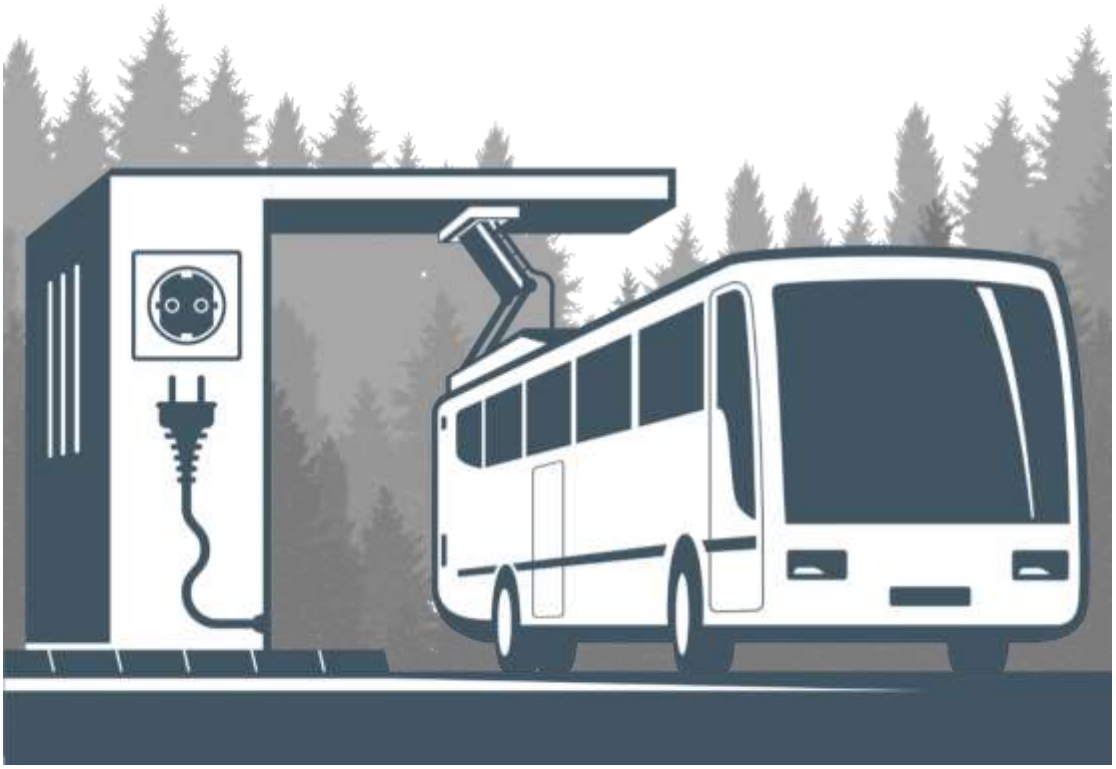
# Attachment A

## Transition Plans



# Bus Electrification Transition Plan for Bangor Community Connector

COMMUNITY CONNECTOR

## Prepared by:

HATCH

**Version: 1.2**
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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.

