity from the 114 Valley St facility but leave the remainder of the city unaffected. These outages are typically too short to implement robust contingency plans, such as extended vehicle charging at Elm St, use of a public fast charger, or implementation of service changes. For long-term localized outages, preparing a contingency plan that incorporates one or more of these measures is recommended. For larger-scale outages that affect a broader swathe of the city, both the available resiliency options and the expected agency performance differ; a greater emphasis will be placed on providing limited service along key corridors, with remaining resources used for emergency transportation, providing buses as warming shelters during winter months, etc. In some cases, Metro's electric buses may also be requested for use as portable batteries to provide power to key buildings.

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 Metro'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 Metro'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 114 Valley St facility because the roof of the future facility is expected to provide a large surface area that could be utilized for a solar array. Although a layout for the new facility has not yet been determined, Metro's current plans call for a building with an approximate roof area of 128,000 square feet. The solar array would likely be installed on racks mounted directly to the facility roof. Given the large available roof footprint, expansion of the solar panels onto an elevated structure above outdoor parking and maneuvering areas is likely uneconomical and is not recommended. Table 8 outlines parameters for the solar power system that could be installed on the future facility roof, as well as the expected annual energy production and resulting cost savings from offsetting energy consumed from the grid.

Table 8 114 Valley St Facility Future Available Roof

Solar System Design Parameters	
Solar System Sizing Method:	Available Area
Solar Array Area Width	357 ft
Solar Array Area Length	358 ft
Solar Array Area	127,806 ft^2
Maximum Number of Panels	5,751 panels
Maximum System Power	2,444 kW
Annual Production Coefficient	1,338 hours
Sunny Days Per Year	200 days
Annual Solar Energy Production	3,270,460 kWh
Annual Electric Usage	2,987,086 kWh
Maximum Percent of Electrical Usage Offset	109%
Electricity Rate	$0.12954 / kwh
System Cost	**$6,732,592**
Utility Bill Savings Per Year	**$423,655**
Simple Payback Period Without Grants	**15.9 years**
Payback Period with 80% Federal Grants	**3.2 years**

Based on the above parameters, the maximum daily production for sunny days is estimated to be approximately 16.3 MWh. Since the energy requirement for charging during the 2-hour outage scenario is estimated to be 2.4 MWh, solar has the potential to provide enough energy to support the operation in the event of an outages on a sunny day. The solar system can harvest enough energy for Portland Metro's needs throughout a full year, though this is likely an oversimplification because power outages tend to be most frequent, and bus energy consumption tends to be highest, during winter months when less sunlight is available. Therefore, solar power generation is not recommended as a primary resiliency system.

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 Metro'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 rather than to only support outage scenarios. A more detailed study should be conducted to determine the battery energy requirements, which are likely to be more than 2.4 MWh based on the above solar estimates.

12. Conceptual Infrastructure Design

12a. Conceptual Layouts

To assist Metro 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 be installed in the 114 Valley St facility, and on-route charging should be installed at the Elm St Pulse. As this is the property of the city of Portland rather than Metro, municipal approval would be required.

Section Summary

- Hatch recommends installing centralized chargers with roof-mounted dispensers in the 114 Valley St facility, and one layover charger at the Elm St Pulse transit hub
- The new depot at 114 Valley St should be designed from the ground up for BEB operation

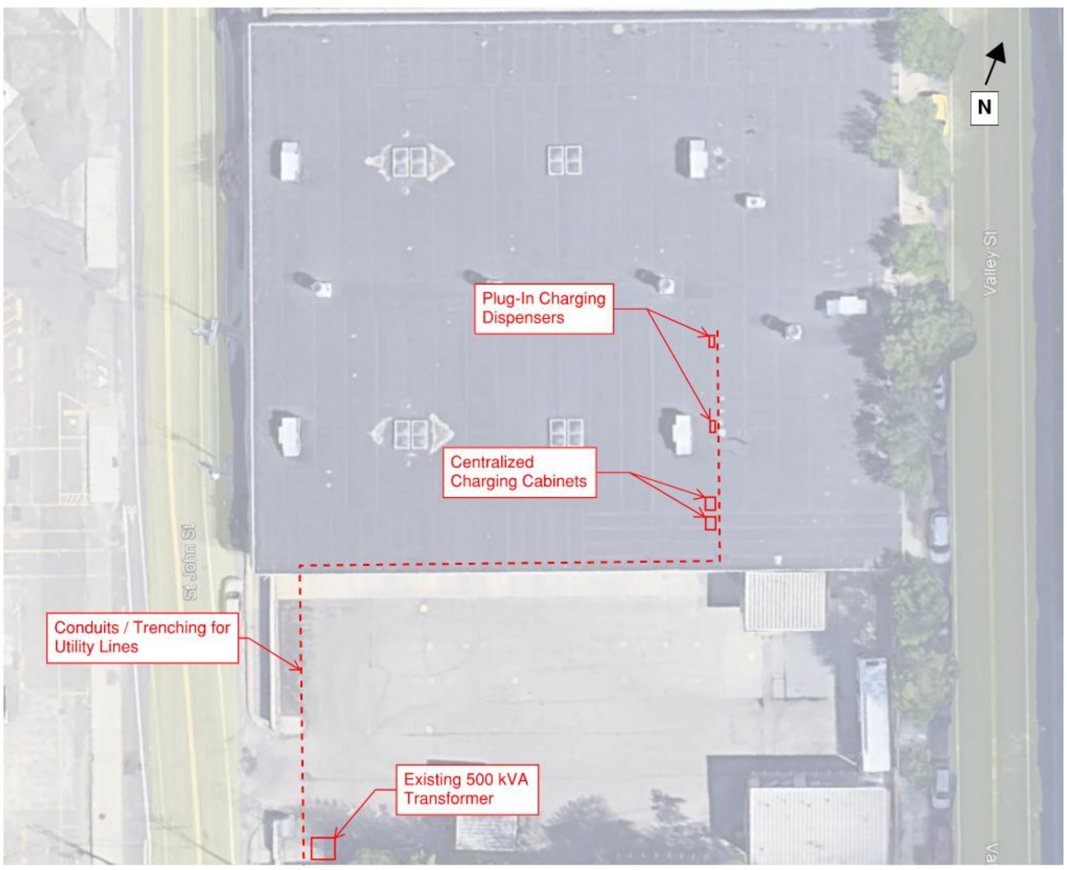


Figure 10 Existing Charging Infrastructure at 114 Valley St

As previously mentioned, at 114 Valley St there are already two existing centralized charging cabinets with one dispenser each; the dispensers are mounted on a wall inside the facility as shown in Figure 10. There is sufficient space to install two additional dispensers along the same wall; to avoid draping charging cables across bus movement paths a fifth and sixth dispenser (to fully utilize the capacity of the existing chargers) would likely need to be suspended from the ceiling. For future charger installations, either at the existing or a new building, there are two primary installation options for the dispensers:

+ Roof-mounted
+ Island-mounted

Each approach has advantages and disadvantages. Roof-mounted dispensers are best for saving space in the depot, as buses can operate around the storage area unencumbered. If pantograph-style dispensers are selected, then the storage capacity of the depot is expected to remain unchanged; the only loss of capacity will result from berths where consistently precise bus positioning is difficult, such as in depot corners or behind building columns. Roof-mounted plug-in dispensers are similarly efficient; although they allow more flexibility for slightly mis-aligned buses, they require marginally wider aisles between buses to provide clearance for the charging cables to hang between buses. The primary disadvantage of roof-mounted dispensers is maintenance, as they are only accessible via a portable lift unless dedicated catwalks are provided. They may also increase building structure cost by increasing the weight of equipment suspended from the roof. Island-mounted dispensers are simpler in both of these regards – they do not require any roof reinforcement and can be readily maintained from ground level. However, their presence on the depot floor reduces space available for bus operation, sometimes by as much as 25%, and introduces “lanes” that make it difficult to maneuver around a stalled bus.

At the Elm St Pulse, the most intuitive location for a pantograph charger is curbside, at the current area used for bus layover and boarding. This is a constrained site, with a sidewalk width of approximately 10 feet, but if aligned roughly parallel to the existing streetlights the pantograph should be able to fit. The road is also sloped gently downward from Congress St to Cumberland Ave; during detailed engineering the slope should be confirmed to not exceed 5 degrees, which is the recommended maximum for typical pantograph chargers. There are also limited spaces nearby for the pantograph charger’s associated cabinets, which are recommended to be no further than 500 feet from the pantograph. In addition to simple geometric compatibility there are several other constraints to consider when placing the pantograph charger; these include bus maneuverability, nearby underground utilities, sight lines around parked buses, snow clearance, and security. Figure 11 below shows a charger location that would probably best accommodate these constraints.

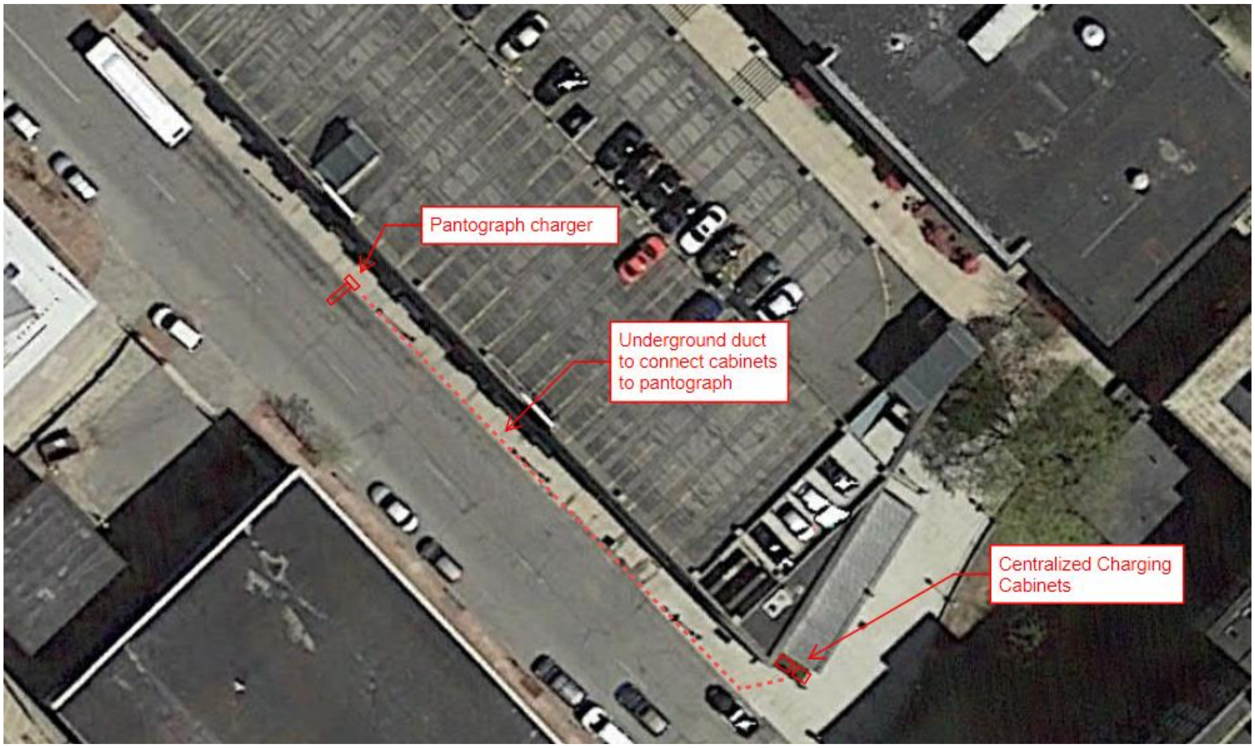


Figure 11 Elm St Pulse On-Route Charger Layout Option

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. Because Metro has a comparatively large fleet and plans to charge it entirely indoors, it is critical that Metro 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 building 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. Each of these requires specific consideration with respect to Metro's operations. Hatch recommends that Metro commission a fire safety study as part of detailed design work for the new depot to consider these factors.

13. Policy Considerations and Resource Analysis

Section Summary

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

In 2021, Metro's operating budget was roughly $12.8 million per year. The agency's funding sources are summarized in Figure 12. As can be seen in the figure, Metro'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.

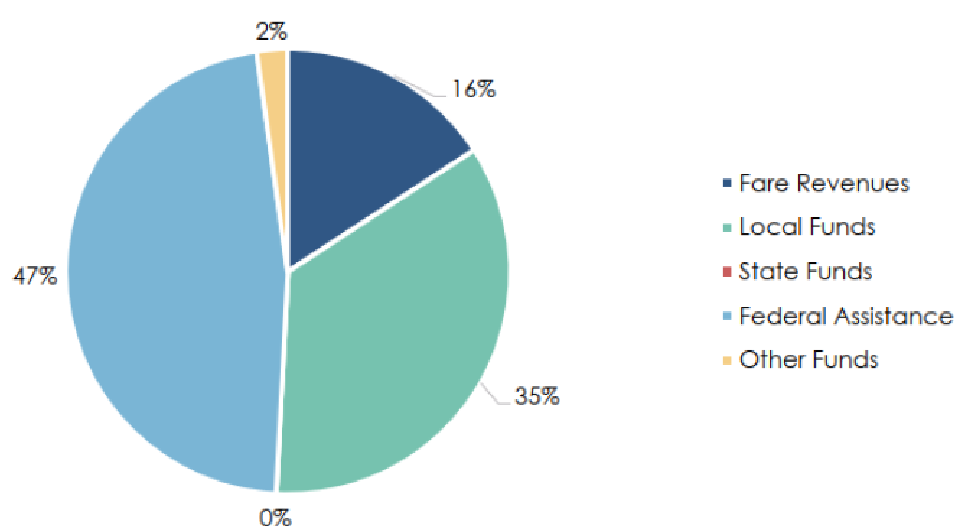


Figure 12 Current Agency Funding Summary (Source: Maine DOT)

As the agency transitions to battery electric technology, additional policies and resources will become applicable to Metro. Table 9 provides a summary of current policies, resources and legislation that are relevant to Metro'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 Metro with guaranteed funding sources. Therefore, this analysis assumes that Metro will only receive funding through the largest grant programs that provide the highest likelihood of issuance to the agency. Specifically, this analysis assumed that Metro 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 Metro

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 Considerations

Section Summary

- Bus electrification is expected to significantly increase capital cost
- However, reduced Metro recurring expenses are expected, as electric vehicles cost less to maintain and fuel

Fleet electrification has significant financial impacts for the transit agency. Substantial capital cost increases are expected for both vehicles and infrastructure, compared to what is required for the agency's existing operations with fossil fuel vehicles. On the other hand, some savings on recurring expenses are likely, because electric vehicles require less maintenance and have cheaper energy costs.

The upfront purchase cost of battery electric and hybrid vehicles is much higher than for fossil fuel ones. For battery-electrics, this is largely due to the high cost of the propulsion batteries. Although the cost of batteries is declining each year it is still very high, particularly for heavy-duty transit vehicles. Because transit agencies prefer high-capacity batteries to extend vehicle range, the additional price of the batteries overshadows the cost savings from eliminating the engine and associated components on a diesel or gasoline vehicle. On the other hand, hybrid vehicles do not have large batteries; however, their drivetrains include a full set of components for fossil fuel operation, with electrical propulsion elements added on. This additional complexity increases the price of a hybrid vehicle above that of a fossil fuel one. The vehicle purchase cost increases are often significant, as shown below.

Electrifying a transit fleet often requires major infrastructure investment as well, to ensure that three separate items – the chargers themselves, the facility, and the utility connection – are suited for electric vehicles. Chargers are, of course, a prerequisite to EV operation; they must be purchased, installed, and commissioned. Particularly for heavy-duty applications like transit service, the required chargers are often high-powered and expensive. The facility itself must also be adapted for EV charging. In some cases, for modern facilities designed with spare electrical capacity, this will only require installation of additional conduit to connect to the electrical panel. For other, older facilities with outdated electrical and fire detection systems this could involve a multimillion-dollar upgrade before the first charger can be installed. Finally, the facility's utility connection often requires upgrades as well, as detailed in Section 10. Although bus depots are industrial facilities, their existing electrical systems are usually unsuited for the heavy power demands of EV charging. Although the cost of utility and facility upgrades varies on a case-by-case basis, the price of chargers themselves is relatively consistent and is presented below.

These upfront capital costs are expected to be balanced out by recurring savings on operations and maintenance cost. For operations, EVs are cheaper to recharge than fossil fuel vehicles are to refuel. This is especially true if a charge management system is used to avoid electricity demand charges. Even hybrids, which still require fueling, use approximately 20% less fuel than non-hybrid vehicles, decreasing operations costs accordingly. In addition to operations spending, maintenance costs are expected to decline as well. EVs have many fewer drivetrain parts, especially moving parts, than fossil fuel vehicles. Therefore, components will wear out less often, meaning that less time has to be spent maintaining them and spare parts can be bought less frequently. For hybrid vehicles, maintenance costs are expected to remain largely unchanged compared to diesel or gasoline vehicles. Although hybrids have more complicated drivetrains, the electric propulsion means that regenerative braking can be used – prolonging the life of components like brake pads – and the fossil fuel engine does not need to handle as intense a duty cycle as it otherwise would.

Table 11 lists the operating and capital costs that Hatch assumed for this study. These are based on METRO's figures and general industry trends and have been escalated to 2023 dollars where necessary.

Table 10 Cost Assumptions

Asset	Estimated Cost Per Unit (2022 $'s)
35' Diesel Transit Bus	$600,000
35' CNG Transit Bus	$650,000
35' Battery Electric Transit Bus (450 kWh)	$1,115,000
40' Diesel Transit Bus	$615,000
40' CNG Transit Bus	$670,000
40' Battery Electric Transit Bus (450 kWh)	$1,170,000
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/CNG bus maintenance	$1.53 / mile
Electric bus maintenance	$1.15 / mile

The proposed fleet transition requires initial capital spending to reduce recurring cost and achieve other strategic goals. This need 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 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 METRO 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 METRO to change the speed of its electrification transition or change the desired end-state altogether.

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 78-87%

One of the motivations behind Metro'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 Metro.

Hatch calculated the anticipated emissions reductions from Metro'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 Metro's existing diesel and CNG fleet were calculated. These calculations used Metro emissions averages for diesel and CNG buses and assumed an average fuel economy of 5.3 miles per gallon of diesel and 4.4 miles per gallon of CNG.

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 and CNG vehicles well-to-tank emissions are due to fuel production, processing, and delivery. This emissions estimate used industry averages for the well-to-wheel emissions associated with the delivery of diesel/CNG fuel to Metro. 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 11 and Figure 13 summarize the results of the emissions calculations. These results demonstrate that the transition plan will achieve 78% emissions reduction assuming the grid mix that existed in 2020, or 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, Metro's transition plan will achieve a reduction in emissions in excess of the 45% goal established by the State of Maine.

Table 11 CO_2 Emissions Estimate Results

Scenario	Well-to-Tank (kg)	Tank-to-Wheel (kg)	Grid (kg)	Total (kg)	Reduction over Baseline
Diesel/CNG Baseline	1,604,926	2,591,298	---	4,196,224	----------
Future Fleet (Assuming 2020 grid mix)	119,276	205,290	611,034	935,600	78%
Future Fleet (Assuming 2030 grid mix)	119,276	205,290	201,641	526,207	87%

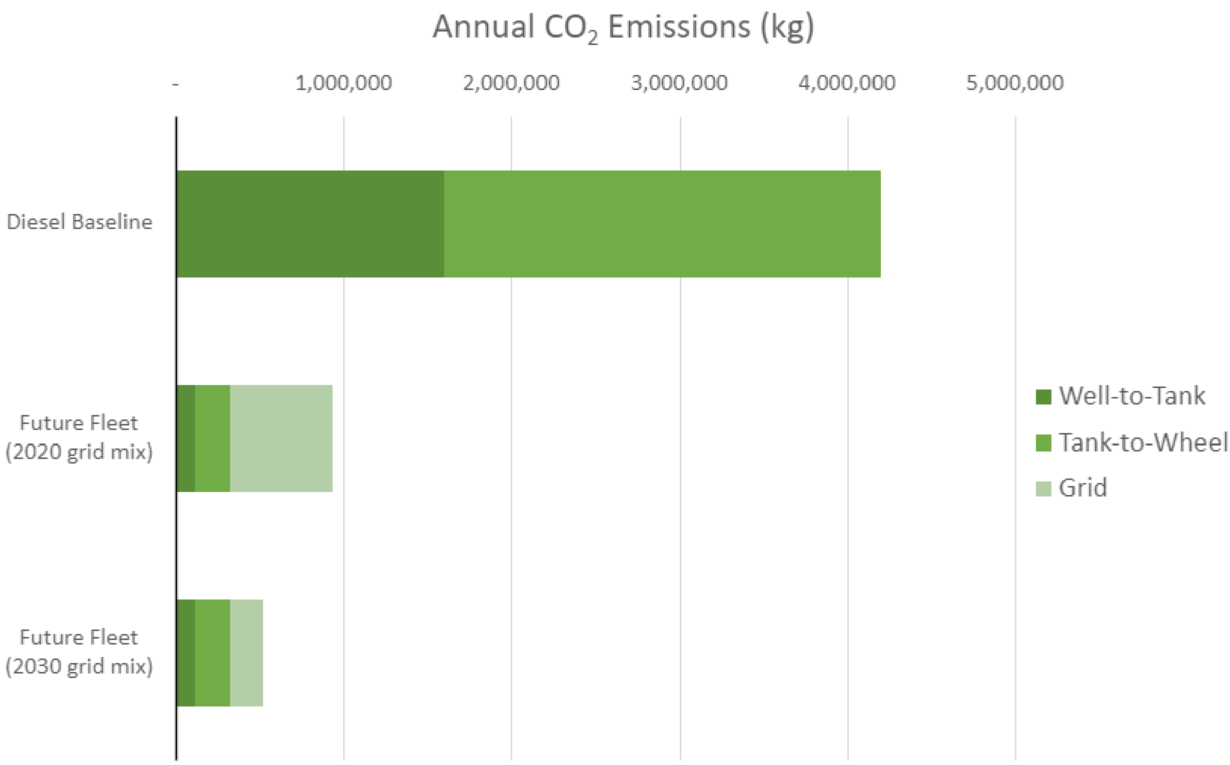


Figure 13 Graph of CO_2 Emissions Estimate Results

Should Metro 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.
+ Install solar panels on the roof of the new facility as detailed in Section 11b.
+ Use spare buses 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, Metro 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 electric vehicle maintenance is currently a relatively niche market, the agency cannot solely rely 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 Metro's future system a workforce assessment was conducted. Table 12 details the key skills that Metro's workforce groups will need to maintain for safe and effective electric bus operation.

Table 12 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 Metro 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 Metro. 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.

As electric vehicles become increasingly widespread, Metro 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 Metro 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

As part of this study, Metro 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, Metro currently favors the transition plan presented in this report. Should Metro'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 Metro review this transition plan on an annual basis to reevaluate the assumptions and decisions made at the time this report was authored.