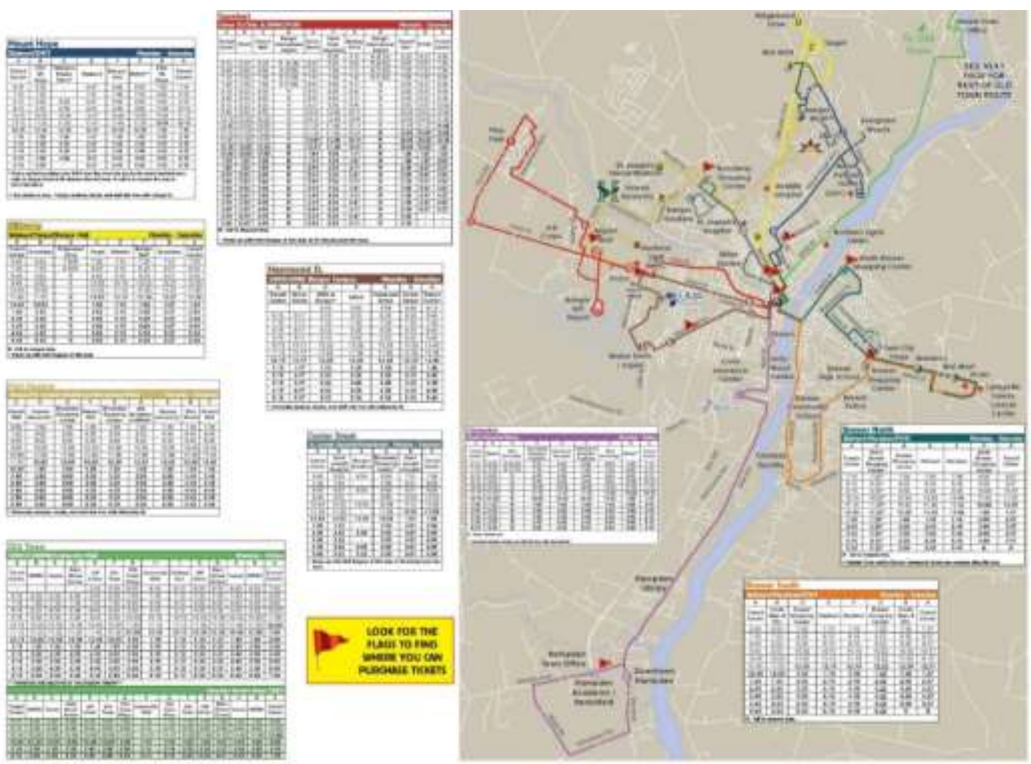



**Figure 1 Bangor CC Route Map**

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.

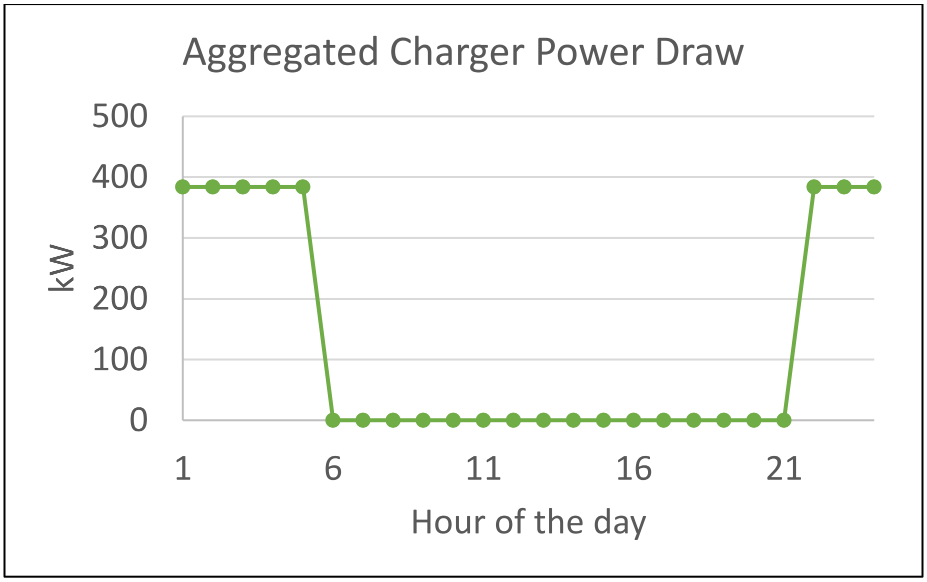



**Figure 3 Proposed Charging Schedule for Bangor CC's Future Fleet**

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 |
|---|---|---|---|
| 2025 | Two Electric Transit Vans | Two level 2 chargers, design work for new Bus Barn | |
| 2026 | One (One Hybrid 35') | Construction of new Bus Barn | 1048 (35', procured 2011) |
| 2027 | 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) |
| 2028 | Two 450 kWh Electric 30' | One 150 kW centralized Bus Barn charger (Three dispensers) | 1743-1744 (30', procured 2017) |
| 2029 | Two (Two Hybrid 30') | | 1858-1859 (30', procured 2018) |
| 2030 | 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) |
| 2031 | | | |
| 2032 | One (One 450 kWh Electric 30') | | 2106 (30', procured 2021) |
| 2033 | | | |
| 2034 | Four (Four 450 kWh Electric 35') | | 2102-2105 (35', procured 2021) |
| 2035 | | | |
| 2036 | | | |
| 2037 | | | |
| 2038 | 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.<br>Cut utility cost through peak-shaving. | Short power supply in case of outages.<br>Batteries degrade over time yielding less available storage as the system ages.<br>Can get expensive for high storage capacity. |
| Generators | Can provide power for prolonged periods.<br>Lower upfront cost. | GHG emitter.<br>Maintenance and upkeep are required and can be costly. |
| Solar Arrays | Can provide power generation in the event of prolonged outages.<br>Cut utility costs. | Cannot provide instantaneous power sufficient to support all operations.<br>Constrained due to real-estate space and support structures.<br>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<br>On-site Battery Storage | | Option 2<br>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.