Section Summary

- Hatch recommends reviewing this report annually for comparison with technology development and Metro operations

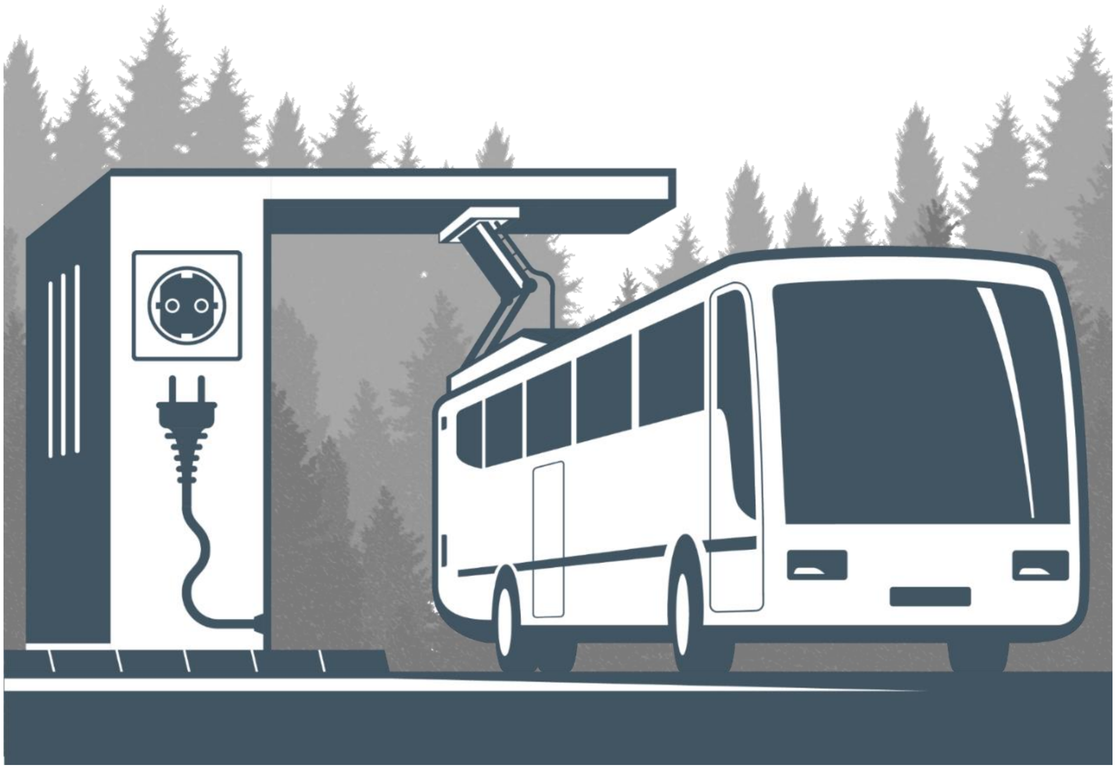
18. Recommendations and Next Steps

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/CNG-powered vehicles in favor of battery-electric. By beginning operation of electric buses Metro 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, Metro will be able to reduce emissions, noise, operating cost, and other negative factors associated with diesel/CNG operations, while complying with the Clean Transportation Roadmap and operating sustainably for years to come.

For Metro 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 combining the four procurements in 2033 – 2036.
  - 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 transit agency in Maine that would let Metro borrow spare buses in case of difficulties with its fleet.
  - Retain diesel/CNG 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 proposed reconstruction of the 114 Valley St facility:
  - Design the roof to support the weight of solar panels.
  - Conduct a fire safety analysis in accordance with Section 12b and standards UL9540, NFPA 70 and 230.
  - Include structural and electrical provisions for a future 100-bus electric fleet.
- For the infrastructure at the Elm St Pulse:
  - Coordinate with the city of Portland on the best location for the Elm St Pulse itself, and on the best positioning of electrical infrastructure at that location
  - Consider adding a plug-in dispenser to the future pantograph charger, for use by RTP's Lakes Region Explorer, BSOOB's Zoom service, or other transit providers
  - Work with the city of Portland to develop contingency plans in case the layover charger fails 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 transition efforts with peer transit agencies, CMP, and Maine DOT.
  - Continually monitor utility structures and peak charge rates and adjust charging schedules accordingly.
  - Review this transition plan annually to update based on current assumptions, plans, and conditions.



Vehicle Electrification Transition Plan for Regional Transportation Program (RTP)

REGIONAL TRANSPORTATION PROGRAM

Prepared by:

HATCH

Version: 1.2

3/17/2023

Table of Contents

1. Executive Summary

Regional Transportation Program (RTP), the paratransit agency serving Cumberland County, Maine, is currently considering transitioning its bus fleet to battery electric and hybrid 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, RTP has expressed a preference for fleet and infrastructure asset configurations that will provide a feasible transition to hybrid and battery electric drivetrain technologies while supporting the agency's operational requirements and financial constraints. The selected configuration maintains the agency's current fleet size of 26 vehicles, replacing four demand-response vehicles with electric vans and the remainder of the fleet with hybrid vehicles. To support the battery electric vans, the agency also plans to procure, install, and commission four level 2 charging stations at the main storage facility in Westbrook, Maine, that will have the capacity to support overnight charging of the electric fleet.

One of the primary motivations behind RTP's transition to hybrid and battery electric drivetrain technologies is to achieve emissions reductions compared to their existing gasoline operations. As part of this analysis, an emissions projection was generated for the proposed future hybrid and battery electric fleet. The results of this emissions projection estimate that the new fleet will provide up to an 29% reduction in emissions compared to RTP's existing gasoline operations.

The conclusion of the analysis is that although battery electric vehicles are not yet ready for complete replacement of RTP's fleet, the agency would benefit from beginning the transition with a small pilot, accompanied by a shift to hybrid technology for the remaining vehicles. These vehicles offer the potential for the agency to greatly reduce emissions, though significant upfront capital spending will be required, and gain the required skillsets and operating experience for future electrification once the technology advances further. Therefore, RTP 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, the Regional Transportation Program (RTP), 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 RTP's future route plans, vehicle technology options, building electrical capacity, emissions impacts, resiliency, and financial implications.

3. Existing Conditions

RTP is a transit agency providing demand-response paratransit service throughout Cumberland County, Maine, in addition to operating one fixed route service. The agency currently owns and operates a fleet of twenty-six passenger vehicles, all of which are gasoline powered. RTP also runs a volunteer-driver program, where drivers use their personal vehicles to fulfill trips and are reimbursed on a per-mile basis; as this is not operated with

Section Summary

- RTP operates one scheduled route and an on-demand paratransit service with a twenty-six-vehicle fleet and volunteer drivers' vehicles
- On-demand vehicles operate for up to eight hours a day on widely varying routes due to unpredictable user demand.

RTP assets it is not considered in this report. There are currently fewer than ten volunteers, but previously there were as many as one hundred volunteer drivers.

Table 1 Current Vehicle Roster

Vehicle Type/Roster Number	Fuel Efficiency (MPG)	Number of Vehicles	Procurement Date/Age	Projected Retirement Date
Non-ADA minivan (90)	19	1	2007	2024
Low floor wheelchair ramp minibus (104, 106)	12.3	2	2010	2023
Wheelchair lift minibus (123)	7.6	1	2013	2023
Wheelchair lift minibus (124)	7.6	1	2014	2023
Wheelchair lift minibus (128)	7.6	1	2011	2025
Wheelchair lift minibus (129, 130, 133)	7.6	3	2010	2024
Wheelchair lift minibus (134-142)	14.5	9	2019	2026
Wheelchair lift bus (143)	9.5	1	2019	2025
Wheelchair lift bus (144)	9.5	1	2019	2027
Wheelchair lift minibus (145-149)	7.6	5	2019	2027
Wheelchair lift minibus (150)	7.6	1	2014	2025

RTP has one scheduled fixed route which typically operates four round trips daily (though it currently only runs three). Each round trip is around three hours long. The route is shown in Figure 1 below. All other RTP services are on-demand paratransit.

Lakes Region Explorer

- Service along Route 302 between Bridgton and Portland.
- Operates every Monday to Friday between 6:00 AM to 7:00 PM, typically four round trips per day.
- Seasonal Saturday service between Memorial Day and Labor Day, 10:00 AM to 6:00 PM.
- Overnight layovers occur at the American Legion in Naples.

On-Demand Paratransit Services

- Based on rider pick-up and drop-off locations, serving all of Cumberland County.
- Service available 5:00 AM to 9:00 PM.
- Trip Master software is used to minimize downtown and optimize route efficiency.
- Volunteer drivers operating their personally owned vehicles are used in remote areas.
- Vehicles are occasionally parked overnight at drivers' homes to decrease deadhead driving.
- Vehicles generally operate for up to eight hours daily, then return to the depot. Vehicles generally operate 80-100 miles per day, though a few operate up to 120 or 150 miles.

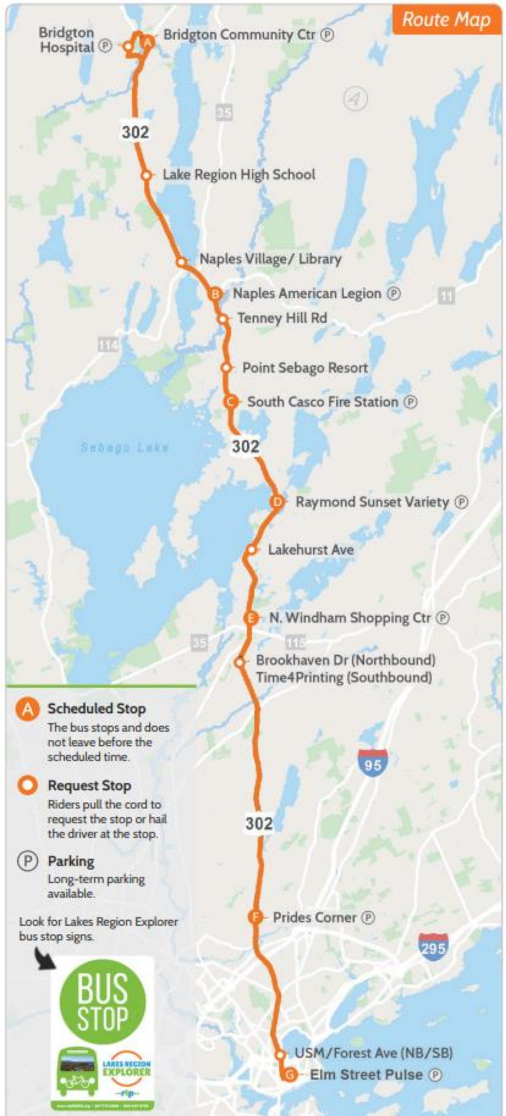


Figure 1 RTP Lakes Region Explorer Route Map

4. Vehicle Technology Options

Section Summary

- Manufacturers' advertised battery capacities do not reflect actual achievable operating range
- Considering a broad range of vehicles may help RTP lower procurement cost

As discussed in Section 3, RTP's revenue service fleet is composed primarily of wheelchair lift minibuses and vans. For future procurements, RTP is planning to shift its demand-response fleet entirely to vans, which are easier to maneuver in narrow streets and driveways. The Lakes Region Explorer vehicles are expected to remain cutaway shuttles as they are today. Both categories of electric vehicles may have limitations that the gasoline versions do not have. For example, because of the weight of the battery, Lightning eMotors's electric van can accommodate eight ambulatory passengers and only one wheelchair (as opposed to two on a gasoline van) while staying under GVWR limits. Shifting from an electric cutaway vehicle (shown in Figure 2) to 30' transit buses would potentially allow greater operating range and passenger capacity; however, such a shift would have cost and maintenance implications for an agency like RTP. In general, though, Hatch recommends that RTP consider a broad range of vehicles in its future procurements, enabling maximum competition and potentially lowering cost.

Figure 2 Lightning eMotors Electric Cutaway Vehicle

In the hybrid and battery electric vehicle space, there is a variety of possible vehicles for RTP to utilize. Hybrids are generally equivalent in range to gasoline vehicles, so no detailed modeling is required. For battery electric vehicles, battery capacity can be varied on many commercially available vehicle platforms to provide varying driving range. For this study, battery electric cutaways were assumed to have 128 kWh battery capacity and vans to have a 120 kWh battery capacity, which are representative values for the range of batteries offered by the industry. Two types of safety margins were also subtracted from the nominal battery capacities of the vehicles. First, the battery was assumed to be six years old (i.e. shortly before its expected replacement). As batteries degrade over time, their capacity decreases. To account for this, the battery capacity was reduced by 20%. Second, the vehicle 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 vehicles from becoming stranded on the road. Combining these two reduction factors yields a usable battery capacity of 64% of the nominal value (82 kWh for the cutaways and 77 kWh for the vans). 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

There are two primary types of chargers that are applicable to RTP's fleet – level 2 chargers, which are common in consumer applications, and DC fast chargers, most often applied toward heavy-duty vehicles. These differ in several key respects, primarily the type of power supplied.

Power distributed by electrical utilities, both at high voltages in long-distance transmission lines and low voltages in conventional wall outlets, is alternating current (AC), while batteries on vehicles use direct current (DC). Smaller vehicles, that require lower power levels, generally accept both types of power and have onboard rectifiers to convert AC input to DC. Accepting AC power reduces the cost of charging equipment. For larger vehicles the required rectifier would be too heavy, so the conversion to DC is conducted within the charger. This has a significant impact on the power levels each type of charger supplies.

The charging power provided by Level 2 chargers can range from 3.1kW to 19.2kW. Typical consumer grade chargers incorporate 6.24 kW of power while commercial grade chargers are available at 19.2 kW charging rates. Examples of such a system are shown in Figure 3.

Figure 3 Example Commercial Level 2 Charging Systems (Source: FLO & Blink)

DC fast chargers, which can provide up to 450 kWh of power, typically come in two types of configurations:

1. Centralized
2. De-centralized

A de-centralized 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. An example of a centralized charging system is shown in Figure 4.

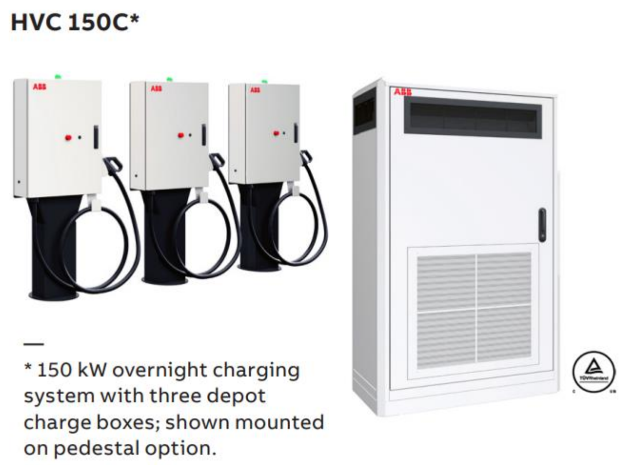


Figure 4 Example Charging Systems (Source: ABB): Charging Cabinet (System) and Three Dispensers (Charge Boxes)

For RTP's operations, Hatch recommends installing 19.2 kW level 2 chargers at the vehicle storage facility. This is advantageous given the initial small pilot fleet – which would make the heavy capital investment for DC chargers less economical – and preference for vans, which require comparatively low power levels. In addition, lower charging levels are generally preferred, as fast charging can shorten the lifespan of the battery pack.

If RTP decides to convert the Lakes Region Explorer route to electric, RTP will need to install a single de-centralized plug-in style DCFC charger at one end of the route. This will allow charging during both overnight layovers (which could also be accommodated by a 19.2 kW level 2 charger if needed) and midday periods (which are short enough that a DCFC charger's high power would be required). This would likely be most feasible at Bridgton Community Center but could also be installed in downtown Portland (or potentially shared with another agency) if the Lakes Region Explorer schedule is modified accordingly. As with the vehicles, charging infrastructure is available in numerous configurations.

6. Route Planning and Operations

Section Summary

- Electric vehicles do not offer comparable operating range to gasoline vehicles – so detailed operations modeling is needed
- Electric cutaways cannot cover RTP's Lakes Region Explorer route without layover charging.
- Shorter on-demand service runs can be electrified with available electric vans

RTP'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 nearly continuously for as long as necessary, and then returns to the depot / overnight parking location. Although RTP'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 vehicles, which have comparable range to gasoline vehicles, but may not always be valid for electric vehicles, which have reduced range, particularly in winter months. (Vans and cutaway shuttles typically do not have auxiliary heaters to reduce the power required for heating, like transit buses; in addition, icy road conditions and cold temperatures degrade electric vehicle performance in the winter). Therefore, battery electric vehicles may not provide adequate range for a full day of service, year-round, on the Lakes Region Explorer and many of the demand-response vehicle runs, particularly if recommended practices like pre-conditioning the vehicle before leaving the garage are not always followed.

RTP's paratransit service operates between 5:00 AM and 9:00 PM on an on-demand basis, though each individual vehicle operates for only eight hours per day. Trip Master software is used to minimize downtime and optimize route efficiency. The vehicles typically do not have long down-times between pick-ups. Therefore, to avoid significant impacts to operations, the electric demand-response vehicles will need to have enough range for a full day of service without top-up charging. Another potential issue is that in some cases, RTP vehicles are parked overnight at the drivers' home to avoid lengthy deadheads to the depot. Doing so with electric vehicles would pose challenges with charging compatibility and reimbursement and is best avoided, at least in the short term.

6a. Operational Simulation

To assess how battery electric vehicles' range limitations may affect RTP'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 RTP's operations. As mentioned above, it was not necessary to simulate hybrid operations because the vehicles offer comparable range to gasoline vehicles.

Hatch conducted a route-specific electric vehicle analysis by generating a drive cycle for the Lakes Region Explorer route, as well as for a route representative of demand-response operation. The full geography (horizontal and vertical alignment), transit infrastructure (location of key stops), road conditions (vehicle congestion, as well as traffic lights, stop signs, crosswalks, etc.), and use of the wheelchair lift were modeled, and the performance of the vehicle was simulated in worst-case weather conditions (cold winter) to create a drive cycle. These RTP-specific drive cycles were used to calculate the energy consumption per mile and therefore total energy consumed by a Lakes Region Explorer or demand-response vehicle.

As discussed in the previous section, the resultant runs were evaluated against a common electric cutaway with a 128-kWh battery and a van with a 120 kWh battery. 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 yielded usable battery energy of 95 kWh for electric cutaways by 2027, which is approximately when the existing cutaway fleet is due for replacement. The electric vans expected to be procured for the initial pilot were based on vehicles available on the market as of this writing; further procurements will be governed by the performance of the initial vehicles. Clearly, if battery electric technology advances faster than anticipated, or if the existing fleet proves reliable and can outlast its 7-year lifespan, more demand-response service will be available for electrification. Conversely, if technology develops more slowly or the existing fleet requires replacement sooner, a pilot deployment may remain the practical limit for the foreseeable future.

Table 2 below presents the mileage and energy requirements for RTP operations. Figures for the Lakes Region Explorer are presented on a per-trip and full-day basis, showing the severe demands the route's length places on the vehicles. Two representative on-demand run lengths are shown, illustrating the operational variability inherent in an on-demand service. Green shading denotes those runs that can be operated by the specified vehicle and red shading denotes those that cannot.

Table 2 Energy Requirements by Run

Block	Mileage	kWh Required	Mileage Shortage/Excess
Lakes Region Explorer (one round trip)	81	87	7
Lakes Region Explorer (full day)	344	372	-256
On-demand (short)	80	77	1
On-demand (long)	120	115	-39

6b. Operational Alternatives

As shown in Table 2, an electric van is expected to have a usable range of approximately 80 miles in the harshest weather conditions. To avoid impact on RTP operations, the most viable service model replaces the vehicles on shorter runs with electric vans, with all other runs being operated by hybrid vehicles. Trip Master's range-conscious routing feature, under development as of this writing, will help RTP choose the best runs on which to assign electric vehicles. The choice of vehicle for subsequent procurements will be heavily influenced by the performance of the pilot fleet: the farther the vehicles are able to travel during harsh winter conditions, the more of RTP's operations are feasible for electrification and the higher a proportion of the fleet Hatch recommends that RTP make electric.

On the Lakes Region Explorer route, an electric cutaway can reliably operate one round-trip before requiring charging. This allows several operating models, which are described below.

One possibility is to recharge the vehicle after each round trip using a fast charger. This would require approximately one hour of charging time to gain sufficient energy to operate another trip. Though this would require revising the schedule, a well-designed timetable could combine vehicle charging time and driver meal break time, maximizing efficiency. As there would not be sufficient time to deadhead to and from the RTP facility for each charging window, this option would require the installation of an RTP-owned fast charger at one of the two terminals, or alternatively an agreement with another party for access to a fast charger during the required times of day and night.

Another possible service pattern is to swap the vehicles at the RTP facility in Westbrook after each round trip, with one vehicle charging while another operates in service. Although this would minimize RTP's dependence on external infrastructure, the resulting increase in fleet size and operator hours make this configuration impractical for RTP.

A third option involves using a transit bus rather than a cutaway vehicle. Because transit buses have more room for batteries on the roof and under the floor, they typically have longer range than cutaway vehicles. In this case, a transit-style bus would likely be able to operate two roundtrips before needing to recharge, allowing charging windows or vehicle swaps to be coordinated with driver shift changes. Adopting a transit bus would also allow RTP to increase capacity on the route, accommodating ridership gains from any service changes the Transit Together project may recommend. However, transit buses are significantly more expensive than cutaways, are less maneuverable on narrow streets, and would require additional training for RTP staff to operate and maintain. Because of these drawbacks, this option is currently not being considered.

A hybrid cutaway vehicle, however, would provide a good balance between the advantages of lower-emission vehicles and the range required for this route. Operations would be able to remain exactly as they are today, since hybrid vehicles have comparable range to gasoline-powered ones. Hatch recommends that RTP tentatively choose this option for the fixed-route vehicles but review this decision at least once before procurement. The state of the electric vehicle market, the performance of RTP's pilot demand-response vehicles, and the feasibility of installing or sharing an enroute fast charger will determine whether electric vehicles are viable for this route or if hybrids are the most practical alternative.

7. Charging Schedule and Utility Rates

Developing a charging schedule is recommended practice while developing a transition plan as charging logistics can have significant effects on fleet operations and costs incurred by the agency. From an operational perspective, charging vehicles during regular service hours introduces operational complexity by requiring a minimum downtime for charging. The operational configuration and fleet composition selected by RTP, and described in the previous section of this report, assumes

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 RTP charge its vehicles economically

that vehicles (excluding the Lakes Region Explorer) will be charged only overnight at the main facility and that all the electric vehicles will be brought back to the facility each night.

RTP's current electricity rates are determined by Central Maine Power's 'MGS-S' rate table, as shown in Table 3. Under this rate table RTP pays a flat "customer charge" monthly, regardless of usage. RTP 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 peak and is local to RTP's usage. Finally, RTP 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 RTP 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 and is available as an optional rate for customers with electric vehicle DCFCs or level 2 charger arrays. To qualify for this rate, Central Maine Power requires that the customers like RTP 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 RTP 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 a 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 RTP to develop a charging plan which avoids charging vehicles 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 5. It can be seen in the figure that the optimized charging schedule assumes that vans will be charged overnight (between 9 PM and 5 AM), outside of the times when RTP's vans are in-service, using the plug-in chargers. This will avoid charging during the Central Maine Power grid's 'coincidental peak' (between 3 PM and 7 PM), and allow RTP 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.

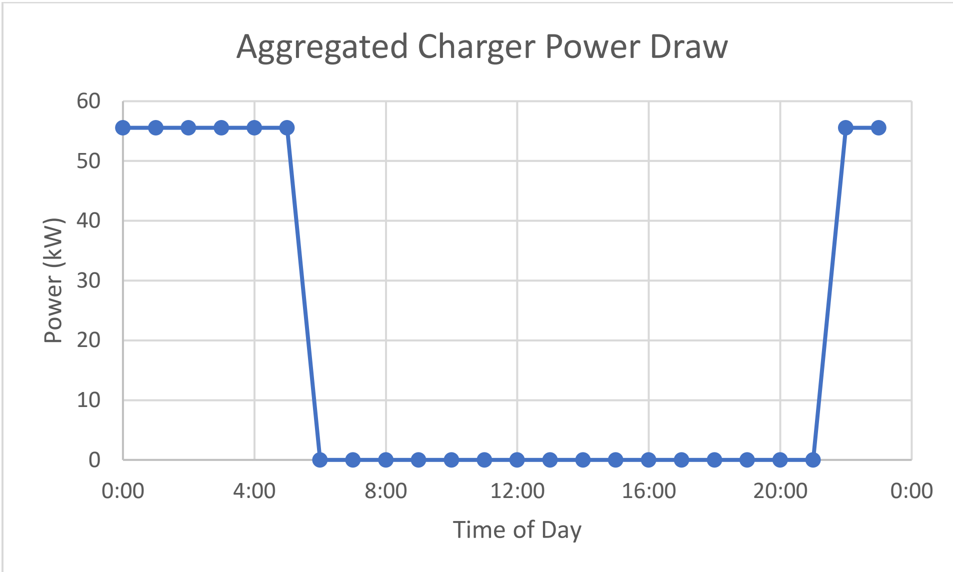


Figure 5 Proposed Charging Schedule for RTP's Future Fleet

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

Daily kWh consumption = 444 kWh
Monthly Non-coincidental peak = 56 kW
Monthly coincidental peak = 0 kW

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

$$Daily\ Charge = Daily\ kWh\ consumption\ \times (Energy\ Delivery\ Charge + Energy\ Cost)$$
$$= 444\ kWh\ \times (\$0.001745 + \$0.12954)$$
$$= \$58.29$$

$$Monthly\ Charge = (Monthly\ Non - coincidental\ Peak\ \times Distribution\ Charge) + (Monthly\ Non - coincidental\ Peak\ \times Transmission\ Charge)$$
$$= 56\ kW\ \times \$16.64$$
$$= \$931.84$$

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

$$Daily\ Charge = Daily\ kWh\ consumption\ \times (Energy\ Delivery\ Charge + Energy\ Cost)$$
$$= 444\ kWh\ \times (\$0.001745 + \$0.12954)$$
$$= \$58.29$$

$$Monthly\ Charge = (Monthly\ Non - coincidental\ Peak\ \times Distribution\ Charge) + (Monthly\ Coincidental\ Peak\ \times Transmission\ Charge)$$
$$= (56\ kW\ \times \$4.39) + (0\ kW \times \$19.35)$$
$$= \$245.84$$

As this estimate shows, the optional 'B-DCFC' rate structure would save RTP $686 per month. These savings are, again, achieved by avoiding charging during the coincidental peak between 3 PM and 7 PM, and the reduced monthly 'distribution' 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 $1,083.60 per month from a 'transmission charge'. As the number of electric vehicles increases in RTP's fleet, the saving from the B-DCFC rate structure will also increase proportionally. Therefore, it is critical that RTP only charges the vehicles 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 RTP 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 RTP's operation.

8. Asset Selection, Fleet Management and Transition Timeline

Section Summary

- Hatch recommends procuring four electric vans to enter service in 2024, with the remainder of the fleet being hybrid
- Hatch recommends installing level 2 chargers at the 1 Ledgeview Drive vehicle storage building

With operational and charging plans established, it was then possible to develop procurement timelines for infrastructure and vehicles to support those plans. RTP, like almost all transit agencies, acquires vehicles 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 commercial vehicle procurement – and especially for a newer technology like electric vehicles – there are advantages to larger orders, such as lower cost and more efficient vendor support. RTP 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 type of vehicles. This is particularly true for the first order of electric vehicles, where the inevitable learning curves are best handled with a larger fleet rather than a single vehicle.

As an additional complication, RTP currently operates a mix of cutaways and vans. The larger cutaways serve the Lakes Region Explorer route, while the vans and smaller cutaways are used to service on-demand paratransit operations. For the Lakes Region Explorer route, the demanding duty cycle means that – in the context of electric vehicles – continuing cutaway operation may pose a constraint on operations and vehicle purchasing flexibility. Most manufacturers of cutaway vehicles do not offer electric versions, and the vendors that do often have range, passenger capacity, or vehicle availability limitations. For example, Lightning eMotors offers a Class 4 (Ford E-450) vehicle but has paused development on its Class 5 (Ford F-550) vehicle. Although alternatives like 30' transit buses are more expensive and require bespoke maintenance skills, keeping a wide range of options open will help RTP procure vehicles as efficiently as possible. For the demand-response service, RTP has plans to shift to an all-van fleet. This is a rapidly changing market, with new entrants annually; RTP is similarly encouraged to monitor the market and keep procurement specifications performance-based to ensure maximum competition during procurement. To maintain a fair comparison, however, this analysis assumes that the existing fleet will be replaced approximately as expected by RTP, with new cutaway vehicles for the Lakes Region Explorer entering service in 2027 and the demand-response vehicles being replaced with vans as their lifetimes expire.

With respect to infrastructure procurements, the vehicle storage building at 1 Ledgeview Drive will eventually need to have enough chargers to accommodate all of RTP's electric vehicles. 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 connections, structural modifications, and civil work make it economical to install all the support infrastructure at once. When additional electric vehicles arrive and more chargers are required, the only work that should be necessary is installation of the chargers themselves. Some of the infrastructure like spare duct banks from the maintenance building to the vehicle storage facility is already in place in anticipation of future electrification, which should help reduce the infrastructure capital costs for the selected scenario in this study. However, additional investment might be required in the future when more of RTP's fleet is electrified. A detailed engineering design will be required to develop an accurate estimate of the costs.

As discussed earlier, Hatch recommends installing level 2 chargers at the vehicle storage facility to charge the pilot electric vehicles. This will allow RTP to charge the entire electric fleet at the same time while minimizing the required infrastructure investment. Some agencies prefer installing additional chargers to provide spare capacity and allow for charger maintenance outages; given the small scale of the pilot deployment, this additional expense would likely not be justified. If the pilot is successful and RTP pursues further vehicle electrification, a more detailed planning study would be needed to determine the correct number of chargers, ensuring that some spares are available for resiliency while avoiding over-investment in infrastructure. Table 4 provides a summary of the proposed vehicle and infrastructure procurement schedule:

Table 4 Proposed Fleet and Charging System Transition Schedule

Year	Vehicles Procured	Infrastructure Procured	Vehicles Replaced
2023	Four (four Hybrid Transit Vans)		104, 106, 123, 124
2024	Four (four Electric Transit Vans)	Four level 2 chargers + electrical upgrades (transformers, switchgears, etc.)	90, 129, 130, 133
2025	Two (two Hybrid Transit Vans)		128, 150
2026	Nine (nine Hybrid Transit Vans)		134, 135, 136, 137, 138, 139, 140, 141, 142
2027	Seven (two Hybrid Cutaways, five Hybrid Transit Vans)		143, 144, 145, 146, 147, 148, 149

Hatch recommends a robust testing program for the pilot order of electric vans on operating cycles across Cumberland County year-round. This experience will help RTP understand electric van operation across different geography (hilly vs flat), environments (urban vs rural), and weather conditions (winter vs summer) to inform future decisions on fleet electrification. If some downtime in vehicle operation is available, RTP can also consider using local public charging infrastructure; the knowledge gained about charger location and reliability/availability will let RTP better plan for vehicle range extension and operational resiliency. Finally, spreading electric vans out will ensure that the benefits of electric vehicles (elimination of tailpipe emissions, reduced noise, etc.) are distributed equitably across the county. This may also prove valuable from a Title VI perspective, particularly as county demographics continue to change over the coming years. Rotating the electric vehicles across the region will ensure that no area is disproportionately negatively impacted by RTP operations.

9. Building Spatial Capacity

RTP's main storage and maintenance facility is located at 1 Ledgeview Drive in Westbrook. One building is used for administration, vehicle maintenance, and vehicle wash, while the second building is used for indoor vehicle storage, with space for 35 vehicles. The facility does not have a gas station but does have a generator for back-up power and space for chargers. In addition to the Westbrook facility, RTP has a dedicated space in the American Legion parking lot at 26 Casco Road in

Section Summary

- The existing 1 Ledgeview Drive facility is suitable for installation of level 2 chargers
- If RTP chooses to electrify the Lakes Region Explorer, RTP should consider installing an overnight charger at Bridgton Community Center, or partnering with an organization with public charger infrastructure interests

Naples, which is used as an overnight layover area for the Lakes Region Explorer vehicle. This site is not owned by RTP, and no inspections or maintenance are performed there.

Based on RTP's current facilities and on-demand paratransit operations, the most suitable location for the required chargers is the Westbrook facility. As shown in Figure 6, the facility should have sufficient space to accommodate these needs.

Figure 6 Existing Indoor Vehicle Storage Building Suitable for Chargers

Assuming the initial pilot is successful and RTP considers continued electrification, an additional overnight charger would also be needed to accommodate the Lakes Region Explorer vehicle's operations given that the vehicle does not have an overnight layover in the Westbrook facility. The following two locations were identified as possible options for overnight charging locations:

- American Legion, 26 Casco Road, Naples
- Bridgton Community Center, 15 Depot Street, Bridgton

Although installing an overnight charger at RTP's existing parking spot at American Legion is a suitable option, this would require organizational coordination as there is no existing infrastructure there. On the other hand, the Bridgton Community Center has an existing charger. Although it is public and would not meet sufficient power requirements, given that a charger is already available it may be more feasible to coordinate with the Community Center to install the required DC fast charger for overnight and midday charging. If this proves infeasible, RTP can also explore a partnership with a local organization interested in creating public charging infrastructure. These options should be reevaluated in the event of future electrification based on updated assumptions, plans, and conditions.

10. Electrical, Infrastructure, and Utility Capacity

Section Summary

- The existing service at the garage might be sufficient to support the charging infrastructure
- Separately metered service would be necessary to take advantage of optional B-DCFC rate structure, unless submetering is permitted.

Central Maine Power is the utility provider for RTP's primary proposed charging location at 1 Ledgeview Drive. As part of the development of this transition plan, RTP has been partnering with Central Maine Power to communicate its projected future utility requirements at this location.

The 1 Ledgeview Drive facility has a 12.47 kV 3-phase service that is stepped down to 120/208V through a 300 kVA step-down transformer located outdoors, as shown in Figure 7. The facility was built with solar provision and as a result likely has additional capacity to support the 56kW load for overnight charging of the initial four electric vans. Hence, RTP might be able to install the initial four level 2 chargers without requiring substantial upgrades to the facility. Because utility information was not available at the time of analysis, a load study will need to be conducted for the facility to confirm availability of the 56kW of spare capacity. If submetering is not permitted, Central Maine Power may require the installation of a separate service to take advantage of the B-DCFC rate.

Figure 7 1 Ledgeview Drive Electrical Distribution Transformer

If RTP decides to electrify further vehicles, it may consider installing DCFC chargers at the 1 Ledgeview Drive facility rather than continuing to add level 2 chargers. The DCFCs typically require 480V 3-phase input voltage which is currently not available at the site (12.7kV is directly stepped down to 208V). Hence, a new 480 V utility service will be required. Hatch has confirmed with Central Maine Power that it can accommodate a new service at the 1 Ledgeview Drive facility if required. Central Maine Power has provided an initial estimate for the new transformers and service feed to be approximately $50,000. In addition, a similar new 480V service and DCFC charger will be required at the Lakes Region Explorer's overnight layover location, as described in Section 9.

11. Risk Mitigation and Resiliency

Section Summary

- As with any new technology, electric vehicle introduction carries the potential for risks that must be managed
- Although only limited power outage data is available, resiliency options must be considered
- Solar panels in conjunction with on-site energy storage can be a viable option for resiliency, reducing GHG and completely offsetting the electricity used by electric vehicles

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 gasoline vehicles, there are new technologies to contend with, potential build quality issues that must be uncovered, and maintenance best practices that can only be learned through experience with a particular vehicle. Vehicle electrification makes some failure modes impossible – for example by eliminating the gasoline 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 vehicle operation.

11a. Technological and Operational Risk

The vehicle and wayside technology required for electric vehicle operation is in its early stages; few operators have operated their electric fleets or charging assets through a complete life cycle of procurement, operation, maintenance, and eventual replacement. As detailed in the earlier Transit Vehicle Electrification Best Practices Report, this exposes electric vehicle 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 gasoline vehicles, 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 vehicles – 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, avoiding full depletion, and preferring lower

power charging to short bursts of high power, best practices in vehicle charging and battery maintenance will become clearer in coming years.

+ Supply availability: Compared with other types of vehicles, electric vans 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 vehicle 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 gasoline vehicles, which can refuel at any public fueling station, electric vehicles require level 2 chargers for overnight charging and specialized DCFC chargers for midday fast charging. Particularly early on, when there is not a widespread network of public chargers, this may pose an operating constraint in case of charger failure.
+ Fire risk: The batteries on electric vehicles require special consideration from a fire risk perspective (see Section 12b).

Most of these risks are likely to be resolved as electric vehicle technology develops. RTP is in a good position in this regard, as the comparatively small size of the recommended pilot fleet and the short lifespan of the vehicles means that any electrification decision does not present a long-term financial commitment. Nevertheless, it will be prudent for RTP 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 vehicle vendor to have a technician nearby in case of problems. This is most economical when the technician is shared with nearby agencies such as YCCAC.
+ Reach a “mutual aid” agreement with another transit agency in Maine that would let RTP borrow spare buses/vehicles in case of difficulties with its fleet. For example, RTP may arrange to borrow a 35’ bus from Portland Metro if the Lakes Region Explorer vehicles are unavailable on a given day.
+ Retain gasoline vehicles for at least two years after they are retired to ensure they can substitute for electric vehicles if any incidents or weather conditions require it.
+ For the Lakes Region Explorer, if RTP chooses to electrify it, develop contingency plans in case of on-route charger failure. This may include using another charger in the area, swapping vehicles after each round trip, or borrowing a vehicle from another agency.
+ Conduct a fire detection, suppression and mitigation study of RTP locations where chargers and electric vehicles will be housed (see section 12b).

11b. Electrical Resiliency

Electricity supply and energy resilience are important considerations for RTP when transitioning from gasoline to electric vehicle 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 RTP 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

The 1 Ledgeview Drive facility currently has a 128 kW generator that might be able to support battery electric vehicle operations should there be an electrical service interruption. However, the existing load of the building needs to be studied to determine the available spare capacity of the generator, which could be done once utility information is available. If additional demand-response vehicles are converted to electric vehicles in the future, the available generator capacity will not be sufficient to support the extra charging load. Additional generation capacity will be required for resiliency in that case.

RTP has at least 5 acres of available land that could be used to install solar panels. This would allow on-site generation of clean energy, which can be used for resiliency as well as to offset the operations cost of charging electric vehicles.

11.b.2. Outage Data and Resiliency Options

Hatch assessed potential resiliency options should the on-site generator not have sufficient capacity to support vehicle charging needs during power outages. Typically, the past five-year power outage data for the utility feed at the facility is analyzed to determine the backup power requirement. Since the 1 Ledgeview Drive facility is very new, the outage data is only available for the last two years. There were only two recorded outages at this location in the last two years

(2021 and 2022). Both the outages were insignificant and only lasted for two minutes and one minute, respectively.

Resiliency system requirements are typically determined based on the worst outage instance outlined above and the charging needs for the full fleet during this type of outage scenario. Since the outage history is not extensive for this site, Hatch assumed the outage requirement to be the charging requirements for one overnight charging session for the electric vehicles. The on-site energy storage requirement to charge the fleet during that outage period would be 444 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 555 kWh. The power requirement for generator capacity was assumed to be the aggregated power draw required during overnight charging for the fleet for four vehicles, which is 50 kW. Assuming an efficiency of 90%, and a 20% spare capacity, the resulting on-site generation capacity required would be approximately 70 kVA.

Hatch next generated cost estimates associated with the two resiliency system options for the 1 Ledgeview Drive facility. Table 6 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 6 Resiliency Options for Overnight Outage Scenario

	Size	Capital Cost
Option 1 On-site Battery Storage	555 kWh	$350,000
Option 2 On-site Diesel Generation	70 kVA	$45,000

The above analysis and corresponding options are based on an assumption. Since outages like this might occur very rarely, the above resiliency options may be oversized for most use cases resulting in a poor return on the capital investment. As the utility industry evolves over the course of RTP'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 energy costs, and further reduce RTP'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. 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 array would primarily be to offset energy from the grid and reduce utility costs.

An on-site solar system was evaluated for the 1 Ledgeview Drive facility because the additional agency-owned vacant land at the site provides a large surface area that could be utilized for a solar array. Though a more detailed study would be needed to determine the optimal location for the solar array, one possible layout is illustrated in Figure 8 below.

Table 7 outlines parameters for the solar power system that would be required to offset total annual electricity usage by the electric vehicle charging infrastructure, the surface area that is required for the solar panels, and the resulting cost savings from offsetting energy consumed from the grid.

Table 7 1 Ledgeview Drive Solar Field Design Parameters

Solar System Design Parameters	
Solar System Sizing Method:	Full Annual Energy Match
Solar Array Area Width	60 ft
Solar Array Area Length	100 ft
Solar Array Area	5,700 ft^2
Maximum Number of Panels	256 panels
Maximum System Power	109 kW
Annual Production Coefficient	1,291 hours
Sunny Days Per Year	203 days
Annual Solar Energy Production	140,730 kWh
Annual Electric Usage	136,889 kWh
Maximum Percent of Electrical Usage Offset	103%
Electricity Rate	$0.12954 / kwh
System Cost	**$300,000**
Utility Bill Savings Per Year	**$18,230**
Simple Payback Period Without Grants	**16.5 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 693 kWh. Since the energy requirement for charging the vehicles overnight during an outage is estimated to be 444 kWh, solar has the potential to provide enough energy to support the operation in the event of an outages on a sunny day.

However, solar power generation is not recommended as a primary resiliency system as 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.

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 energy use for the site. In addition, having on-site solar energy production can help further reduce RTP's GHG contribution by reducing energy consumed from the grid, which is partially produced using 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 rather than to only support outage scenarios, and potentially for future expansion of the electric fleet. A more detailed study should be conducted to determine the battery energy requirements, which are likely to be more than 555 kWh based on the above solar estimates.

12. Conceptual Infrastructure Design

12a. Conceptual Layouts

Section Summary

- Hatch recommends installing four wall-mounted chargers in vehicle storage building at the 1 Ledgeview Drive facility

To assist RTP 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 the charging infrastructure be placed inside the vehicle storage building.

At the 1 Ledgeview Drive location, the utility service enters the admin building where the electrical room, housing the service panel, is located. The electrical service is carried to the vehicle storage building via a set of conduits installed between the two buildings. There are space conduits installed between the buildings that could be utilized to carry cables for the charging equipment from the admin building electrical room. The availability of these spare conducts needs to be evaluated as part of a detailed engineering study.

There are two primary methods for installing the overnight chargers:

- Mounted on the wall
- Suspended from the ceiling

Of these options, the ceiling suspension would allow the most layout flexibility, but would also be the most expensive and maintenance-intensive. The wall-mounted alternative would offer comparable utility for the small fleet size of the recommended pilot; vehicles would be able to park adjacent to the dispensers to charge overnight. Hatch recommends that RTP selects the wall-mounted alternative to minimize the capital and operational impacts of charger installation. It is recommended that the chargers are installed on the southeast wall of the vehicle storage building as that is where the spare conduits are terminated. Installing the chargers closer to the existing conduit will reduce the civil work required, resulting in reduced capital cost and operations disruption. (If RTP chooses to install additional chargers in the future, placing these along the northwest wall is recommended as this would allow wall-mounting rather than requiring ceiling-hung chargers.) Figure 8 illustrates the suggested layout for the chargers, as well as the suggested solar array discussed previously.

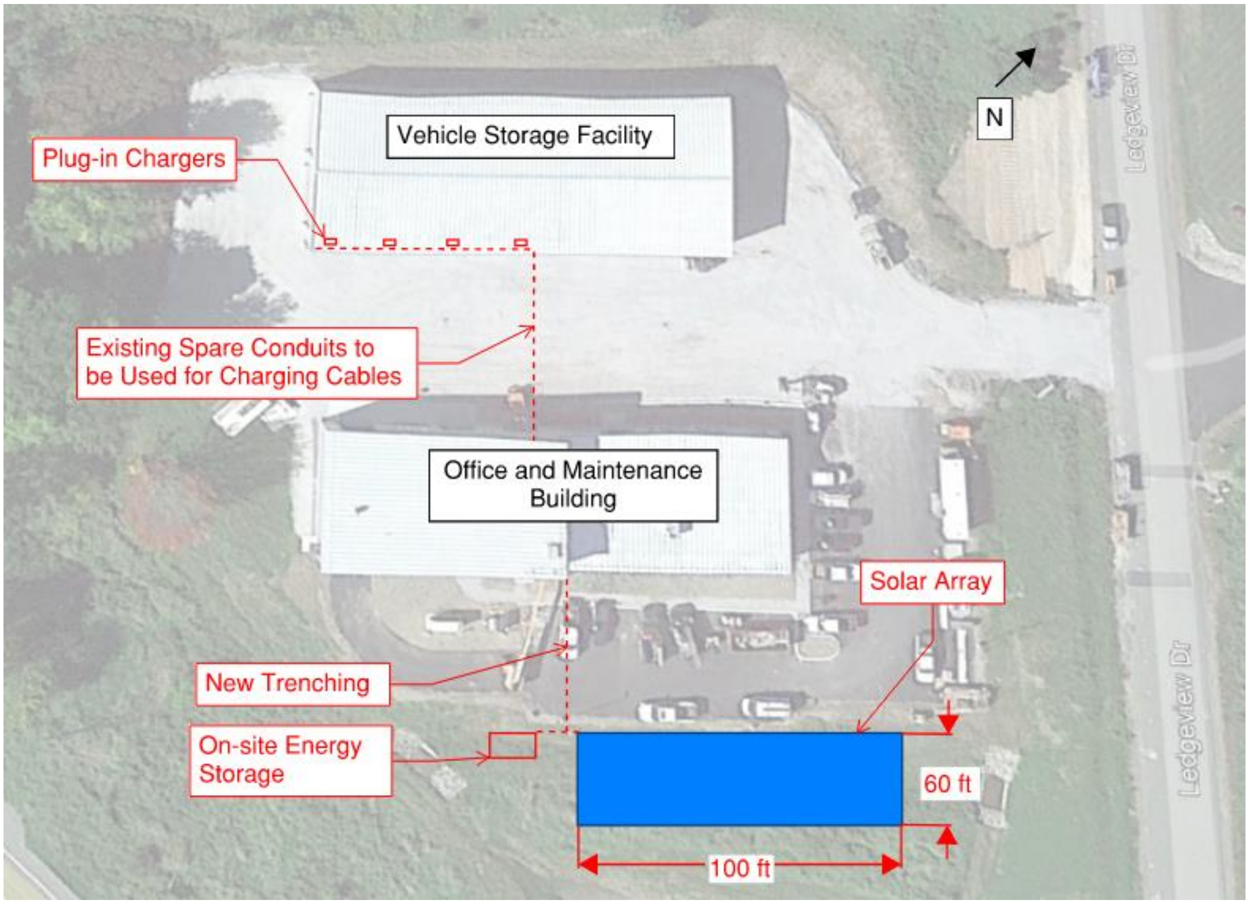


Figure 8 Conceptual Layout

12b. Fire Mitigation

An electric vehicle'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 vehicles. If this is another electric vehicle then a chain reaction can occur, with the heat emanating from one vehicle overheating (and likely igniting) the batteries of another vehicle. This can endanger all the vehicles in the storage facility.

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 RTP's risk is relatively low because of the smaller initial size of the electric fleet size, Hatch still recommends that RTP 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 vehicles or the building structure. In terms of staffing, it is recommended that staff be located nearby to respond in case of a fire and move unaffected vehicles out of harm's way. If RTP does not maintain staff at the depot overnight, staff at the nearby Scarborough Engine 5 firehouse may be able to fulfill this function during their response to an incident. Each of the factors mentioned above requires specific consideration with respect to RTP's facility and operations. Hatch recommends that RTP 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

Section Summary

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

RTP's current operating budget is roughly $2.5 million per year. The agency's funding sources are summarized in Figure 9. As can be seen in the figure, RTP's largest source of funding comes from federal assistance. For vehicle, 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.

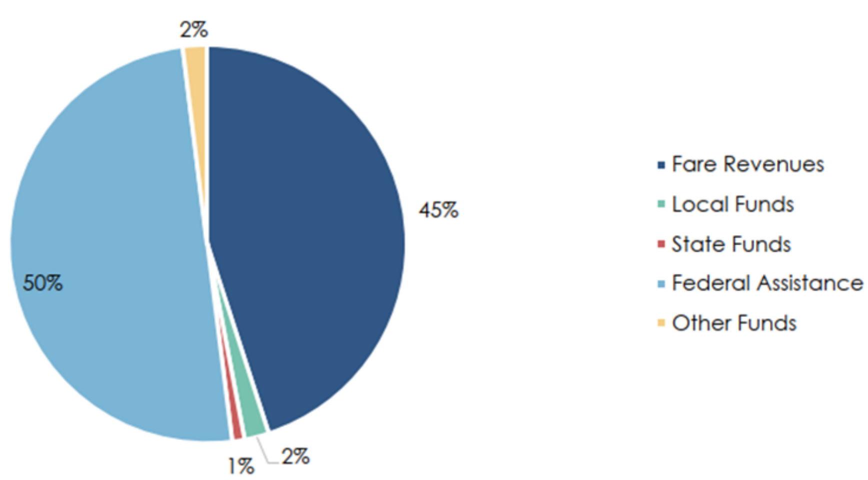


Figure 9 Current Agency Funding Summary (Source: Maine DOT)

As the agency transitions to hybrid and battery electric technology, additional policies and resources will become applicable to RTP. Table 8 provides a summary of current policies, resources and legislation that are relevant to RTP's fleet electrification transition.