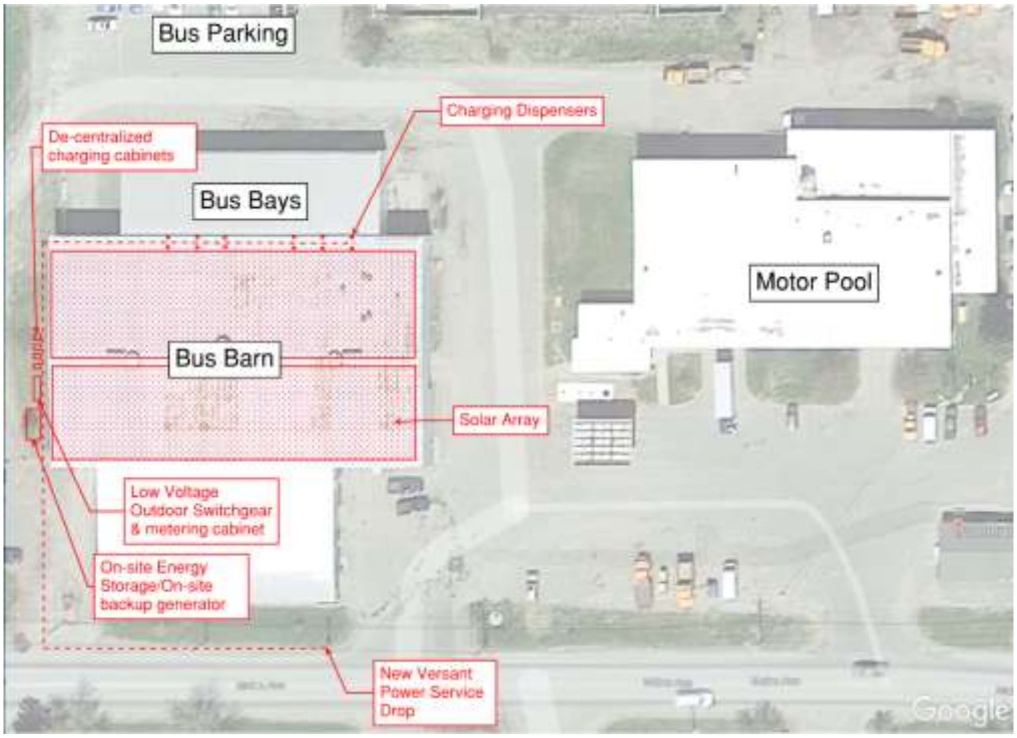



**Figure 12 Bus Barn Infrastructure Conceptual Layout (Source: Google Maps)**

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.