Despite the large number of potential funding opportunities available to transit agencies seeking to transition to hybrid and battery electric technologies, these programs are competitive and do not provide RTP with guaranteed funding sources. Therefore, this analysis assumes that RTP will only receive funding through the largest grant programs that provide the highest likelihood of issuance to the agency. Specifically, this analysis assumed that RTP will receive 80% of the capital required to complete the vehicle, 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 8 Policy and Resources Available to RTP

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 vehicle 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 vehicles 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 vehicles 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 vehicles 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 vehicle 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 at the main facility. (*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 Considerations

Section Summary

- Bus electrification is expected to significantly increase capital cost
- However, reduced RTP recurring expenses are expected, as electric vehicles cost less to maintain and fuel

Fleet electrification has significant financial impacts for the transit agency. Substantial capital cost increases are expected for both vehicles and infrastructure, compared to what is required for the agency's existing operations with fossil fuel vehicles. On the other hand, some savings on recurring expenses are likely, because electric vehicles require less maintenance and have cheaper energy costs.

The upfront purchase cost of battery electric and hybrid vehicles is much higher than for fossil fuel ones. For battery-electrics, this is largely due to the high cost of the propulsion batteries. Although the cost of batteries is declining each year it is still very high, particularly for heavy-duty transit vehicles. Because transit agencies prefer high-capacity batteries to extend vehicle range, the additional price of the batteries overshadows the cost savings from eliminating the engine and associated components on a diesel or gasoline vehicle. On the other hand, hybrid vehicles do not have large batteries; however, their drivetrains include a full set of components for fossil fuel operation, with electrical propulsion elements added on. This additional complexity increases the price of a hybrid vehicle above that of a fossil fuel one. The vehicle purchase cost increases are often significant, as shown below.

Electrifying a transit fleet often requires major infrastructure investment as well, to ensure that three separate items – the chargers themselves, the facility, and the utility connection – are suited for electric vehicles. Chargers are, of course, a prerequisite to EV operation; they must be purchased, installed, and commissioned. Particularly for heavy-duty applications like transit service, the required chargers are often high-powered and expensive. The facility itself must also be adapted for EV charging. In some cases, for modern facilities designed with spare electrical capacity, this will only require installation of additional conduit to connect to the electrical panel. For other, older facilities with outdated electrical and fire detection systems this could involve a multimillion-dollar upgrade before the first charger can be installed. Finally, the facility's utility connection often requires upgrades as well, as detailed in Section 10. Although bus depots are industrial facilities, their existing electrical systems are usually unsuited for the heavy power demands of EV charging. Although the cost of utility and facility upgrades varies on a case-by-case basis, the price of chargers themselves is relatively consistent and is presented below.

These upfront capital costs are expected to be balanced out by recurring savings on operations and maintenance cost. For operations, EVs are cheaper to recharge than fossil fuel vehicles are to refuel. This is especially true if a charge management system is used to avoid electricity demand charges. Even hybrids, which still require fueling, use approximately 20% less fuel than non-hybrid vehicles, decreasing operations costs accordingly. In addition to operations spending, maintenance costs are expected to decline as well. EVs have many fewer drivetrain parts,

especially moving parts, than fossil fuel vehicles. Therefore, components will wear out less often, meaning that less time has to be spent maintaining them and spare parts can be bought less frequently. For hybrid vehicles, maintenance costs are expected to remain largely unchanged compared to diesel or gasoline vehicles. Although hybrids have more complicated drivetrains, the electric propulsion means that regenerative braking can be used – prolonging the life of components like brake pads – and the fossil fuel engine does not need to handle as intense a duty cycle as it otherwise would.

Table 10 lists the operating and capital costs that Hatch assumed for this study. These are based on RTP’s figures and general industry trends and have been escalated to 2023 dollars where necessary.

Table 9 Cost Assumptions

Asset	Estimated Cost Per Unit (2023 $’s)
Gasoline Transit van	$40,000
Hybrid Transit van	$55,000
Electric Transit van	$200,000
Gasoline Cutaway	$70,000
Hybrid Cutaway	$125,000
Electric Cutaway	$250,000

Expense	Estimated Cost (2023 $’s)
Gasoline Vehicle maintenance	$0.97 / mile
Hybrid Vehicle maintenance	$0.97 / mile
Electric Vehicle maintenance	$0.73 / mile

The proposed fleet transition requires initial capital spending to reduce recurring cost and achieve other strategic goals. This need 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 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 RTP 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 RTP to change the speed of its electrification transition or change the desired end-state altogether.

15. Emissions Impacts

One of the motivations behind RTP's transition towards battery electric vehicles 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 RTP.

Section Summary

- Vehicle electrification will be critical to helping meet State emission goals
- Forecasted grid conversion to clean energy will maximize the benefit of vehicle electrification
- The transition is expected to reduce emissions by 27-29%

Hatch calculated the anticipated emissions reductions from RTP'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 vehicles are operated. As a tank-to-wheel baseline, the 'tailpipe' emissions associated with RTP's existing gasoline fleet were calculated. These calculations used industry emissions averages for gasoline vehicles and RTP's fuel economy data.

Hybrid vehicles were assumed to have an average fuel economy 25% better than that of gasoline vehicles. Battery electric vehicle propulsion systems do not create emissions, and therefore there are no 'tailpipe' emissions.

Well-to-tank emissions are those associated with energy production. For gasoline (and hybrid) vehicles well-to-tank emissions are due to gasoline production, processing, and delivery. This emissions estimate used industry averages for the well-to-wheel emissions associated with the delivery of gasoline fuel to the gas stations RTP uses.

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 10 and Figure 10 summarize the results of the emissions calculations. These results demonstrate that the transition plan will achieve 27% emissions reduction assuming the grid mix that existed in 2020, or 29% 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, RTP's transition plan will help reduce emissions but will not meet the 45% goal established by the State of Maine.

Table 10 CO_2 Emissions Estimate Results

Scenario	Well-to-Tank (kg)	Tank-to-Wheel (kg)	Grid (kg)	Total (kg)	Reduction over Baseline
Gasoline Baseline	281,990	476,820	-----	758,811	----------
Future Fleet (2020 grid mix)	197,003	333,114	24,899	555,016	27%
Future Fleet (2030 grid mix)	197,003	333,114	8,217	538,334	29%

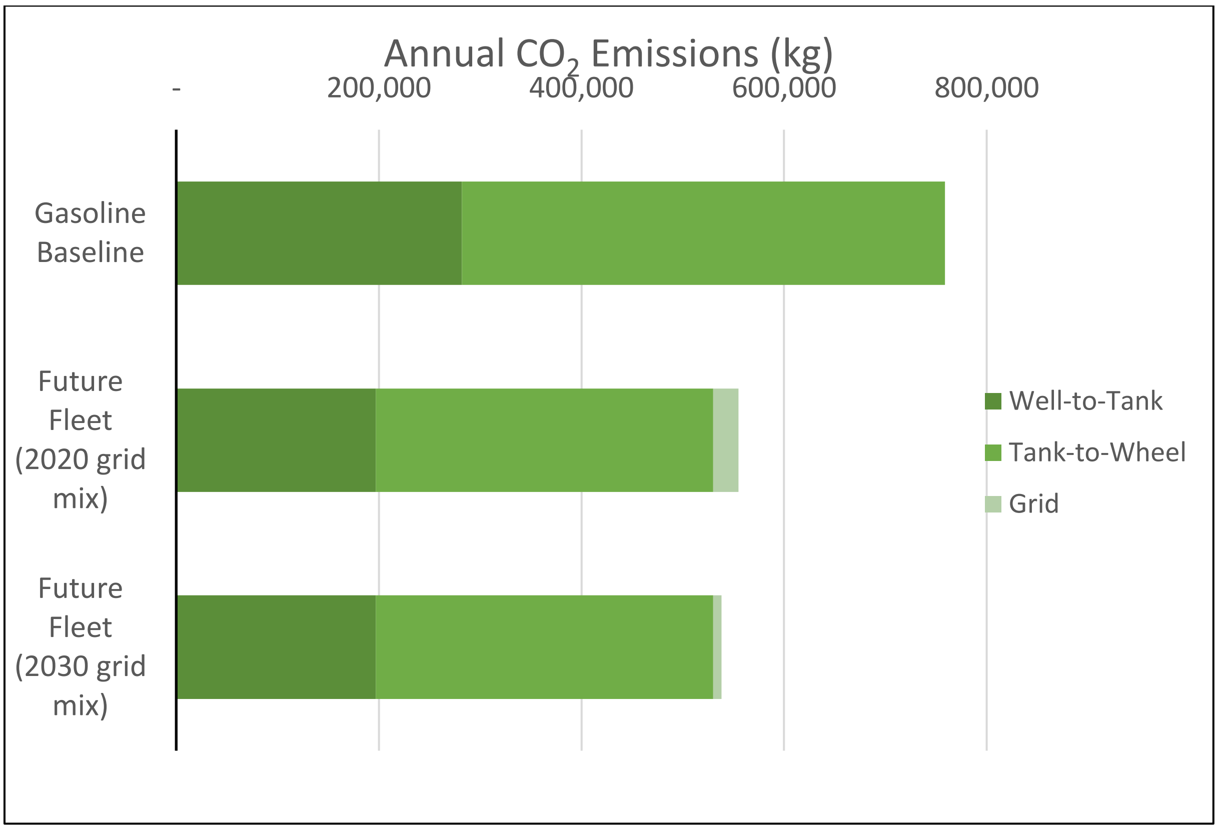


Figure 10 Graph of CO_2 Emissions Estimate Results

Should RTP 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
- Assuming the initial pilot is successful, purchase additional electric vehicles, potentially including the Lakes Region Explorer fleet

16. Workforce Assessment

RTP staff currently operate a revenue fleet composed entirely of gasoline vehicles. As a result, the staff have skill gaps related to battery electric vehicle and charging infrastructure technologies that will be operated in the future. To ensure that both existing and future staff members can operate RTP's future system a workforce assessment was conducted. Table 11 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 RTP success
- Hatch recommends partnering with local colleges and other transit agencies to share skills

Table 11 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 RTP consider the following training strategies:

+ Add requirements to the operations contract for the system operator to train its staff on the safe operation and maintenance of electric vehicles.
+ 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 vehicles 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.

17. Alternative Transition Scenarios

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

As part of this study, RTP was presented with alternative fleet and infrastructure transition scenarios that would also satisfy the agency's operational requirements. These alternatives considered different scales of electrification, vehicle choices, and charging locations. Through discussions, however, RTP currently favors the transition plan presented in this report. Should RTP'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 RTP review this transition plan on an annual basis to reevaluate the assumptions and decisions made at the time this report was authored.

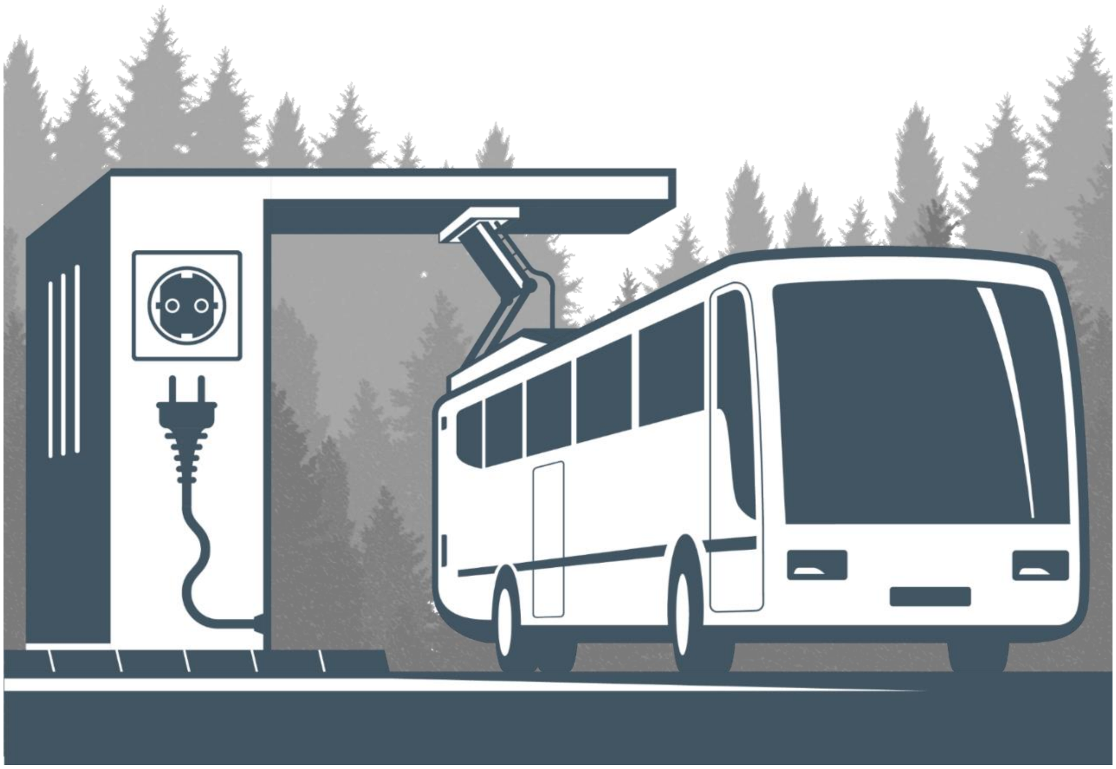
18. Recommendations and Next Steps

The 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 gasoline- and diesel-powered vehicles in favor of battery-electric. By facilitating this study RTP 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, RTP will be able to reduce emissions, noise, operating cost, and other negative factors associated with gasoline operations, while helping the state comply with the Clean Transportation Roadmap and operating sustainably for years to come.

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

- Proceed with transitioning the agency's vehicles and infrastructure in the manner described in this report.
- For the vehicles:
  - Consider ordering vehicles as part of larger orders or partnering with other agencies or the DOT to form large joint procurements.
  - Develop specifications for battery electric vehicles.
  - Consider a broad range of vehicles during procurements, ensuring maximum competitiveness in procurements.
  - Operate the demand-response vehicles on as wide a variety of cycles as possible to gain maximum knowledge of their advantages and limitations.
  - Retain gasoline vehicles for at least two years after they are retired to ensure they can substitute for electric vehicles if incidents or weather require it.
- For the infrastructure at 1 Ledgeview Drive:
  - Upgrade the electrical utilities to support charging infrastructure if necessary.

  - Conduct a fire safety analysis in accordance with Section 12b and standards UL9540, NFPA 70 and 230.
  - Develop specifications for chargers and other required infrastructure.
  - Develop contingency plans for alternate charging locations to use in case of a charger malfunction.
  - Consider energy storage and solar panel installation.
- For other components of the transition:
  - Plan for staff training programs, as described in Section 16.
  - Coordinate transition efforts with peer transit agencies, CMP, and Maine DOT.
  - Continually monitor utility structures and peak charge rates and adjust charging schedules accordingly.
  - Review this transition plan annually to update based on current assumptions, plans, and conditions.



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

City of South Portland

Prepared by:

HATCH

Version: 1.2

3/17/2023

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.

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, though significant upfront capital spending will be required. 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.

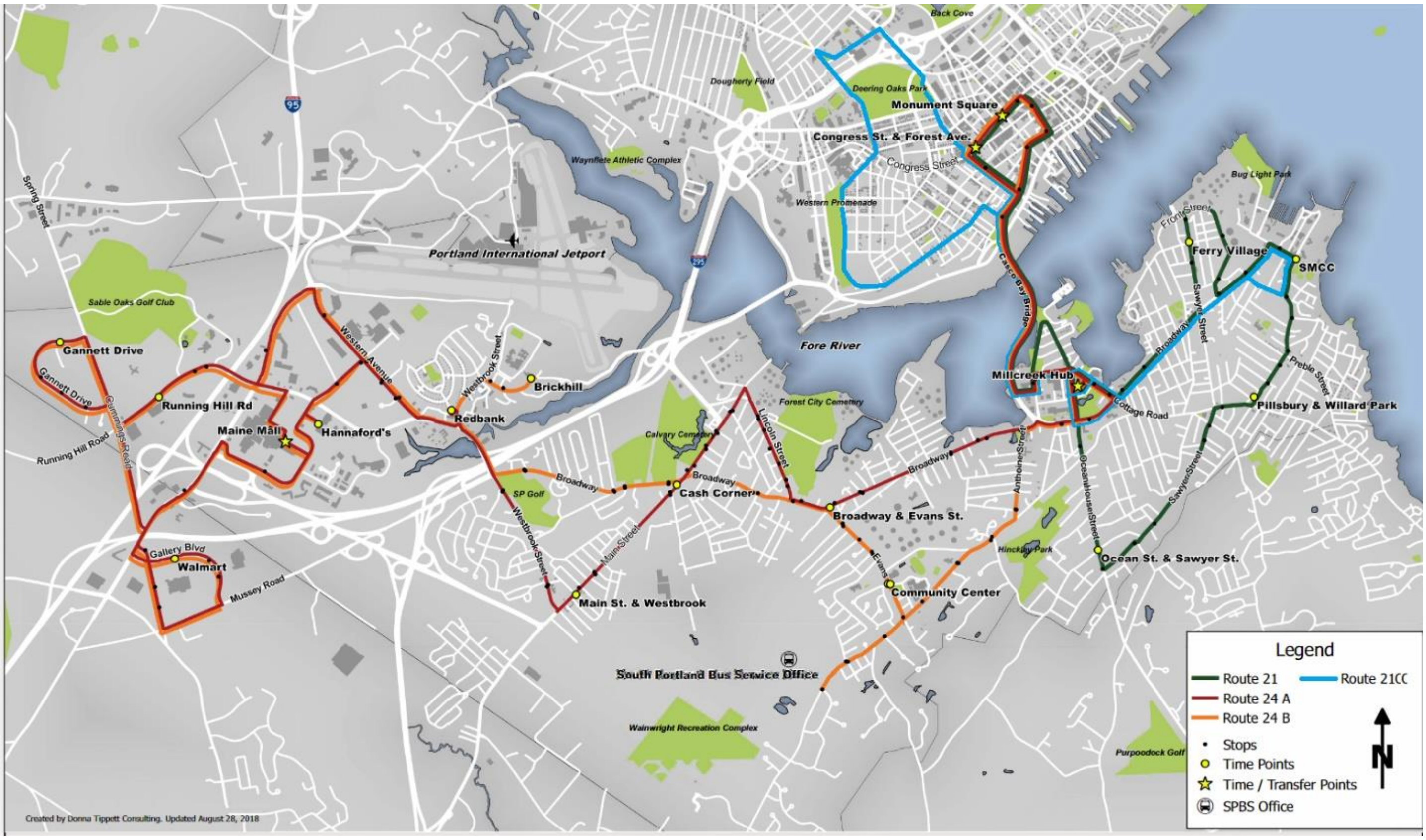


Figure 1 South Portland System Map Including Future Route 21 Campus Connector

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. In the battery electric vehicle space, 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.

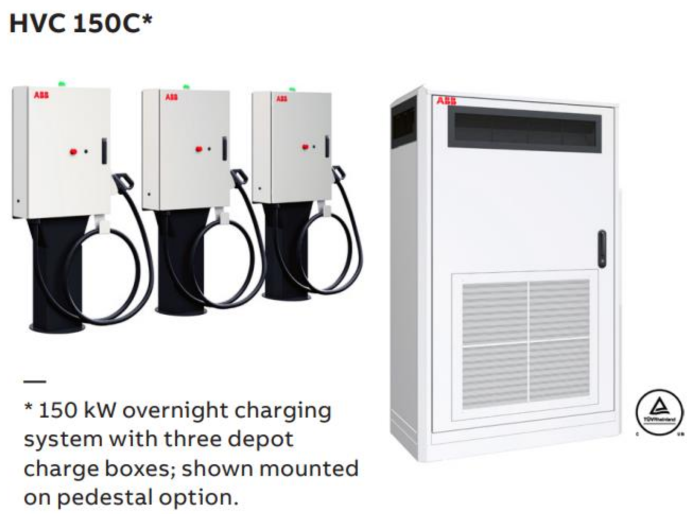


Figure 2 Example Charging System: Charging Cabinet (System) and Three Dispensers (Charge Boxes) (Source: ABB)

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.

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.

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.

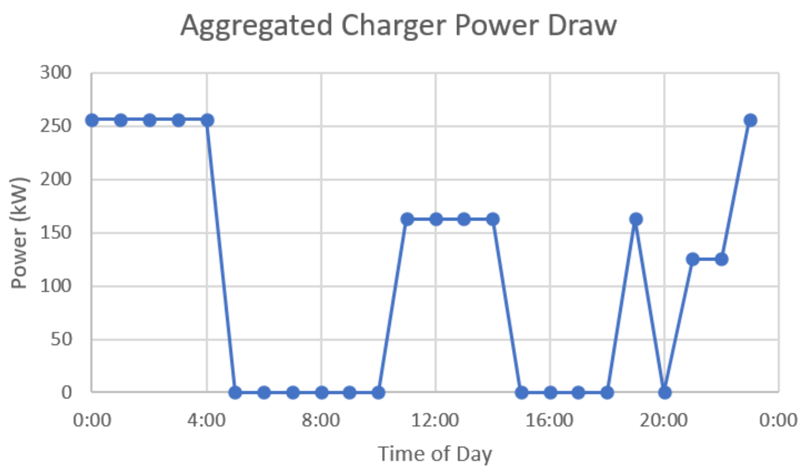


Figure 4 Proposed Charging Schedule for SPBS's Future Fleet

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

Under Current MGS-S Rate Structure:

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

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

Under New B-DCFC Structure:

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

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

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.

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.

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.

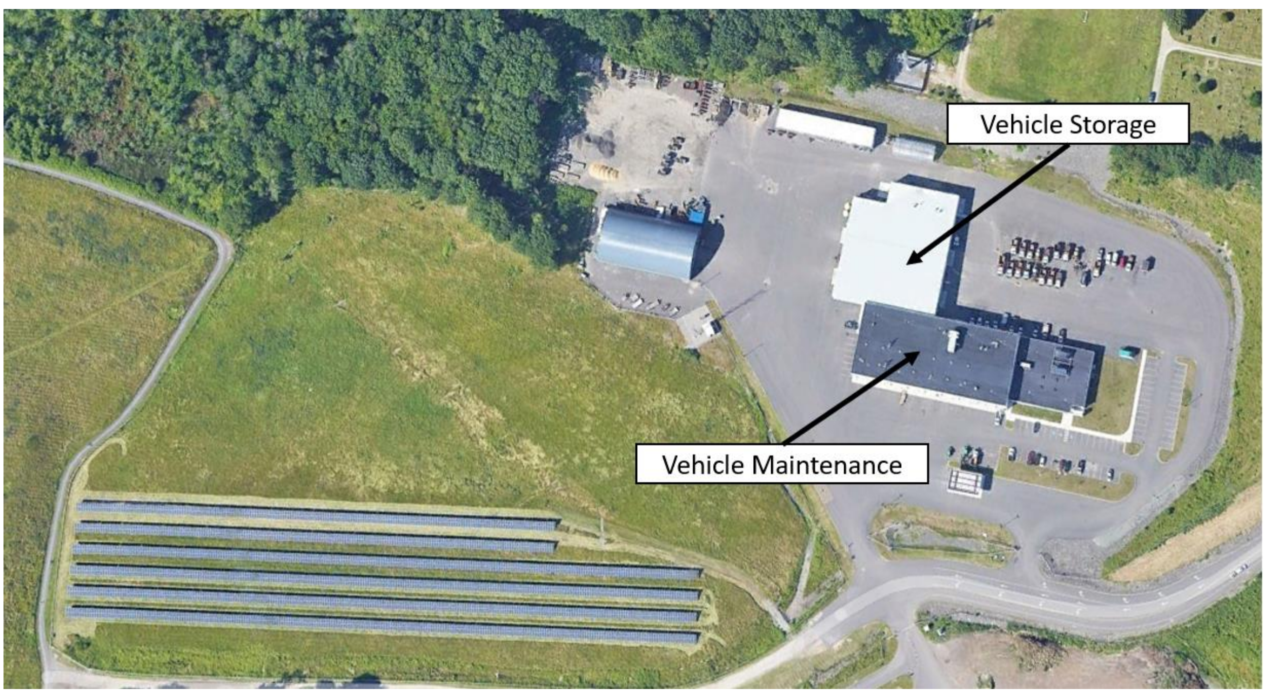


Figure 5 SPBS's Main Facilities (929 Highland Ave) (Source: Google Maps)

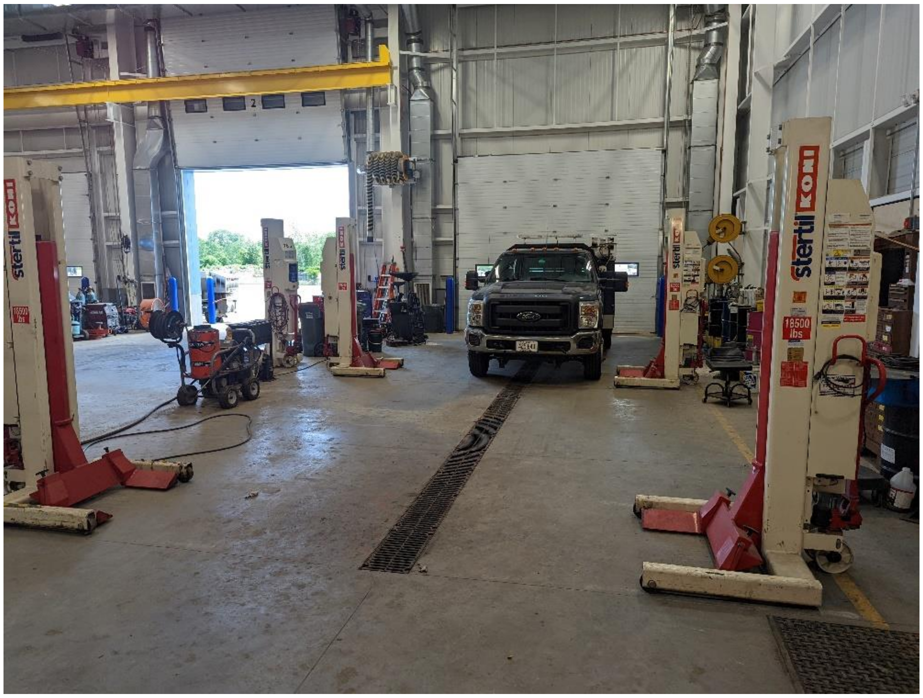


Figure 6 Main Vehicle Maintenance Area

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.

- 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.

Section Summary

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

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

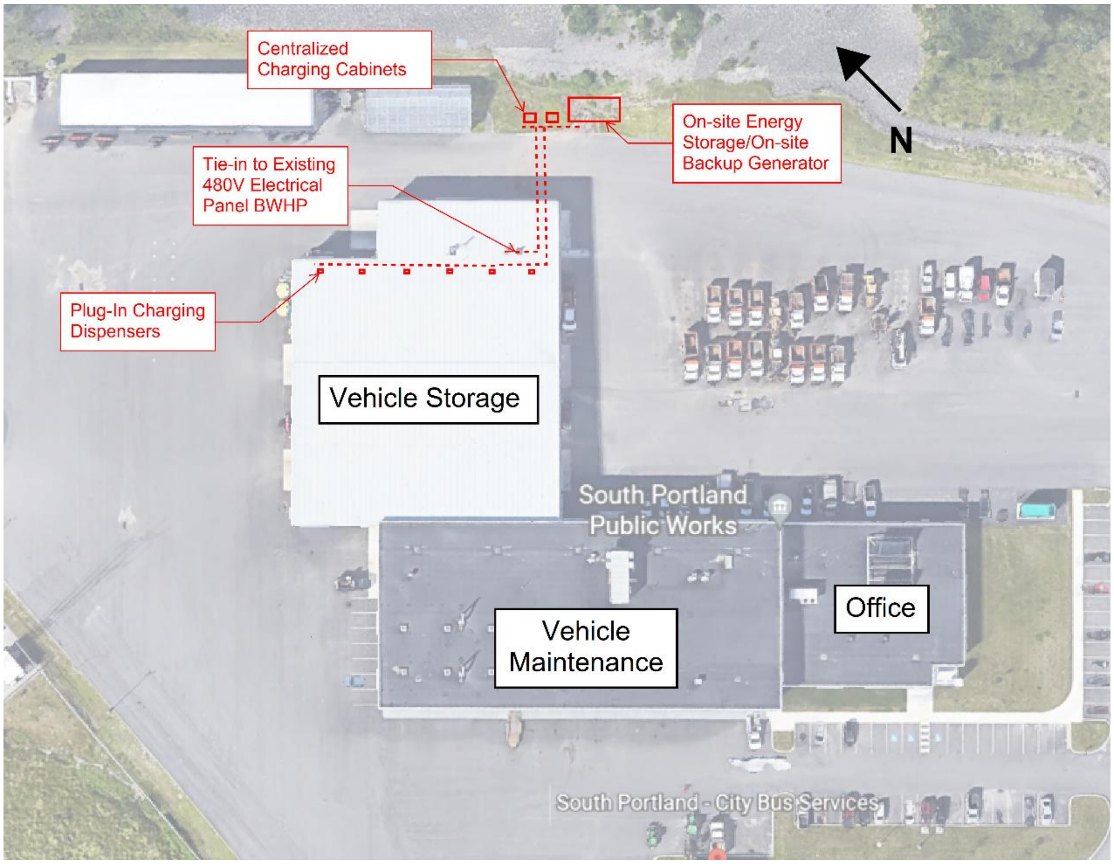


Figure 13 929 Highland Facility Infrastructure Conceptual Layout (Source: Google Maps)

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.

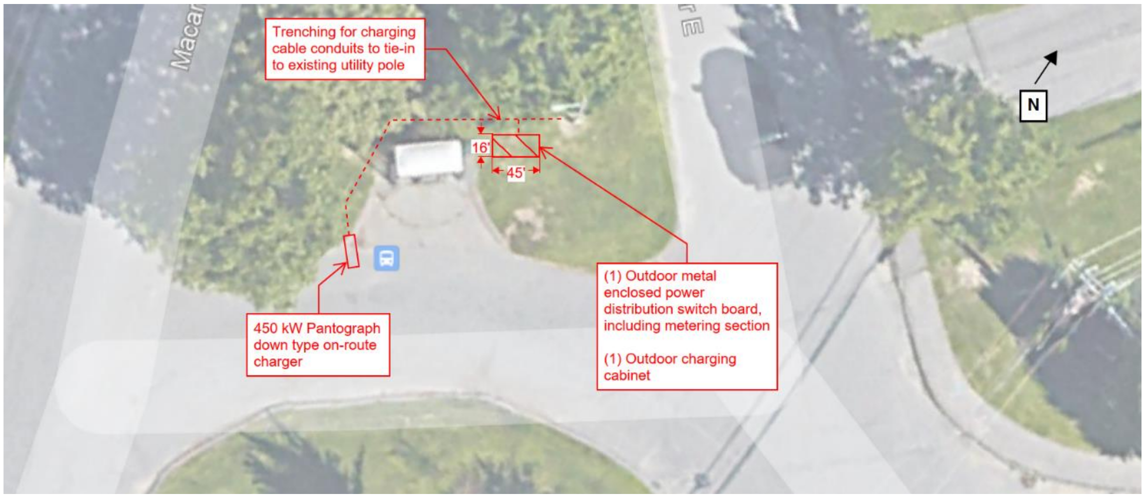


Figure 14 Redbank Charger Location Concept (Source: Google Maps)

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.

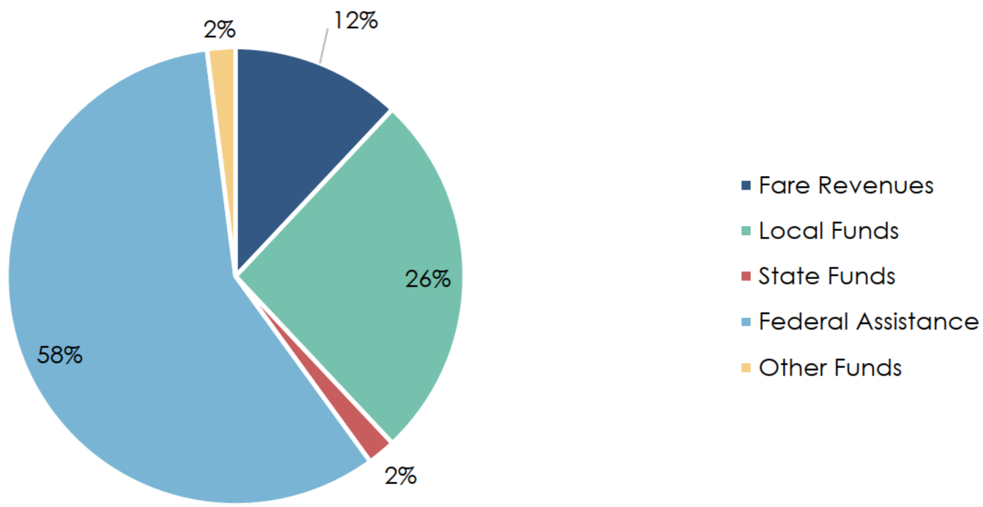


Figure 15 Current Agency Funding Summary (Source: Maine DOT)

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 Considerations

Fleet electrification has significant financial impacts for the transit agency. Substantial capital cost increases are expected for both vehicles and infrastructure, compared to what is required for the agency's existing operations with fossil fuel vehicles. On the other hand, some savings on recurring expenses are likely, because electric vehicles require less maintenance and have cheaper energy costs.

Section Summary

- Bus electrification is expected to significantly increase capital cost
- However, reduced SPBS recurring expenses are expected, as electric vehicles cost less to maintain and fuel

The upfront purchase cost of battery electric and hybrid vehicles is much higher than for fossil fuel ones. For battery-electrics, this is largely due to the high cost of the propulsion batteries. Although the cost of batteries is declining each year it is still very high, particularly for heavy-duty transit vehicles. Because transit agencies prefer high-capacity batteries to extend vehicle range, the additional price of the batteries overshadows the cost savings from eliminating the engine and associated components on a diesel or gasoline vehicle. On the other hand, hybrid vehicles do not have large batteries; however, their drivetrains include a full set of components for fossil fuel operation, with electrical propulsion elements added on. This additional complexity increases the price of a hybrid vehicle above that of a fossil fuel one. The vehicle purchase cost increases are often significant, as shown below.

Electrifying a transit fleet often requires major infrastructure investment as well, to ensure that three separate items – the chargers themselves, the facility, and the utility connection – are suited for electric vehicles. Chargers are, of course, a prerequisite to EV operation; they must be purchased, installed, and commissioned. Particularly for heavy-duty applications like transit service, the required chargers are often high-powered and expensive. The facility itself must also be adapted for EV charging. In some cases, for modern facilities designed with spare electrical capacity, this will only require installation of additional conduit to connect to the electrical panel. For other, older facilities with outdated electrical and fire detection systems this could involve a multimillion-dollar upgrade before the first charger can be installed. Finally, the facility's utility connection often requires upgrades as well, as detailed in Section 10. Although bus depots are industrial facilities, their existing electrical systems are usually unsuited for the heavy power demands of EV charging. Although the cost of utility and facility upgrades varies on a case-by-case basis, the price of chargers themselves is relatively consistent and is presented below.

These upfront capital costs are expected to be balanced out by recurring savings on operations and maintenance cost. For operations, EVs are cheaper to recharge than fossil fuel vehicles are to refuel. This is especially true if a charge management system is used to avoid electricity demand charges. Even hybrids, which still require fueling, use approximately 20% less fuel than non-hybrid vehicles, decreasing operations costs accordingly. In addition to operations spending, maintenance costs are expected to decline as well. EVs have many fewer drivetrain parts,

especially moving parts, than fossil fuel vehicles. Therefore, components will wear out less often, meaning that less time has to be spent maintaining them and spare parts can be bought less frequently. For hybrid vehicles, maintenance costs are expected to remain largely unchanged compared to diesel or gasoline vehicles. Although hybrids have more complicated drivetrains, the electric propulsion means that regenerative braking can be used – prolonging the life of components like brake pads – and the fossil fuel engine does not need to handle as intense a duty cycle as it otherwise would.

Table 8 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 2023 dollars where necessary.

Table 8 Cost Assumptions

Item	Estimated Cost Per Unit (2023 $'s)	Item	Estimated Cost Per Unit (2023 $'s)
35' Diesel Transit Bus	$600,000	**DC Fast Charger – Plug-in Garage (centralized unit and 3 dispensers)**	$270,000
35' Battery Electric Transit Bus (225 kWh)	$900,000	**Diesel and hybrid bus maintenance**	$1.46 / mile
35' Battery Electric Transit Bus (450 kWh)	$1,115,000	**Electric bus maintenance**	$1.10 / mile

The proposed fleet transition requires initial capital spending to reduce recurring cost and achieve other strategic goals. This need 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 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.

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.

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%

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:

- 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 9 and Figure 16 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 an 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 9 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%

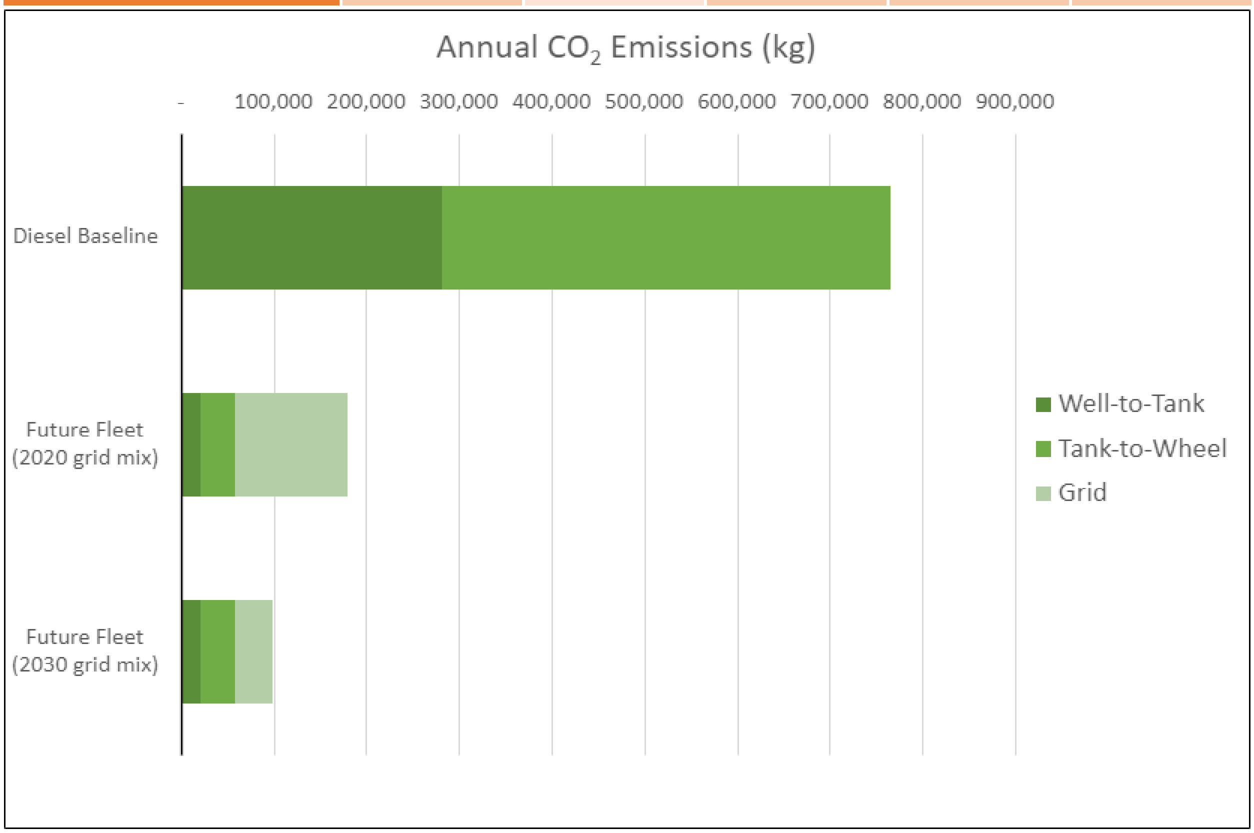


Figure 16 Graph of CO2 Emissions Estimate Results

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 10 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 10 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

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. 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.

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

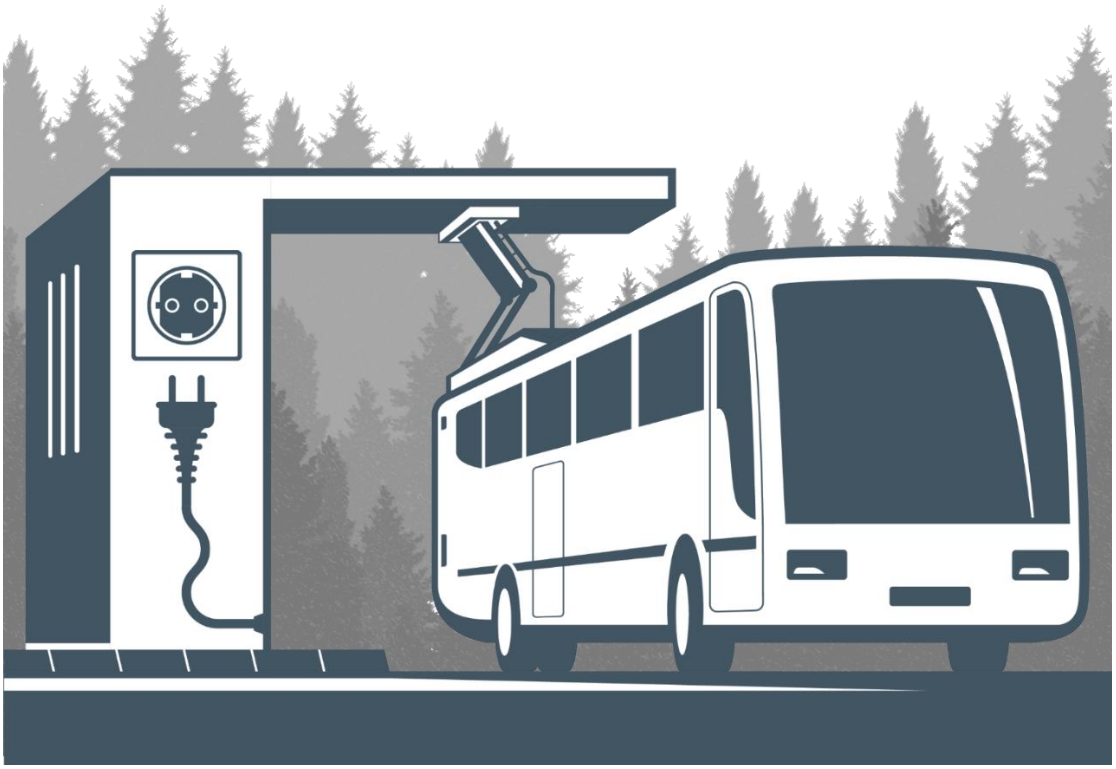
18. Recommendations and Next Steps

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.
  - 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.
  - Review this transition plan annually to update based on current assumptions, plans, and conditions.



Vehicle Electrification Transition Plan for York County Community Action Corporation (YCCAC)

York County COMMUNITY ACTION Corporation

Prepared by:

HATCH

Version: 1.2
3/17/2023

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1. Executive Summary

York County Community Action Corporation (YCCAC), the bus and paratransit agency serving York County, Maine, is currently considering transitioning its vehicle fleet to battery electric and hybrid 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, YCCAC has expressed a preference for fleet and infrastructure asset configurations that will provide a feasible transition to hybrid and battery electric drivetrain technologies while supporting the agency's operational requirements and financial constraints. The selected configuration increases the agency's fleet size from 30 to 31 vehicles, with six electric flex-route cutaways, seven electric trolleys, and four electric demand-response vans, with hybrid vehicles comprising the remainder of the demand-response fleet. To support the battery electric vehicles, the agency also plans to procure, install, and commission one centralized and seven level 2 chargers at the main storage facility in Sanford, Maine, one plug-in DCFC-type charger at the Nasson Healthcare site, and two centralized chargers at the Wells Regional Transportation Center.

One of the primary motivations behind YCCAC's transition to hybrid and battery electric drivetrain technologies is to achieve emissions reductions compared to their existing gasoline operations. As part of this analysis, an emissions projection was generated for the proposed future hybrid and battery electric fleet. The results of this projection estimate that the new fleet will yield a 63-70% reduction in emissions compared to YCCAC's existing gasoline operations.

The conclusion of the analysis is that although battery electric vehicles are not yet ready for complete replacement of YCCAC's fleet, the agency would benefit from electrifying its flex-route and trolley services and beginning the demand-response transition with a small pilot, accompanied by a shift to hybrid technology for the remaining vehicles. These vehicles offer the potential for the agency to greatly reduce pollution and noise, take a leadership role in vehicle electrification in York County, and gain the required skillsets and operating experience for future electrification once the technology advances further. Therefore, YCCAC 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 inspect zero-emissions vehicles and related infrastructure and avoid displacement of the existing workforce.

In response to the Governor's Roadmap and the FTA requirements, the York County Community Action Corporation (YCCAC), 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 YCCAC's future route plans, vehicle technology options, building electrical capacity, emissions impacts, resiliency, and financial implications.

3. Existing Conditions

YCCAC is a transit agency providing demand-response paratransit services throughout York County, Maine, in addition to operating four flex route services. The agency currently owns and operates a fleet of thirty passenger vehicles, all of which are gasoline powered, though it plans to transition to a demand-response fleet primarily composed of vans.

Section Summary

- YCCAC currently operates four scheduled routes, two seasonal trolley routes, and three on-demand paratransit / curb-to-curb services with a thirty-vehicle fleet.
- On-demand vehicles operate for up to twelve hours a day on widely varying routes due to unpredictable user demand.

Table 1 Current Vehicle Roster

Vehicle Type/Roster Number	Fuel Efficiency (MPG)	# of Vehicles	Procurement Date/Age	Projected Retirement Date
Dodge mini-van (83, 84, 86)	20	3	2014-2015	2023
Chevy Arboc (147-149, 151-153)	8.9	6	2010-2011	2021
Chevy Arboc (201)	8.9	1	2012	2024
Chevy Glaval (154-156)	8.9	3	2017	2022
Ford Champion Defender (157-158)	5.6	2	2019	2026
Ford E-450 / Startrans (159-167)	7.8	9	2019	2024
Ford Molly Trolley (Dory, Driftwood, Lobstah, Osprey, Scallop, Seahorse)	6.5	6	2009	2022

YCCAC operates four year-round flex routes and two seasonal trolley routes. There are also three additional trolley routes which, despite being branded together with YCCAC's routes from a public perspective, are run by private operators. Because these vehicles are not owned or operated by YCCAC, they are not considered in this report. All other YCCAC services are on-demand paratransit. The flex routes and YCCAC service area are shown in Figure 1 below.

Sanford Transit

+ Service from Springvale to South Sanford.
+ Operates approximately every 80 minutes Mondays to Fridays between 8:00 AM to 3:30 PM.

Orange Line

+ Service from Sanford to Wells.
+ Operates every 1.5-2.5 hours, daily except major holidays, between 6:00 AM to 7:00 PM.

Kennebunk In Town Transportation (KITT)

+ Local shuttle service in Kennebunk.
+ Operates approximately every 2.5 hours only on Tuesdays between 10:00 AM to 4:00 PM.

Southern Maine Connector

+ Shuttle service connecting Springvale to Saco.
+ Operates approximately every 3 hours on Mondays to Fridays between 7:30 AM to 3:45 PM.

WAVE

+ On-demand curb to curb service within Sanford as well as to Biddeford and Wells.
+ Operates eight trips every day from Sanford to Biddeford between 6:00 AM and 11:00 PM.
+ Operates eleven trips every day from Sanford to Wells between 6:00 AM and 11:00 PM.

Local Rides

+ On-demand curb to curb service, for local shopping and medical appointments.
+ Service available in various York County towns.
+ Operates every Monday from 7:45 AM to 4:15 PM, with morning service in South Sanford and afternoon service in Alfred/Waterboro/North Sanford.