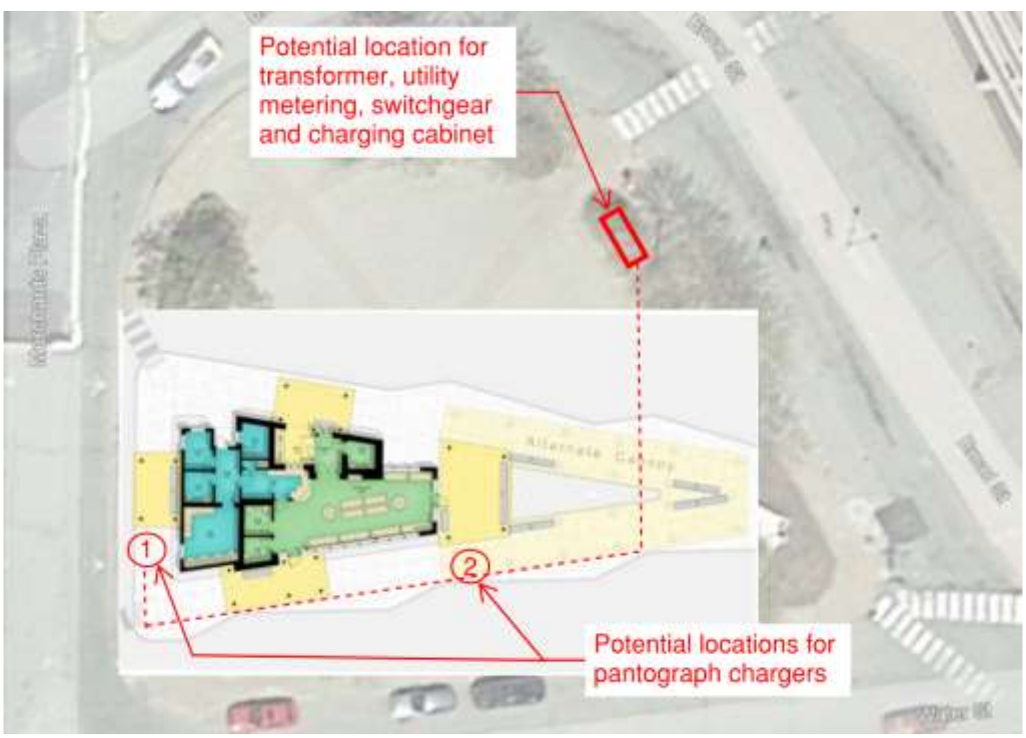



**Figure 13 Pickering Square Transit Center Charger Location Concept (Source: Google Maps)**

### 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.

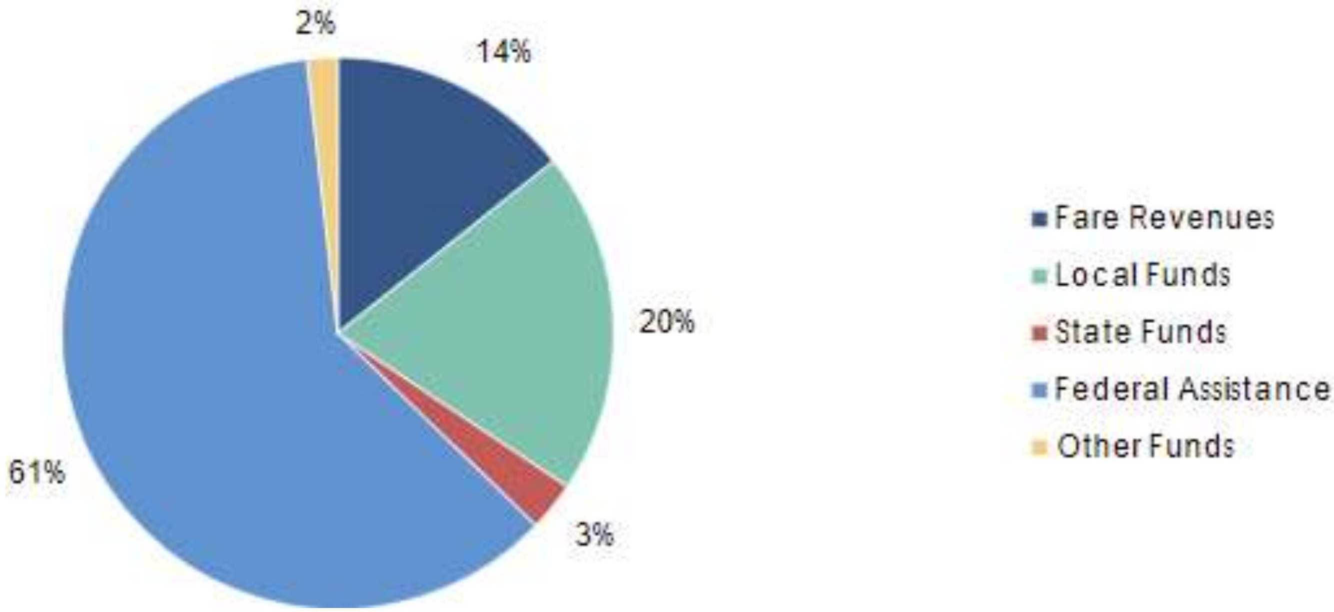



**Figure 14 Current Agency Funding Summary (Source: MaineDOT)**

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.<br>(*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<br>(*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.<br>(*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.<br>(*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.<br>(*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.<br>(*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.<br>(*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.<br>(*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.<br>(*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% |