+ Operates every Wednesday from 7:45 AM to 4:15 PM, with morning service in Kennebunk/Biddeford and afternoon service in Saco/Old Orchard Beach.
+ Operates every Thursday from 8:00 AM to 12:00 PM with service in Berwicks.
+ Operates every Friday from 8:00 AM to 12:00 PM with service in Eliot/York/Kittery.

Connecting Cancer Care Program

+ On-demand curb to curb service, serving York County residents traveling for cancer care.

Shoreline Explorer – Blue 4, Blue 4b

+ Two lines that service Wells, Kennebunk, Perkins Cove, and York Short Sands.

Figure 1 YCCAC Route Map

YCCAC is currently studying the possibility of providing a micro-transit service that would provide service to Kittery, by the Portsmouth Naval Shipyard. This service is expected to involve a partner such as Via and use vans. Additionally, YCCAC is included in PACTS's *Transit Tomorrow* and *Transit Together* studies. The results and recommendations from these studies will have an impact on YCCAC operations in the future but have not yet been implemented. Although YCCAC will need to adapt its electrification strategy to any future service changes, the recommendations in this report are generally expected to remain relevant even after those changes are made.

4. Vehicle Technology Options

Section Summary

- Manufacturers' advertised battery capacities do not reflect actual achievable operating range
- Considering a broad range of vehicles may help YCCAC lower procurement cost

As discussed in Section 3, YCCAC's revenue service fleet is composed of wheelchair lift minibuses, vans, and trolleys. For future procurements, YCCAC is planning to shift its demand-response fleet largely to vans, which are easier to maneuver in narrow streets and driveways. (Because any remaining demand-response services using cutaways would be operated ad-hoc, for consistency they were not considered here). The flex route vehicles are expected to remain cutaway shuttles as they are today, and the trolley vehicles will likewise remain unchanged. Each category of electric vehicles may have limitations that the gasoline versions do not have. For example, because of the weight of the battery, one of the commercially available electric vans on the market can accommodate eight ambulatory passengers and only one wheelchair (as opposed to two on a gasoline van) while staying under GVWR limits. Such a change would have an impact on agency operations. In some cases YCCAC can consider alternate options; for example, shifting from an electric cutaway vehicle (shown in Figure 2) to 30' transit buses would potentially allow greater operating range and passenger capacity, even though such a shift would have cost and maintenance implications. In general, Hatch recommends that YCCAC consider a broad range of vehicles in its future procurements, enabling maximum competition and potentially lowering cost.

Figure 2 Example Electric Cutaway Vehicle

In the hybrid and battery electric vehicle space, there is a variety of possible vehicles for YCCAC to utilize. Hybrids are generally equivalent in range to gasoline vehicles, so no detailed modeling is required. For battery electric vehicles, battery capacity can be varied on many commercially available vehicle platforms to provide varying driving range. For this study, battery electric cutaways were assumed to have 157 kWh battery capacity, vans 120 kWh battery capacity, and trolleys 226 kWh battery capacity, which are representative values for the range of batteries offered by the industry. Two types of safety margins were also subtracted from the nominal battery capacities of the vehicles. First, the battery was assumed to be six years old (i.e. shortly before its expected replacement). As batteries degrade over time, their capacity decreases. To account for this, the battery capacity was reduced by 20%. Second, the vehicle 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 vehicles from becoming stranded on the road. Combining these two reduction factors yields a usable battery capacity of 64% of the nominal value (100 kWh for the cutaways, 77 kWh for the vans, and 145 kWh for the trolleys).

5. Infrastructure Technology Options

There are two primary types of chargers that are applicable to YCCAC’s fleet – level 2 chargers, which are common in light-duty commercial applications, and DC fast chargers, most often applied toward heavy-duty vehicles. These differ in several key respects, primarily the type of power supplied.

Power distributed by electrical utilities, both at high voltages in long-distance transmission lines and low voltages in conventional wall outlets, is alternating current (AC), while batteries on vehicles use direct current (DC). Smaller vehicles, that require lower power levels, generally accept both types of power and have onboard rectifiers to convert AC input to DC. Accepting AC power reduces the cost of charging equipment. For larger vehicles the required rectifier would be too heavy, so the conversion to DC is conducted within the charger. This has a significant impact on the power levels each type of charger supplies.

The charging power provided by Level 2 chargers can range from 3.1kW to 19.2kW. Typical consumer grade chargers incorporate 6.24 kW of power while commercial grade chargers are available at 19.2 kW charging rates. Examples of such a system are shown in Figure 3.

Figure 3 Example Commercial Level 2 Charging Systems (Source: FLO & Blink)

DC fast chargers, which can provide up to 450 kWh of power, typically come in two types of configurations:

1. Centralized
2. De-centralized

A de-centralized 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. An example of a centralized charging system is shown in Figure 4.

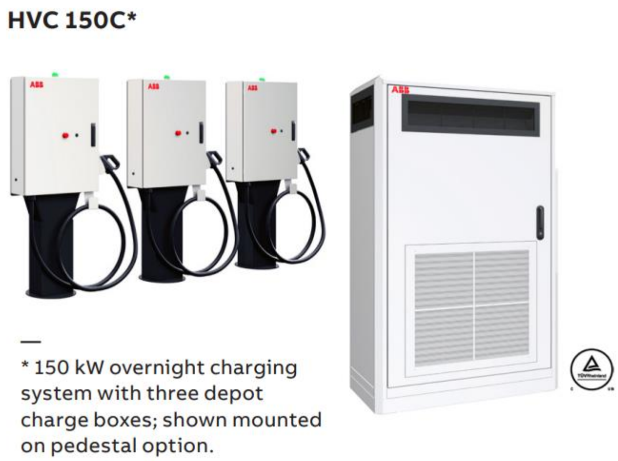

Figure 4 Example Charging Systems (Source: ABB): Charging Cabinet (System) and Three Dispensers (Charge Boxes)

For YCCAC's operations, a mix of 19.2 kW level 2 chargers, decentralized DC fast chargers, and centralized 150 kW fast chargers will be appropriate. Each type of charger has distinct advantages. Level 2 chargers are the easiest and cheapest to install and maintain, as they do not require electrical equipment to convert AC to DC power. They are also the most commonplace on the market, reducing the risk of obsolescence. Decentralized DC fast chargers are best in locations where quick top-up charging (that level 2 chargers could not accommodate) is needed, but with only one vehicle at a time, making a centralized charger uneconomical. Where a large number of vehicles is charging, with at least some vehicles requiring fast charging, centralized chargers are recommended. Although they are the most expensive, their advanced power distribution algorithms allow the agency maximum flexibility. If only one vehicle is plugged in, it will be provided with as much power as it can accommodate (up to 150 kW), and if multiple vehicles are plugged in the power will be distributed between them. As with the vehicles, charging infrastructure is available in numerous configurations. The specific recommended installation locations for each type of charger are discussed in Section 8.

6. Route Planning and Operations

Section Summary

- Electric vehicles do not offer comparable operating range to gasoline vehicles – so detailed operations modeling is needed
- Shorter on-demand runs can be electrified with electric vans, or with cutaways if necessary
- Flex-route and trolley vehicles will need charging throughout the day.

YCCAC'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 nearly continuously for as long as necessary, and then returns to the depot / overnight parking location. Although YCCAC'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 vehicles, which have comparable range to gasoline vehicles, but may not always be valid for electric vehicles, which have reduced range, particularly in winter months. (Vans and cutaway shuttles typically do not have auxiliary heaters to reduce the power required for heating, like transit buses do; in addition, icy road conditions and cold temperatures degrade electric vehicle performance in the winter). Therefore, battery electric vehicles may not provide adequate range for a full day of service, year-round, on the flex routes and many of the demand-response vehicle runs, particularly if recommended practices like pre-conditioning the vehicle before leaving the garage are not always followed.

YCCAC's paratransit service operates throughout the day on an on-demand basis. The busiest periods are the early morning and late afternoon; though some vehicles operate continuously throughout the day, others return to the storage facility during the midday. Easy Rides software is used to minimize downtime and optimize route efficiency. The vehicles typically do not have long down-times between pick-ups. Therefore, to avoid significant impacts to operations, the electric demand-response vehicles will need to have enough range to operate without charging until they return to the depot.

YCCAC's trolley services operate in the Wells area, which is a 30 minute drive from the vehicle storage facility in Sanford. This presents an operational hindrance as vehicles must deadhead to and from the depot each day. Previously, the trolleys were stored overnight at the highway department facility near Wells; however, this option is no longer available. YCCAC is interested in identifying an alternate location near the trolley routes to store (and potentially charge) the trolleys. As discussed in Section 9, this study assumed that a storage and charging location is available at the Wells Regional Transportation Center, as planned for storage for the 2023 season.

6a. Operational Simulation

To assess how battery electric vehicles' range limitations may affect YCCAC'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 YCCAC's operations. As mentioned above, it was not necessary to simulate hybrid operations because the vehicles offer comparable range to gasoline vehicles.

Hatch conducted a route-specific electric vehicle analysis by generating a drive cycle for the scheduled routes, as well as for routes representative of demand-response operations. The full geography (horizontal and vertical alignment), transit infrastructure (location of key stops), road conditions (vehicle congestion, as well as traffic lights, stop signs, crosswalks, etc.), and use of the wheelchair lift were modeled, and vehicle performance was simulated in worst-case weather conditions (hot summer for the trolleys and cold winter for other vehicles) to create a drive cycle. These YCCAC-specific drive cycles were used to calculate the energy consumption per mile and therefore total energy consumed by a flex-route, trolley, or demand-response vehicle.

As discussed in the previous section, the resultant runs were evaluated against common electric cutaways, vans, and trolleys with 157 kWh, 120 kWh, and 226 kWh batteries respectively. As technology advances, these battery capacities are likely to increase by approximately 3% each year, allowing for additional range. As all three of YCCAC's vehicle types are approaching their replacement dates, the agency will not be able to take advantage of these future improvements during the current procurement cycle. However, during subsequent procurement cycles, the combination of market advancements and YCCAC's experience with already-procured EVs will let the agency electrify its fleet further. Clearly, if battery electric technology advances faster than anticipated, if the first-generation electric fleet proves reliable and long-lasting, or if cutaway range improves significantly over that of vans, a greater portion of the demand-response vehicles will be available for electrification. Conversely, if technology develops more slowly or the first-generation fleet requires replacement sooner, a pilot deployment may remain the practical limit on the demand-response services for the foreseeable future.

Table 2 below presents the mileage and energy requirements for YCCAC flex-route and trolley operations. Green shading denotes those runs that can be operated by the specified vehicle and red shading denotes those that cannot. As mileage on the demand-response services varies by day and by vehicle, a representative route was used to estimate vehicle range.

Table 2 Energy Requirements by Run

Block	Mileage	kWh Required	Mileage Shortage/Excess
Kennebunk In-Town Transit (KITT)	64	98	1
Orange Line	213	245	-125
Sanford Transit	107	149	-34
Southern Maine Connector	150	177	-65
Trolley Blue 4	205	270	-94
	184	242	-72
Trolley Blue 4b	181	239	-71
	181	239	-71

6b. Operational Alternatives

For the demand-response services, an electric van is expected to have a usable range of approximately 80 miles in the harshest weather conditions. (Due to the larger vehicle weight, a cutaway's range is roughly comparable). To avoid impact on YCCAC operations, the most viable service model replaces the vehicles on shorter runs with electric vans, with all other runs being operated by hybrid vehicles. Easy Rides's route distance measurement tool, already available to YCCAC, will help YCCAC choose the best runs on which to assign electric vehicles. The choice of vehicle for subsequent procurements will be heavily influenced by the performance of the pilot fleet: the farther the vehicles are able to travel during harsh winter conditions, the more of YCCAC's demand-response vehicles are feasible for electrification.

On the flex-route services, an electric cutaway can operate the KITT (Kennebunk In-Town Transportation) route, but not the other three routes, before recharging. This allows several operating models, which are described below.

One possibility is to use hybrid vehicles, which as discussed above have identical range to gasoline vehicles. Operations would be able to remain exactly as they are today. However, this would increase vehicle procurement cost for comparatively small reductions in emissions and would not allow the agency to meet the State's climate goals. Because other operating alternatives are available, unlike for demand-response services, YCCAC chose not to consider hybrid vehicles for flex-route and trolley services.

Another possibility is to operate electric vehicles and swap them at the YCCAC facility in Sanford after one or several round trips, with one vehicle charging while another operates in service. This would simplify YCCAC's infrastructure by consolidating it at the storage facility and would improve on-time performance by extending vehicle layover times. However, this would require a substantial increase in fleet size, to allow service to be operated while some vehicles are charging. In addition, the additional deadheading to and from the depot would increase operations costs, making this configuration impractical for YCCAC.

A third option involves using a transit bus rather than a cutaway vehicle. Because transit buses have more room for batteries on the roof and under the floor, they typically have longer range than cutaway vehicles. Adopting a transit bus would also let YCCAC increase capacity, accommodating ridership gains from any service changes the Transit Together project may recommend. However, transit buses are significantly more expensive than cutaways, are less maneuverable on narrow streets, and would require additional training for YCCAC staff to operate and inspect. Because of these drawbacks, this option is currently not being considered.

A fourth choice, and the one YCCAC selected, is to recharge the vehicle during its layovers using a fast charger. Though this would require revising the schedule, a well-designed timetable could combine vehicle charging time and driver meal break time, maximizing efficiency. As most blocks do not have sufficient time to deadhead to and from the YCCAC facility for each charging window, this option would require the installation of an YCCAC-owned fast charger at one terminal for each route. For the Sanford Transit and Southern Maine Connector routes, this is most practical at the Nasson Healthcare site (see Sections 9 and 12). As the Orange Line terminates a half-mile from the vehicle storage facility, it is most practical to deadhead the vehicle to and from the depot when needed, with a fast charger installed at the depot to facilitate prompt charging. As the current schedules do not include allowances for charge time, YCCAC would need to tweak the schedules slightly, but the general span of service and number of trips is expected to remain unchanged. A comparison of the current schedule, and a conceptual schedule that would allow a full day of electric operation on all flex-route services, is presented in Figure 5. This schedule assumes fast charging at the depot (for the Orange Line) and at the Nasson Healthcare site (for the other two flex-route services).

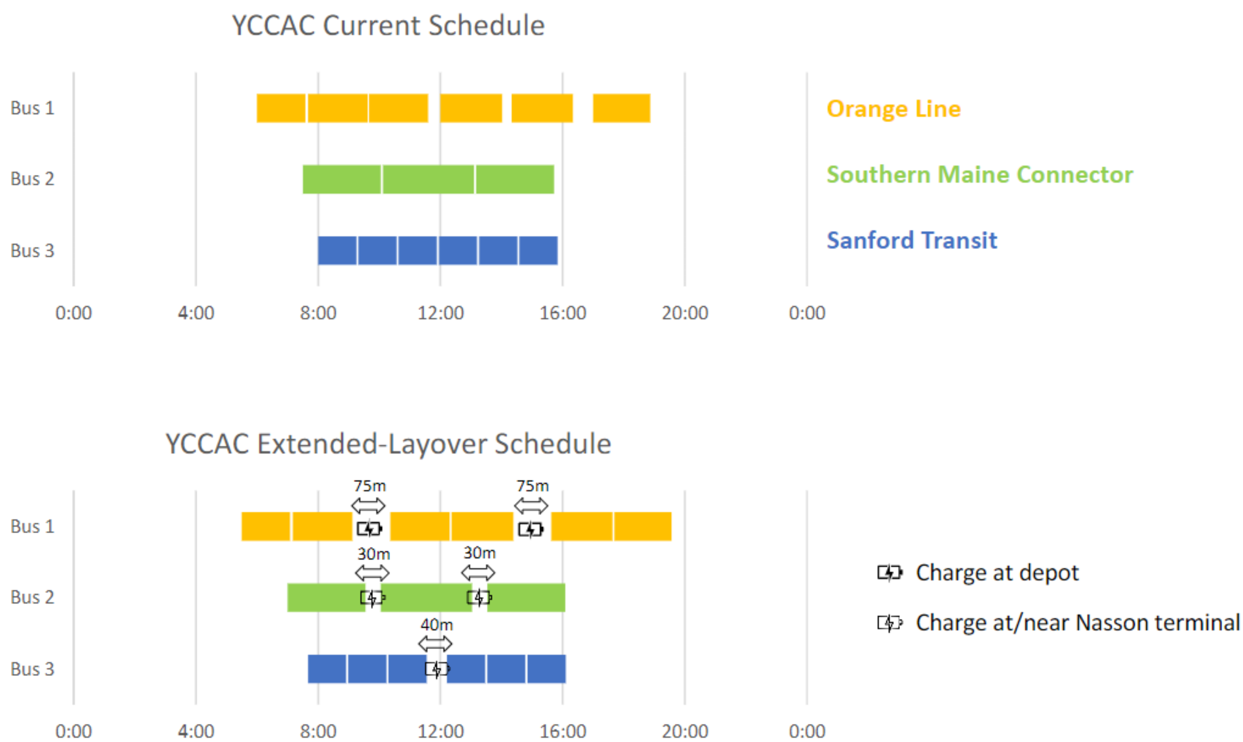

Figure 5 Comparison of Current and Conceptual Electric-Vehicle Schedules

For the trolley services, a similar operating model is assumed. As mentioned above, charging is assumed to occur at Wells Regional Transportation Center. Because the Blue 4 trolley route does not serve Wells RTC directly, deadheading between the eastern terminal and Wells RTC was assumed. Alternatively, YCCAC could choose an operating schedule that would swap buses between the Blue 4 and Blue 4b routes at the Bypass Road eastern terminal, allowing all trolleys to access the charger without deadheading.

7. Charging Schedule and Utility Rates

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

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 YCCAC charge its vehicles economically

YCCAC's current electricity rates are determined by Central Maine Power's 'MGS-S' rate table, as shown in Table 3. Under this rate table YCCAC pays a flat "customer charge" monthly, regardless of usage. YCCAC 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 peak and is local to YCCAC's usage. Finally, YCCAC 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 YCCAC 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 and is available as an optional rate for customers with electric vehicle DCFCs or level 2 charger arrays. To qualify for this rate, Central Maine Power requires that the customers like YCCAC 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 YCCAC 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 a 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 YCCAC to develop a charging plan which avoids charging vehicles 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, for each of the three proposed charging sites, around the operational plan developed in the previous section of the report and the above listed utility schedules. The results of this optimization for proposed charging locations at YCCAC office, Nasson Healthcare and Wells RTC are shown in Figure 6, Figure 7 and Figure 8 respectively. It can be seen in the figures that the optimized charging schedule assumes that vehicles will be charged primarily overnight (between 9 PM and 5 AM), with on-route/mid-day charging as needed during the daytime. This will avoid charging during the Central Maine Power grid's 'coincidental peak' (between 3 PM and 7 PM) as much as possible and allow YCCAC 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.

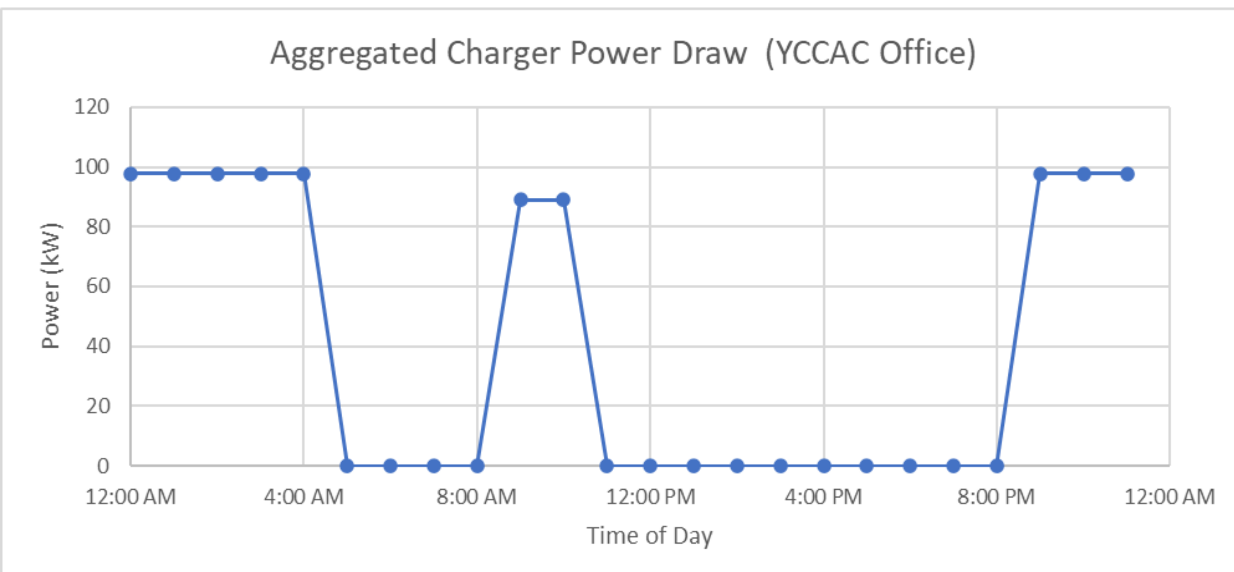

Figure 6 Proposed Overnight Charging Schedule for YCCAC's Flex-Route and Demand Response Vehicles

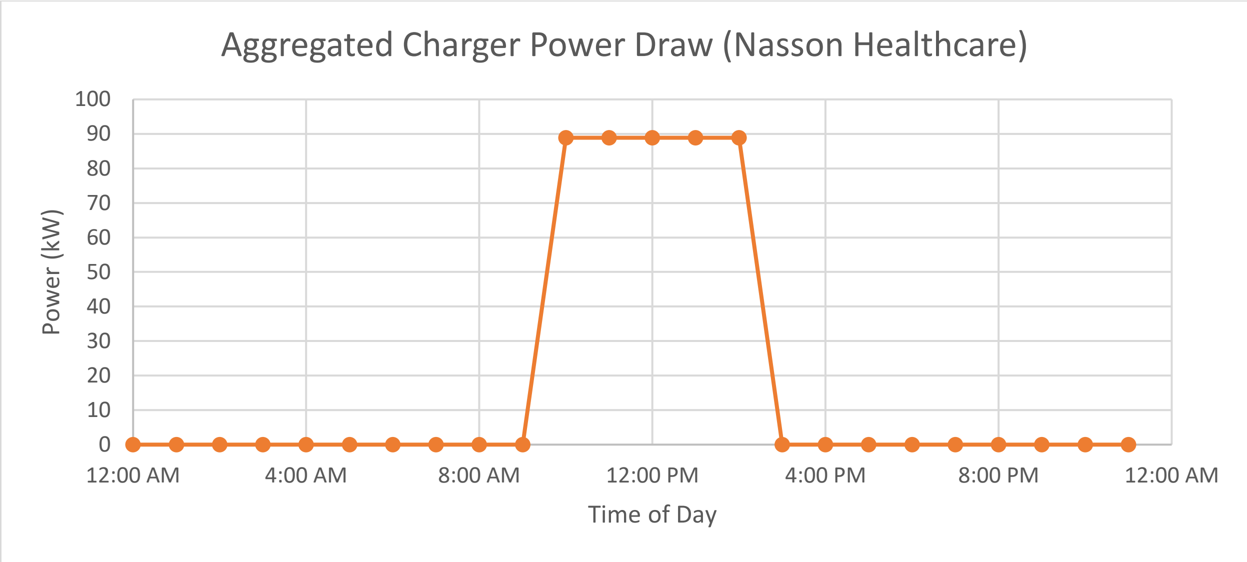

Figure 7 Proposed On-Route Charging Schedule for YCCAC's Flex Route Vehicles

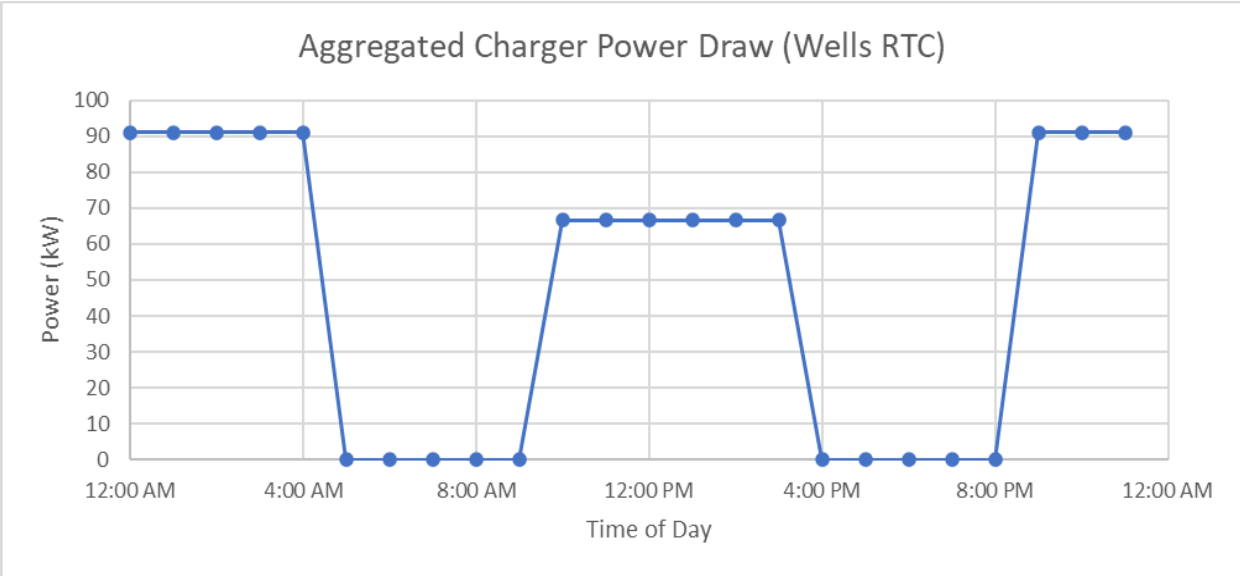

Figure 8 Proposed Overnight and Mid-day Charging Schedule for YCCAC's Trolley Buses

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

Depot – YCCAC office (6 Spruce St.)

Daily kWh consumption = 878 kWh
Monthly Non-coincidental peak = 98 kW
Monthly coincidental peak = 0 kW

Under Current MGS-S Rate Structure:

$$Daily\ Charge = Daily\ kWh\ consumption\ \times (Energy\ Delivery\ Charge + Energy\ Cost)$$
$$= 878\ kWh\ \times (\$0.001745 + \$0.12954)$$
$$= \$115.27$$

$$Monthly\ Charge = (Monthly\ Non - coincidental\ Peak\ \times Distribution\ Charge) + (Monthly\ Non - coincidental\ Peak\ \times Transmission\ Charge)$$
$$= 98\ kW\ \times \$16.64$$
$$= \$1{,}630.72$$

Under New B-DCFC Rate Structure:

$$Daily\ Charge = Daily\ kWh\ consumption\ \times (Energy\ Delivery\ Charge + Energy\ Cost)$$
$$= 878\ kWh\ \times (\$0.001745 + \$0.12954)$$
$$= \$115.27$$

$$Monthly\ Charge = (Monthly\ Non - coincidental\ Peak\ \times Distribution\ Charge) + (Monthly\ Coincidental\ Peak\ \times Transmission\ Charge)$$
$$= (98\ kW\ \times \$4.39) + (0\ kW \times \$19.35)$$
$$= \$430.22$$

On-Route – Nasson Healthcare (15 Oak St)

Daily kWh consumption = 246 kWh
Monthly Non-coincidental peak = 89 kW
Monthly coincidental peak = 0 kW

Under Current MGS-S Rate Structure:

$$Daily\ Charge = Daily\ kWh\ consumption\ \times (Energy\ Delivery\ Charge + Energy\ Cost)$$
$$= 246\ kWh\ \times (\$0.001745 + \$0.12954)$$
$$= \$32.29$$

$$Monthly\ Charge = (Monthly\ Non - coincidental\ Peak\ \times Distribution\ Charge) + (Monthly\ Non - coincidental\ Peak\ \times Transmission\ Charge)$$
$$= 89\ kW\ \times \$16.64$$
$$= \$1{,}480.96$$

Under New B-DCFC Rate Structure:

$$Daily\ Charge = Daily\ kWh\ consumption \times (Energy\ Delivery\ Charge + Energy\ Cost)$$
$$= 246\ kWh \times (\$0.001745 + \$0.12954)$$
$$= \$32.29$$

$$Monthly\ Charge = (Monthly\ Non-coincidental\ Peak \times Distribution\ Charge) + (Monthly\ Coincidental\ Peak \times Transmission\ Charge)$$
$$= (89\ kW \times \$4.39) + (0\ kW \times \$19.35)$$
$$= \$390.71$$

Depot – Wells RTC

Daily kWh consumption = 999 kWh
Monthly Non-coincidental peak = 91 kW
Monthly coincidental peak = 0 kW

Under Current MGS-S Rate Structure:

$$Daily\ Charge = Daily\ kWh\ consumption \times (Energy\ Delivery\ Charge + Energy\ Cost)$$
$$= 999\ kWh \times (\$0.001745 + \$0.12954)$$
$$= \$131.15$$

$$Monthly\ Charge = (Monthly\ Non-coincidental\ Peak \times Distribution\ Charge) + (Monthly\ Non-coincidental\ Peak \times Transmission\ Charge)$$
$$= 91\ kW \times \$16.64$$
$$= \$1{,}514.24$$

Under New B-DCFC Rate Structure:

$$Daily\ Charge = Daily\ kWh\ consumption \times (Energy\ Delivery\ Charge + Energy\ Cost)$$
$$= 999\ kWh \times (\$0.001745 + \$0.12954)$$
$$= \$131.15$$

$$Monthly\ Charge = (Monthly\ Non-coincidental\ Peak \times Distribution\ Charge) + (Monthly\ Coincidental\ Peak \times Transmission\ Charge)$$
$$= (91\ kW \times \$4.39) + (0\ kW \times \$19.35)$$
$$= \$399.49$$

As this estimate shows, the optional 'B-DCFC' rate structure would save YCCAC $3,405.50 per month combined for all sites. These savings are, again, achieved by avoiding charging during the coincidental peak between 3 PM and 7 PM, and the reduced monthly 'distribution' 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 $5,379.30 per month from a 'transmission charge'. As the number of electric vehicles increases in YCCAC's fleet, the saving from the B-DCFC rate structure will also increase proportionally. Therefore, it is important YCCAC charges the vehicles outside the coincidental peak window between 3 PM and 7 PM as much as possible or procures a smart charging management system which is programmed to avoid charging during the coincidental peak. (Although the charging schedule in Figure 8 requires some charging for a brief period after 3 PM, the variability in grid peak times means that this limited charging is unlikely to trigger demand charges). Furthermore, it is also important that YCCAC 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 summer load. 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 YCCAC's operation.

8. Asset Selection, Fleet Management and Transition Timeline

Section Summary

- Hatch recommends procuring four electric vans, 7 electric trolleys, and 6 electric cutaways, with the remainder of the fleet being hybrid
- Hatch recommends installing seven chargers at the YCCAC office, two at Wells RTC, and one at the Nasson Healthcare site

With operational and charging plans established, it was then possible to develop procurement timelines for infrastructure and vehicles to support those plans. YCCAC, like almost all transit agencies, acquires vehicles 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 commercial vehicle procurement – and especially for a newer technology like electric vehicles – there are advantages to larger orders, such as lower cost and more efficient vendor support. YCCAC 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 type of vehicles. This is particularly true for the first order of electric vehicles, where the inevitable learning curves are best handled with a larger fleet rather than a single vehicle.

As an additional complication, YCCAC operates a mix of cutaways, vans, and trolleys. As commercial electric vehicles remain a comparatively niche market, this means that YCCAC will likely have a small pool of potential suppliers to choose from. To increase procurement competition, YCCAC is encouraged to keep its vehicle specifications flexible, for example by allowing small-size buses to be proposed instead of cutaways for the flex-route services. A vehicle like the Hometown Urban, if selected, would allow parts and diagnostics commonality with the most likely electric trolley fleet, as well as allowing for growth in passenger demand. In addition, the EV market is changing rapidly, with new entrants annually; YCCAC is similarly encouraged to monitor the market and adjust specifications as needed. To maintain a fair comparison, however, this analysis assumes that the existing fleet will be replaced as planned by YCCAC, with vans for demand-response service, cutaways for flex-route operation, and trolley-style vehicles for seasonal routes.

With respect to infrastructure procurements, the choice of charger type at each will be important for future operations. At 6 Spruce St., the primary use case is slow overnight charging of demand-response vans and cutaways, which have comparatively small batteries. This need is best fulfilled by level 2 chargers. However, some demand-response vehicles have short midday layovers during which they need to replenish their charge; additionally, the Orange Line's midday layovers will be too short for the low level of power provided by a level 2 charger. In the short term, this is best accommodated by a single DC fast charger; as the electric fleet grows, Hatch recommends installing one centralized 150 kW charger with three dispensers. As mentioned above, this can accommodate both fast charging of a single vehicle and lower-power charging of up to three vehicles at a time. A 1:1 dispenser to vehicle ratio is recommended to allow all vehicles to be charged overnight without requiring staff intervention. To accommodate the remainder of the 10-vehicle electric fleet charging at 6 Spruce St., six level 2 chargers are also recommended. If configured accordingly, all eight chargers can be used during the daytime hours by the personal vehicles of YCCAC staff.

At the Nasson Healthcare site, YCCAC's only charging need is during short midday layovers. As there is only one vehicle expected to charge there at a time, a single 80 kW DC fast charger is recommended. When not in use by YCCAC vehicles the charger could be made available for public use, generating additional revenue for the agency.

At Wells TC, the charging infrastructure must accommodate both midday fast charging and overnight lower-powered charging. Although the midday fast charging need could be served by a single DC fast charger, with level 2 chargers used for overnight charging, for redundancy and design simplicity Hatch recommends installing two centralized 150 kW chargers, with six dispensers total, at this site. As at Nasson, when not in use by trolleys the chargers can be opened for use by the public as a revenue-generating measure.

The main depot of Biddeford Saco Old Orchard Beach Transit (BSOOB) is used for maintenance of some YCCAC vehicles. Charger use during maintenance is generally small in scale and short in duration, with vehicles only needing to be connected to a charger for fault diagnosis. Although YCCAC will need to reach a payment agreement with BSOOB regarding electricity use by YCCAC vehicles during maintenance, BSOOB's existing and already-planned chargers are expected to be sufficient for maintaining YCCAC vehicles.

As fleet electrification continues in future vehicle procurements beyond the horizon of this report, the vehicle storage area at 6 Spruce St. will eventually need to have enough chargers to accommodate all of YCCAC's electric vehicles. 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 connections, structural modifications, and civil work make it economical to install all the support infrastructure at once. When additional electric vehicles arrive and more chargers are required, the only work that should be necessary is installation of the chargers themselves. Hatch recommends that spare capacity in ductbanks, transformer pads, etc. be included in the initial design for charging infrastructure at 6 Spruce St. to offset some of these future costs.

Providing sufficient resiliency and redundancy to continue operation after failure of a single charger is an important concern. The suggested infrastructure strikes a reasonable balance between mitigating the impact of a charger outage and avoiding excess capital and maintenance cost. At 6 Spruce St., the proposed number of dispensers exactly matches the proposed number of electric vehicles charging there. This allows some room for charger outages, as some vehicles will be in reserve or undergoing minor maintenance on a given day and will therefore not need charging. At the Nasson site, it is uneconomical to provide more than one charger for YCCAC use, unless as part of a larger public charging station. In case of charger failure or maintenance YCCAC will be required to deadhead vehicles to and from the depot. At Wells, the recommended six dispensers will provide allowance for a standby trolley or for dispenser maintenance.

Table 4 provides a summary of the proposed vehicle and infrastructure procurement schedule:

Table 4 Proposed Fleet and Charging System Transition Schedule

Year	Vehicles Procured	Infrastructure Procured	Vehicles Replaced
2023	7 (7 Hybrid Transit Vans)		147-9, 151-3, 201
2024	13 (7 Electric Trolleys, 4 Electric Transit Vans, 2 Hybrid Transit Vans)	Spruce St.: 7 level 2 chargers, 1 centralized 150 kW charger Wells TC: 2 centralized 150 kW chargers Nasson HC: 1 80 kW DCFC	83-4, 86, 154-6, all trolleys
2025			
2026	11 (6 Electric Cutaways, 5 Hybrid Transit Vans)		157-67

For the demand-response services, Hatch recommends a robust testing program for the pilot order of electric vans on operating cycles across York County year-round. This experience will help YCCAC understand electric van operation across different geography (hilly vs flat), environments (urban vs rural), and weather conditions (winter vs summer) to inform future decisions on fleet electrification. YCCAC can also consider using local public charging infrastructure for occasional charging during driver breaks; the knowledge gained about charger location and reliability/availability will let YCCAC better plan for vehicle range extension and operational resiliency. Finally, spreading electric vans out will ensure that the benefits of electric vehicles (elimination of tailpipe emissions, reduced noise, etc.) are distributed equitably across the county. This may also prove valuable from a Title VI perspective, particularly as county demographics continue to change over the coming years. Rotating the electric vehicles across the region will ensure that no area is disproportionately negatively impacted by YCCAC operations.

9. Building Spatial Capacity

Section Summary

- The existing 6 Spruce St. facility is suitable for installation of level 2 and centralized DC fast chargers
- The Nasson Healthcare site has space for a charger, assuming landowner agreement
- Wells TC has space for vehicle charging as well; the bus parking area is recommended

YCCAC's headquarters, and main storage facility is located at 6 Spruce St. in Sanford. There is a vehicle wash located inside the facility, but no depot or covered storage building. The facility does not have a gas station. All vehicles are usually stored onsite, though in the winter the seasonal trolleys are sometimes stored in rented indoor spaces such as shipyards. As shown in Figure 11 and Figure 10, most of the vehicles are stored on an unpaved area adjacent to YCCAC's main building; financing improvements to

Figure 10 Unpaved Storage Lot

Figure 9 Paved Storage Lot

Figure 11 Aerial View of YCCAC Property and Adjacent Unpaved Storage Lot (Source: AxisGIS)

this area is likely infeasible because it is included in the nearby Stenton Trust building parcel, rather than the parcel owned by YCCAC. However, there are several paved parking lots on YCCAC land, shown in Figure 9, that are used for storage of some vehicles.

In addition to the Sanford facility, YCCAC owns eleven other properties that are used for non-transportation YCCAC services. As these sites are generally small and used for non-transportation uses (e.g. daycare) they are not expected to provide charging location opportunities.

The Nasson Healthcare site is located at 15 Oak St., in Springvale, on the former campus of Nasson College, which closed in the 1980s. The property is currently divided between a variety of public and private landowners, as shown in Figure 12. This complex arrangement may make attempts at infrastructure development (e.g. installation of a bus shelter) politically challenging. However, there are no spatial obstacles to installation of a charger. In addition, because multiple government entities are present on the site, it is likely that YCCAC will be able to form a partnership with one of these organizations to advance vehicle electrification, which is a State priority.

Figure 12 Nasson Healthcare Site and Property Lines (Source: AxisGIS)

The Wells Regional Transportation Center, shown in Figure 13, is an Amtrak train station located at 696 Sanford Rd. in Wells, Maine. This site is owned by the Maine Turnpike Authority and has several acres of parking lots and unused land that could be used for charging infrastructure. Although it is not near YCCAC's primary operations in the Sanford area, it is located in close proximity to the seasonal trolley services and is the terminal of the Blue 4b service. Therefore, it is an ideal candidate for a trolley charging and overnight storage location. Although there are several possibilities for the specific location of chargers within the WRTC, this study assumed that they are placed in the existing bus parking area. This area could be expanded if significant use by non-YCCAC buses during summer overnight periods is expected.

Figure 13 Wells Regional Transportation Center (Source: Google Earth)

The Sanford Seacoast Regional Airport, located at 199 Airport Rd. in Sanford is closer to YCCAC's headquarters and has ample space for future charging infrastructure. The airport is also the site of the largest solar array in New England, shown in Figure 14, ensuring that any electricity used for charging will be as renewably-sourced as possible. However, it is not located near a terminal for any flex-route services, so charging any cutaway or trolley vehicles would require significant deadheading each day. Therefore, it was not selected as a charging location for further study.

Figure 14 Sanford Airport Solar Farm

As mentioned above, the BSOOB facility at 13 Pomerleau St in Biddeford is used to maintain a portion of the YCCAC fleet. Because maintenance typically occurs during the daytime (when revenue vehicles are not charging), and since BSOOB plans to install additional chargers to continue its fleet electrification, Hatch expects that BSOOB will be able to continue maintaining YCCAC vehicles after electrification without needing to install chargers especially for that purpose.

10. Electrical, Infrastructure, and Utility Capacity

Section Summary

- The existing service at 6 Spruce St. is likely at capacity.
- Separately metered service would be necessary to take advantage of optional B-DCFC rate structure, unless submetering is permitted.

Central Maine Power is the utility provider for YCCAC's proposed charging locations at the YCCAC office, Nasson site, and Wells RTC. As part of the development of this transition plan, YCCAC has been partnering with Central Maine Power to communicate its projected future utility requirements at these locations.

The 6 Spruce St. facility has a 12.47 kV 3-phase service that is stepped down to 480/277V through a step-down transformer located outdoors, as shown in Figure 15. The transformer feeds a 480V panel located inside the electrical room. This main 480V panel appears to be at capacity with no spare breakers for the centralized charger that is recommended earlier in this report. Additionally, because the panel schedule and utility drawing were not available at the time of this analysis, space availability on 120/208V panels could not be determined. However, given that a new 480V panel will likely be required for the centralized charger and a new service with separate meter is required to qualify for the special B-DCFC rate structure, Hatch recommends installing a brand new 480V service under a separate meter, with a new 480V panel and a 120/208V panel dedicated for the charging operation. As mentioned previously, the centralized charger requires a 480V 3-phase input while the level 2 chargers, that are also recommended for this site, require either 1-phase 208V or 240V input.

Figure 15 6 Spruce St. Electrical Distribution Transformer

Hatch has confirmed with Central Maine Power that, as of this writing, it can accommodate a new service and required power at the 6 Spruce St. facility. However, the local feeder is approaching its rated capacity and availability of the power is not guaranteed in the future. Hatch highly recommends engaging with Central Maine Power very early in the design stage for its chargers to ensure that the utility has time to upgrade their assets in the area if required. Central Maine Power has provided an initial estimate for the new transformers and service feed to be approximately $50,000. This cost estimate is based on the current available capacity, and it could increase if additional capital investments are required by Central Maine Power to upgrade local distribution assets.

In addition, a similar new 480V service will be required at the Nasson site and Wells RTC for the DCFC chargers, as described in Section 9.

11. Risk Mitigation and Resiliency

Section Summary

- As with any new technology, electric vehicle introduction carries the potential for risks that must be managed
- Although only limited power outage data is available, resiliency options must be considered
- Solar panels in conjunction with on-site energy storage can be a viable option for resiliency, reducing GHG and completely offsetting the electricity used by electric vehicles

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 gasoline vehicles, there are new technologies to contend with, potential build quality issues that must be uncovered, and maintenance best practices that can only be learned through experience with a particular vehicle. Vehicle electrification makes some failure modes impossible – for example by eliminating the gasoline 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 vehicle operation.

11a. Technological and Operational Risk

The vehicle and wayside technology required for electric vehicle operation is in its early stages; few operators have operated their electric fleets or charging assets through a complete life cycle of procurement, operation, maintenance, and eventual replacement. As detailed in the earlier Transit Vehicle Electrification Best Practices Report, this exposes electric vehicle 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 gasoline vehicles, 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 vehicles – 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, avoiding full depletion, and preferring lower power charging to short bursts of high power, best practices in vehicle charging and battery maintenance will become clearer in coming years.
+ Supply availability: Compared with other types of vehicles, electric vans 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 vehicle 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 gasoline vehicles, which can refuel at any public fueling station, electric vehicles require level 2 chargers for overnight charging and specialized DCFC chargers for midday fast charging. Particularly early on, when there is not a widespread network of public chargers, this may pose an operating constraint in case of charger failure.
+ Fire risk: The batteries on electric vehicles require special consideration from a fire risk perspective (see Section 12b).

Most of these risks are likely to be resolved as electric vehicle technology develops. As YCCAC plans to adopt electric vehicles comparatively quickly and is looking to purchase relatively non-standard types of vehicles, it will be critical for YCCAC to develop its operating strategy with an eye toward operating robustness in case of unexpected issues. Hatch recommends several strategies to maximize robustness:

+ Require the electric vehicle vendor to have a technician nearby in case of problems. This is most economical when the technician is shared with nearby agencies such as RTP.
+ Reach a “mutual aid” agreement with another transit agency in Maine that would let YCCAC borrow spare buses/vehicles in case of difficulties with its fleet. For example, YCCAC may arrange to borrow a 35’ bus from BSOOB if the Southern Maine Connector vehicle is unavailable on a given day, or to borrow a van from RTP to cover for shortfalls in the demand-response fleet.
+ Retain gasoline vehicles for at least two years after they are retired to ensure they can substitute for electric vehicles if any incidents or weather conditions require it.
+ For the Southern Maine Connector, Sanford Transit, and seasonal trolleys, develop contingency plans in case of on-route charger failure. This may include using another

charger in the area, swapping vehicles after each round trip, or borrowing a vehicle from another agency.

+ Conduct a fire detection, suppression and mitigation study of locations where chargers and electric vehicles will be housed (see section 12b).

11b. Electrical Resiliency

Electricity supply and energy resilience are important considerations for YCCAC when transitioning from gasoline to electric vehicle 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 YCCAC 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

The 6 Spruce St. facility currently does not have any generator for backup power during electrical service interruption. Because of the limited real estate and orientation of the building roofs, the site does not have enough space available for a meaningful solar array installation. Resiliency options in the form of an on-site storage system or on-site generator should be considered for this location for service reliability.

The Nasson Health Center also does not have any backup power. Like the 6 Spruce St. facility, due to the space constraints, solar is not feasible at this location and backup power in form of on-site storage system or on-site generator should be considered.

The Wells Regional Transportation Center has acres of available land that could be used to install solar panels. This would allow on-site generation of clean energy, which can be used for resiliency as well as to offset the operations cost of charging electric vehicles.

11.b.2. Outage Data and Resiliency Options

After noting no viable resiliency systems in place currently, 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 the three locations to determine the requirements for backup power. Following is a summary of the outages at each of the locations in the last five years.

- 6 Spruce St. facility – There were only five outages at this location in the last five years. Out of the five outages, the one in 2019 lasted for approximately 2.5 hours. This outage was caused by a squirrel contact and was the longest one in the last five years. The rest of the outages were very insignificant and only lasted for less than 2 mins.
- Nasson Health Center – There were only seven outages at this location in the last five years. Most of the outages were minor and lasted between 0.5 and 2 hours.
- Wells Regional Transportation Center – There were total 18 outages at this location in the past five year. Out of these 18 outages, one was the most significant one that lasted for 28 hours. There were two other outages that were long and lasted 13 and 15 hours each. The remaining outages lasted anywhere between 1 and 5 hours.

Resiliency system requirements are typically determined based on the worst outage instance outlined above and the charging needs for the full fleet during this type of outage scenario.

At the 6 Spruce St. location, the on-site energy storage requirement to charge the fleet during the 2.5 hour outage period would be 245 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 306 kWh. The power requirement for generator capacity was assumed to be the aggregated power draw required during overnight charging for the fleet, which is 98 kW. Assuming an efficiency of 90%, and a 20% spare capacity, the resulting on-site generation capacity required would be approximately 140 kVA.

At the Nasson Health Center, the on-site energy storage requirement to charge the fleet during the 2-hour outage period would be 176 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 220 kWH. The power requirement for generator capacity was assumed to be the aggregated power draw required during overnight charging for the fleet, which is 89 kW. Assuming an efficiency of 90%, and a 20% spare capacity, the resulting on-site generation capacity required would be approximately 125 kVA.

At the Wells Regional Transportation Center, the on-site energy storage requirement to charge the fleet during the 28-hour outage period would be 1363 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 1704 kWh. The power requirement for generator capacity was assumed to be the aggregated power draw required during mid-day charging for the fleet, which is 91 kW. Assuming an efficiency of 90%, and a 20% spare capacity, the resulting on-site generation capacity required would be approximately 130 kVA.