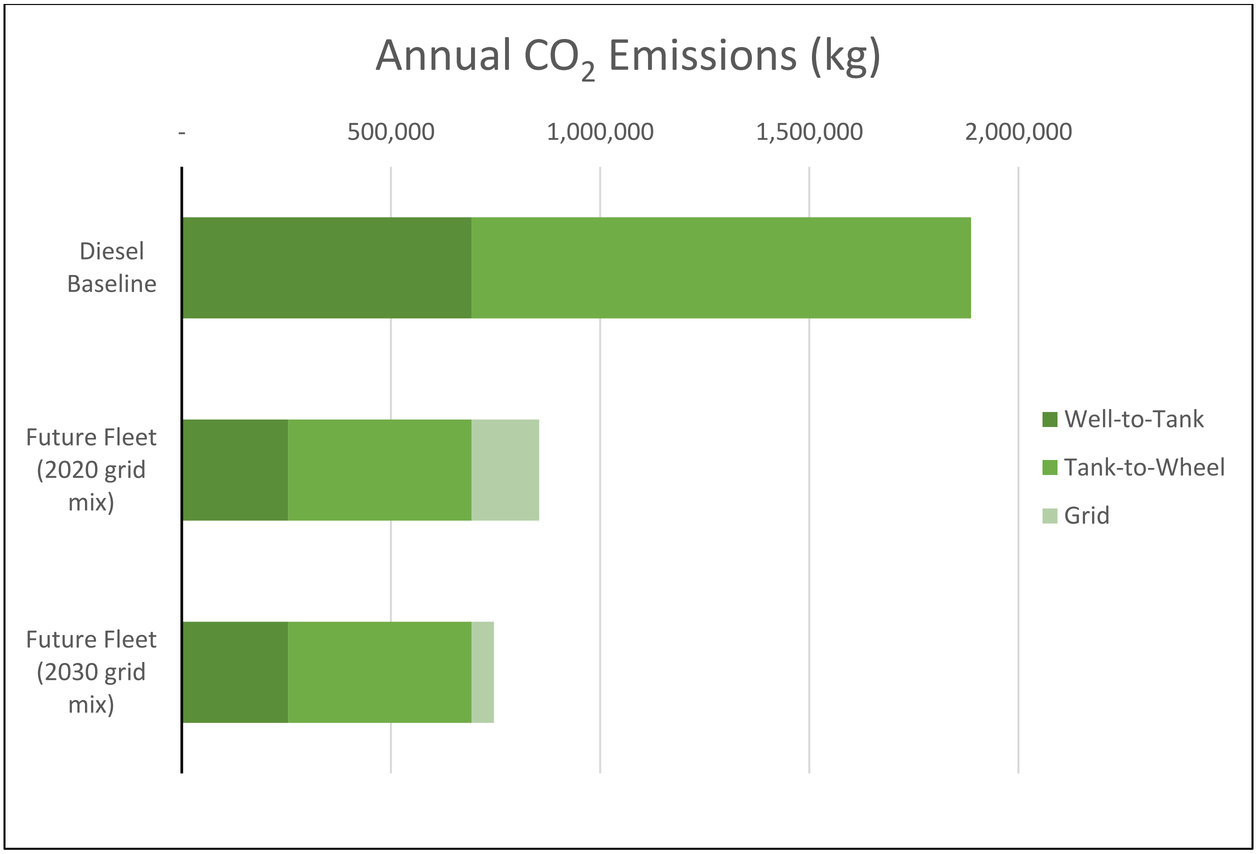



**Figure 15 Graph of $CO_2$ Emissions Estimate Results**

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

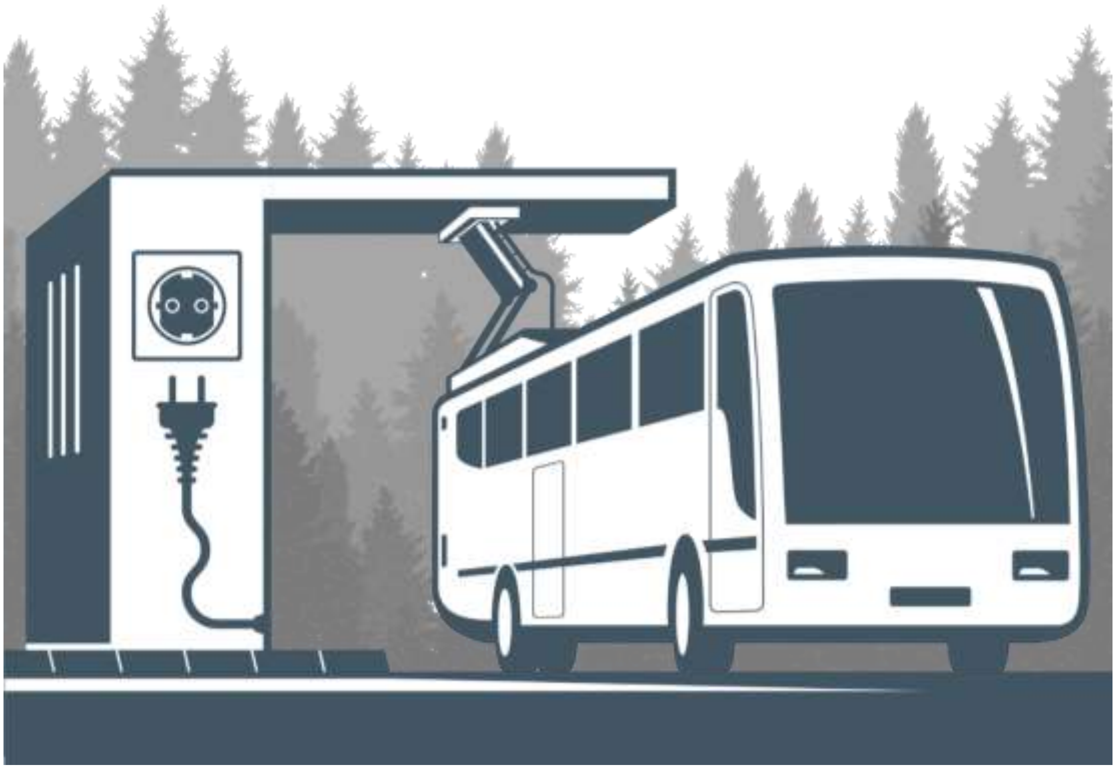
## 18. Recommendations and Next Steps

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**
**April 2024**

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# 1. Executive Summary

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

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

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

A life cycle cost estimate was also developed as part of the analysis to assess the financial implications of the transition. The cost estimate includes the capital costs to procure the new vehicles, charging systems, and supporting infrastructure, as well as the operational and maintenance expenditures. The costing analysis indicates that BSOOB can anticipate a 51% increase in capital expenditures due to the transition. It is estimated, however, that there will be a 13% annual reduction in operational and maintenance costs due to the improved reliability and efficiency of battery electric drivetrain technologies. In summation, the cost estimate predicts that BSOOB will see roughly 1% life cycle cost increase by transitioning to an entirely battery electric bus fleet.