Hatch next generated cost estimates associated with the two resiliency system options for all three facilities. Table 6 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 6 Resiliency Options for Worst Case Outage Scenarios

		Size	Capital Cost
Option 1 On-site Battery Storage	6 Spruce St. facility	245 kWh	$160,000
	Nasson Health Center	176 kWh	$115,000
	Wells RTC	1704 kWh	$1,082,000
Option 2 On-site Diesel Generation	6 Spruce St. facility	140 kVA	$65,000
	Nasson Health Center	125 kVA	$58,000
	Wells RTC	130 kVA	$60,000

The above analysis and corresponding options are based on an assumption of full service operated and maximum-duration outages. Since outages like this might occur very rarely, the above resiliency options may be oversized for most use cases resulting in a poor return on the capital investment. As the utility industry evolves over the course of YCCAC'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 can also be considered to add resiliency, offset energy costs, and further reduce YCCAC'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. 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 array would primarily be to offset energy from the grid and reduce utility costs.

As discussed previously, 6 Spruce St. and Nasson Health Center are too space constrained for a meaningful solar installation. However, on-site solar system was evaluated for the Wells Transportation Center because the vacant land at the site provides a large surface area that could be utilized for a solar array. Though a more detailed study would be needed to determine the optimal location for the solar array, one possible layout is illustrated in Figure 16 below.

Table 7 outlines parameters for the solar power system that would be required to offset total annual electricity usage by the electric vehicle charging infrastructure at this site, the surface area that is required for the solar panels, and the resulting cost savings from offsetting energy consumed from the grid.

Table 7 Wells Transportation Center Solar Field Design Parameters

Solar System Design Parameters	
Solar System Sizing Method:	Full Annual Energy Match
Solar Array Area Width	49 ft
Solar Array Area Length	65 ft
Solar Array Area	3,325 ft^2
Maximum Number of Panels	150 panels
Maximum System Power	64 kW
Annual Production Coefficient	1,318 hours
Sunny Days Per Year	200 days
Annual Solar Energy Production	83,833 kWh
Annual Electric Usage	79,911 kWh
Maximum Percent of Electrical Usage Offset	105%
Electricity Rate	$0.12954 / kwh
System Cost	**$175,137**
Utility Bill Savings Per Year	**$10,860**
Simple Payback Period Without Grants	**16.1 years**
Payback Period with 80% Federal Grants	**3.2 years**

Based on the above parameters, YCCAC would need to install approximately 3,325 ft^2 of solar panels by surface area to offset the energy used for charging trolley buses over the year. This, however, does not mean that the charging operation can be performed completely off grid. YCCAC still needs the utility connection for charging during the days when there is not enough sunlight, as well as for charging during the summer months. In the winter, when no charging will occur, the solar array will produce excess energy; this energy can either be sold back to the grid or stored in the on-site energy storage system for later use.

An on-site battery storage system would not only allow 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 energy use for the site. In addition, having on-site solar energy production can help further reduce YCCAC's GHG contribution by reducing energy consumed from the grid, which is partially produced using GHG emitting conventional energy sources.

However, solar power generation is not recommended as a primary resiliency system as 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.

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

12. Conceptual Infrastructure Design

12a. Conceptual Layouts

Section Summary

- Hatch recommends installing chargers at:
  - The southwestern parking lot at 6 Spruce St.
  - The Springvale public library at the Nasson site
  - The existing bus parking area at Wells RTC
- At the Nasson site and Wells RTC, public-sector landowners may be more ready to cooperate on vehicle electrification, which is a State initiative

To assist YCCAC with visualizing the required infrastructure transition, conceptual plans were next developed based on the previous information established in this report. Due to spatial constraints, Hatch recommends that the charging infrastructure be placed outdoors at each charging location.

At the 6 Spruce St. location, multiple parking lots are available for potential charger installation. Chargers could potentially be constructed at any of them. Key considerations for selecting optimal charger location include vehicle maneuverability into the parking space, proximity to charging cabinets, nearby underground utilities, sight lines and vehicle circulation around parked vehicles, ease of snow clearance, and security. In light of these factors, and in keeping with YCCAC's existing vehicle storage practices, Hatch recommends installing the chargers at the southwestern parking lot, closest to downtown Sanford. The most optimal location for dispenser installation is along the western property line, allowing the berths with easiest access to and from the main driveway to be used by the (larger) electric vehicles. Figure 16 shows a conceptual layout for the proposed chargers. In addition to the chargers, YCCAC should install fencing and cameras to deter any potential vandalism to the vehicles or chargers.

Figure 16 Conceptual Layout of Chargers at the 6 Spruce St. Facility (Source: Google Earth)

At the Nasson Healthcare site, any decision on charger location will be highly dependent on agreement with local stakeholders. In addition to the considerations outlined above for 6 Spruce St., the ideal charger location at the Nasson site will allow YCCAC vehicles to pull out of the flow of traffic while charging, as well as being in a location easily accessible by the public during off-hours. Figure 17 shows one possible location for the charger; this location offers the advantage of being located on a single property owner's land, potentially easing implementation.

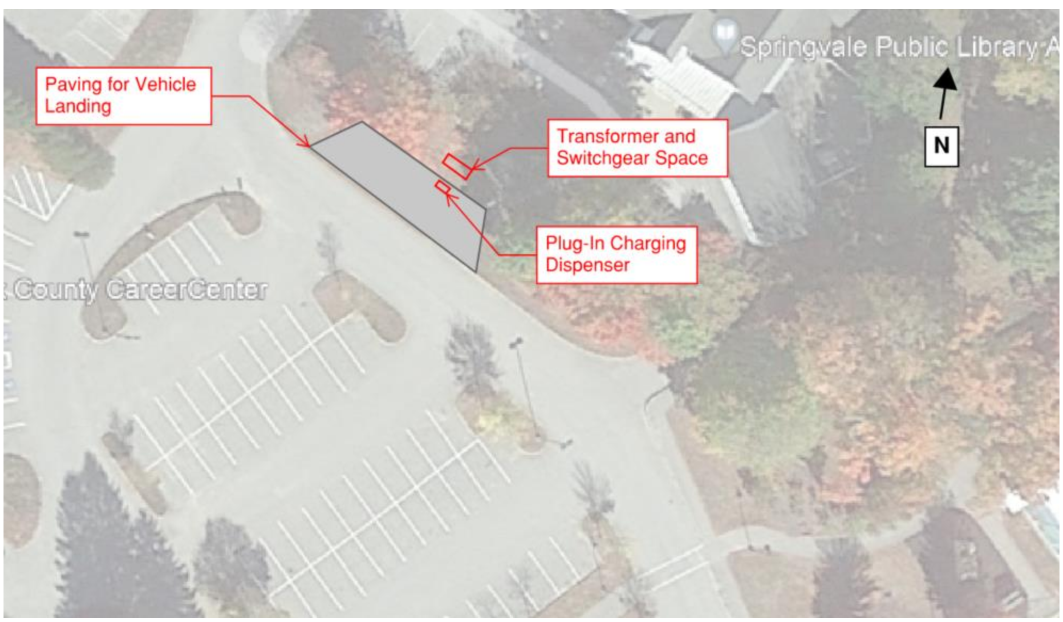

Figure 17 Conceptual Layout of Charger at the Nasson Healthcare Site (Source: Google Earth)

At the Wells Regional Transportation Center, the preferred location for the chargers – and the decision on whether to use existing parking spots for the chargers or create additional paved area – will require consultation with the Maine Turnpike Authority and local leadership. This study assumed that the existing bus parking area is used as a charging station. If significant usage by non-YCCAC buses is expected during summer overnight periods (which is when the maximum number of trolleys would be parked there), the lot could potentially be expanded. Assuming this is not necessary, the space and chargers could be made available for public use during midday hours as well as throughout the off-season, with signage or a charge management system enforcing priority for YCCAC vehicles during trolley charging times. Figure 18 shows a potential layout for the chargers at WRTC.

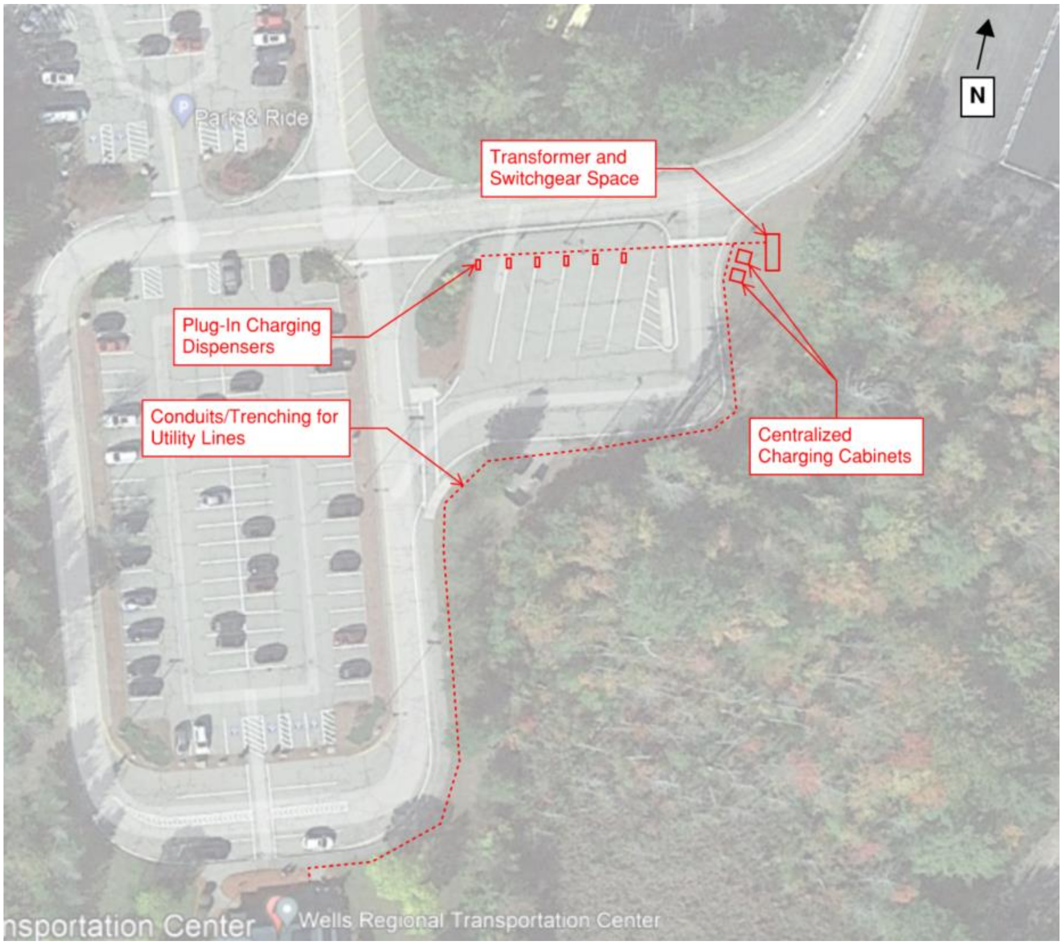

Figure 18 Conceptual Layout of Chargers at the Wells Regional Transportation Center (Source: Google Earth)

12b. Fire Mitigation

An electric vehicle'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 vehicles. If this is another electric vehicle then a chain reaction can occur, with the heat emanating from one vehicle overheating (and likely igniting) the batteries of another vehicle. This can endanger all the vehicles in the 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 YCCAC's risk is comparatively low because all vehicles will be charged outdoors, Hatch still recommends that YCCAC 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 vehicles or the building structure. In terms of staffing, it is recommended that staff be located nearby to respond in case of a fire and move unaffected vehicles out of harm's way. If YCCAC does not maintain staff at the depot overnight, responding firefighters could potentially be trained to fulfill this function during their response to an incident. Each of the factors mentioned above requires specific consideration with respect to YCCAC's facility and operations. Hatch recommends that YCCAC 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

Section Summary

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

YCCAC's current operating budget is roughly $2.8 million per year. The agency's funding sources are summarized in Figure 19. As can be seen in the figure, YCCAC's largest source of funding comes from federal assistance. For vehicle, 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.

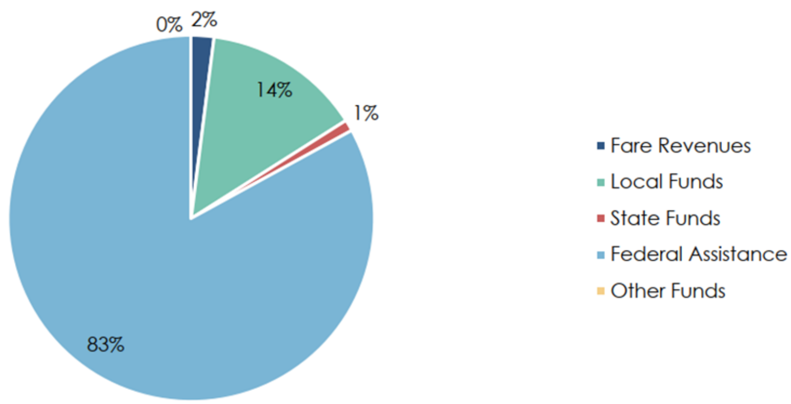

Figure 19 Current Agency Funding Summary (Source: Maine DOT)

As the agency transitions to hybrid and battery electric technology, additional policies and resources will become applicable to YCCAC. Table 8 provides a summary of current policies, resources and legislation that are relevant to YCCAC's fleet electrification transition.

Despite the large number of potential funding opportunities available to transit agencies seeking to transition to hybrid and battery electric technologies, these programs are competitive and do not provide YCCAC with guaranteed funding sources. Therefore, this analysis assumes that YCCAC will only receive funding through the largest grant programs that provide the highest likelihood of issuance to the agency. Specifically, this analysis assumed that YCCAC will receive 80% of the capital required to complete the vehicle, 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 8 Policy and Resources Available to YCCAC

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 vehicle 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 vehicles 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 vehicles 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 vehicles 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 vehicle 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 Considerations

Section Summary

- Bus electrification is expected to significantly increase capital cost
- However, reduced YCCAC recurring expenses are expected, as electric vehicles cost less to maintain and fuel

Fleet electrification has significant financial impacts for the transit agency. Substantial capital cost increases are expected for both vehicles and infrastructure, compared to what is required for the agency's existing operations with fossil fuel vehicles. On the other hand, some savings on recurring expenses are likely, because electric vehicles require less maintenance and have cheaper energy costs.

The upfront purchase cost of battery electric and hybrid vehicles is much higher than for fossil fuel ones. For battery-electrics, this is largely due to the high cost of the propulsion batteries. Although the cost of batteries is declining each year it is still very high, particularly for heavy-duty transit vehicles. Because transit agencies prefer high-capacity batteries to extend vehicle range, the additional price of the batteries overshadows the cost savings from eliminating the engine and associated components on a diesel or gasoline vehicle. On the other hand, hybrid vehicles do not have large batteries; however, their drivetrains include a full set of components for fossil fuel operation, with electrical propulsion elements added on. This additional complexity increases the price of a hybrid vehicle above that of a fossil fuel one. The vehicle purchase cost increases are often significant, as shown below.

Electrifying a transit fleet often requires major infrastructure investment as well, to ensure that three separate items – the chargers themselves, the facility, and the utility connection – are suited for electric vehicles. Chargers are, of course, a prerequisite to EV operation; they must be purchased, installed, and commissioned. Particularly for heavy-duty applications like transit service, the required chargers are often high-powered and expensive. The facility itself must also be adapted for EV charging. In some cases, for modern facilities designed with spare electrical capacity, this will only require installation of additional conduit to connect to the electrical panel. For other, older facilities with outdated electrical and fire detection systems this could involve a multimillion-dollar upgrade before the first charger can be installed. Finally, the facility's utility connection often requires upgrades as well, as detailed in Section 10. Although bus depots are industrial facilities, their existing electrical systems are usually unsuited for the heavy power demands of EV charging. Although the cost of utility and facility upgrades varies on a case-by-case basis, the price of chargers themselves is relatively consistent and is presented below.

These upfront capital costs are expected to be balanced out by recurring savings on operations and maintenance cost. For operations, EVs are cheaper to recharge than fossil fuel vehicles are to refuel. This is especially true if a charge management system is used to avoid electricity demand charges. Even hybrids, which still require fueling, use approximately 20% less fuel than non-hybrid vehicles, decreasing operations costs accordingly. In addition to operations spending, maintenance costs are expected to decline as well. EVs have many fewer drivetrain parts, especially moving parts, than fossil fuel vehicles. Therefore, components will wear out less often, meaning that less time has to be spent maintaining them and spare parts can be bought less frequently. For hybrid vehicles, maintenance costs are expected to remain largely unchanged compared to diesel or gasoline vehicles. Although hybrids have more complicated drivetrains, the electric propulsion means that regenerative braking can be used – prolonging the life of components like brake pads – and the fossil fuel engine does not need to handle as intense a duty cycle as it otherwise would.

Table 10 lists the operating and capital costs that Hatch assumed for this study. These are based on YCCAC's figures and general industry trends and have been escalated to 2023 dollars where necessary.

Table 9 Cost Assumptions

Asset	Estimated Cost Per Unit (2023 $'s)
Gasoline Transit van	$40,000
Hybrid Transit van	$55,000
Electric Transit van	$200,000
Gasoline Cutaway	$70,000
Hybrid Cutaway	$125,000
Electric Cutaway	$250,000
Gasoline Trolley	$325,000
Hybrid Trolley	$375,000
Electric Trolley	$800,000

Expense	Estimated Cost (2023 $'s)
Gasoline Vehicle maintenance	$0.84 / mile
Hybrid Vehicle maintenance	$0.84 / mile
Electric Vehicle maintenance	$0.63 / mile

The proposed fleet transition requires initial capital spending to reduce recurring cost and achieve other strategic goals. This need 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 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 YCCAC 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 YCCAC to change the speed of its electrification transition or change the desired end-state altogether.

15. Emissions Impacts

One of the motivations behind YCCAC's transition towards battery electric vehicles 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 YCCAC.

Section Summary

- Vehicle electrification will be critical to helping meet State emission goals
- Forecasted grid conversion to clean energy will maximize the benefit of vehicle electrification
- The transition is expected to reduce emissions by 63-70%

Hatch calculated the anticipated emissions reductions from YCCAC'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 vehicles are operated. As a tank-to-wheel baseline, the 'tailpipe' emissions associated with YCCAC's existing gasoline fleet were calculated. These calculations used industry emissions averages for gasoline vehicles and YCCAC's fuel economy data.

Hybrid vehicles were assumed to have an average fuel economy 25% better than that of gasoline vehicles. Battery electric vehicle propulsion systems do not create emissions, and therefore there are no 'tailpipe' emissions.

Well-to-tank emissions are those associated with energy production. For gasoline (and hybrid) vehicles well-to-tank emissions are due to gasoline production, processing, and delivery. This emissions estimate used industry averages for the well-to-wheel emissions associated with the delivery of gasoline fuel to the gas stations YCCAC uses.

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 10 and Figure 20 summarize the results of the emissions calculations. These results demonstrate that the transition plan will achieve 63% emissions reduction assuming the grid mix that existed in 2020, or 70% 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, YCCAC's transition plan will let the agency exceed the 45% goal established by the State of Maine.

Table 10 CO_2 Emissions Estimate Results

Scenario	Well-to-Tank (kg)	Tank-to-Wheel (kg)	Grid (kg)	Total (kg)	Reduction over Baseline
Gasoline Baseline	264,540	447,314	-----	711,854	-----
Future Fleet (2020 grid mix)	68,828	116,382	80,292	265,501	63%
Future Fleet (2030 grid mix)	68,828	116,382	26,496	211,706	70%

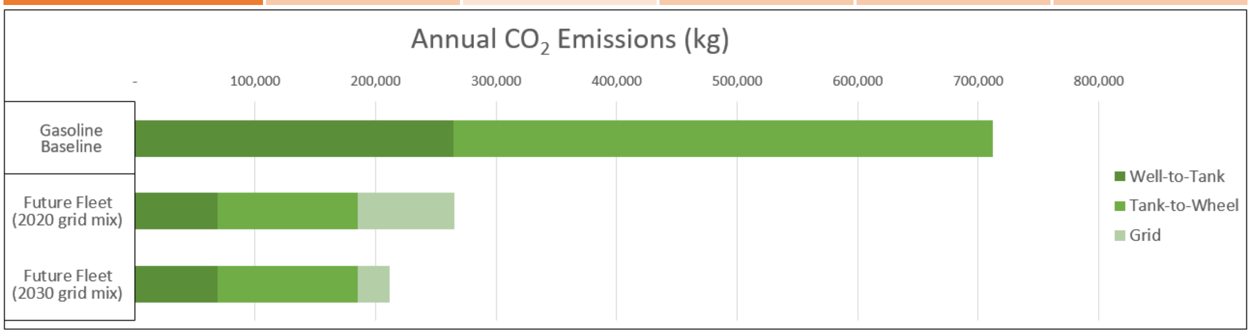

Figure 20 Graph of CO_2 Emissions Estimate Results

Should YCCAC 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
- Assuming the initial pilot is successful, purchase additional electric vehicles for the remainder of the demand-response fleet

16. Workforce Assessment

YCCAC staff currently operate a revenue fleet composed entirely of gasoline vehicles. As a result, the staff have skill gaps related to battery electric vehicle and charging infrastructure technologies that will be operated in the future. To ensure that both existing and future staff members can operate YCCAC's future system a workforce assessment was conducted. Table 11 details skills gaps for the workforce groups within the agency

Section Summary

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

and outlines training requirements to properly prepare the staff for future operations.

Table 11 Workforce Skill Gaps and Required Training

Workforce Group	Skill Gaps and Required Training
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

Although BSOOB maintenance staff (who maintain some YCCAC vehicles) have gained many of these skills as part of that agency's recent acquisition of two electric buses, for long-term successful electrification YCCAC will need to train its own workforce as well. To address these training requirements Hatch recommends that YCCAC consider the following training strategies:

+ Add requirements to the operations contract for the system operator to train its staff on the safe operation and inspection of electric vehicles.
+ 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 vehicles 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.

17. Alternative Transition Scenarios

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

As part of this study, YCCAC was presented with alternative fleet and infrastructure transition scenarios that would also satisfy the agency's operational requirements. These alternatives considered different scales of electrification, vehicle choices, and charging locations. Through discussions, however, YCCAC currently favors the transition plan presented in this report. Should YCCAC'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 YCCAC 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 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 gasoline- and diesel-powered vehicles in favor of battery-electric. By facilitating this study YCCAC 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, YCCAC will be able to reduce emissions, noise, operating cost, and other negative factors associated with gasoline operations, while helping the state comply with the Clean Transportation Roadmap and operating sustainably for years to come.

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

- Proceed with transitioning vehicles and infrastructure as described in this report.
- For the vehicles:
  - Consider ordering vehicles as part of larger orders or partnering with other agencies or the DOT to form large joint procurements.
  - Develop specifications for battery electric and hybrid vehicles.
  - Consider a broad range of vehicles during procurements, ensuring maximum competitiveness in procurements.
  - Operate the demand-response vehicles on as wide a variety of cycles as possible to gain maximum knowledge of their advantages and limitations.
  - Retain gasoline vehicles for at least two years after they are retired to ensure they can substitute for electric vehicles if incidents or weather require it.
  - Reach an agreement with BSOOB regarding electricity use during vehicle maintenance.
- For the infrastructure at 6 Spruce St., the Nasson site, and Wells RTC:
  - Negotiate with landowners at the two non-YCCAC sites to coordinate charger installation.
  - Upgrade the electrical utilities to support charging infrastructure as necessary.
  - Conduct a fire safety analysis in accordance with Section 12b and standards UL9540, NFPA 70 and 230.
  - Develop specifications for chargers and other required infrastructure.
  - Develop contingency plans for alternate charging locations to use in case of a charger malfunction.
  - Consider energy storage and solar panel installation.
- For other components of the transition:
  - Plan for staff training programs, as described in Section 16.
  - Coordinate transition efforts with peer transit agencies, CMP, and Maine DOT.
  - Continually monitor utility structures and peak charge rates and adjust charging schedules accordingly.
  - Review this transition plan annually to update based on current assumptions, plans, and conditions.