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

## 2. Introduction

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

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

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

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

## 3. Existing Conditions

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

***Section Summary***

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

**Table 1 Current Vehicle Roster**

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

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

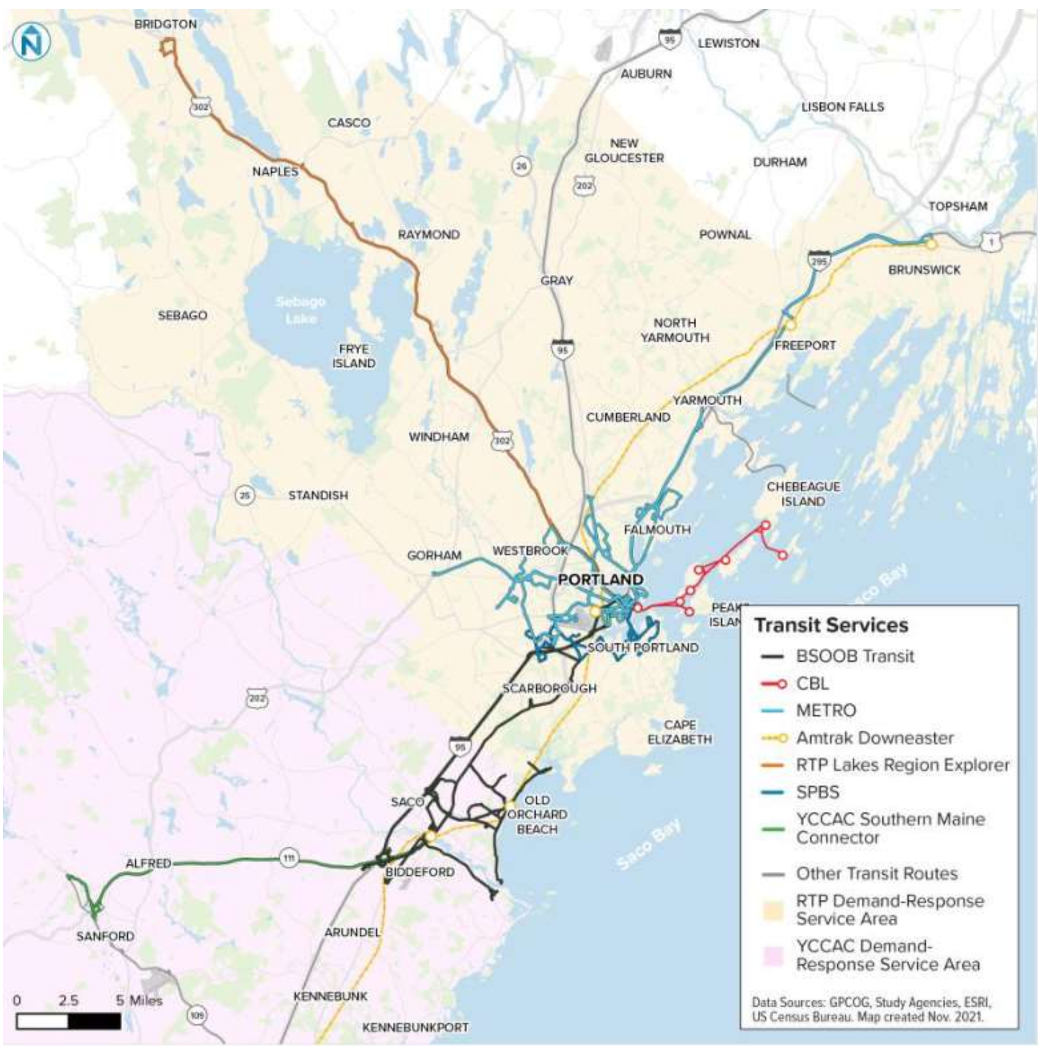



**Figure 1 Map of BSOOB and Other Regional Transit Services (Source: GPCOG/Transit Together)**

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

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

# 4. Vehicle Technology Options

***Section Summary***

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

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

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

## 5. Infrastructure Technology Options

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

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

1. Centralized
2. De-centralized

***Section Summary***

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

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


**Figure 2 Example Charging Systems (Source: ABB):**

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

**Right – Overhead Pantograph Charger and Centralized Cabinets**

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

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

# 6. 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. More information about the tradeoffs between the operating strategies below is presented in Appendix B and E.

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

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

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

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

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

## 7. Charging Schedule and Utility Rates

***Section Summary***

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

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

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

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

**Table 3 Utility Rates Structure Comparison**

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

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

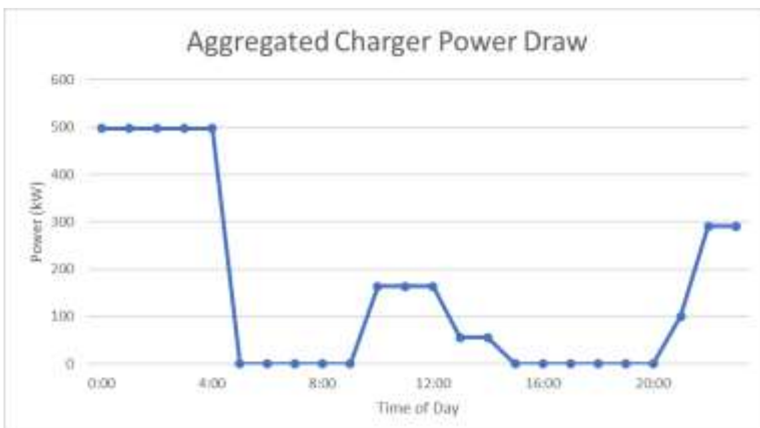



**Figure 3 Proposed Depot Charging Schedule for BSOOB's Future Fleet**

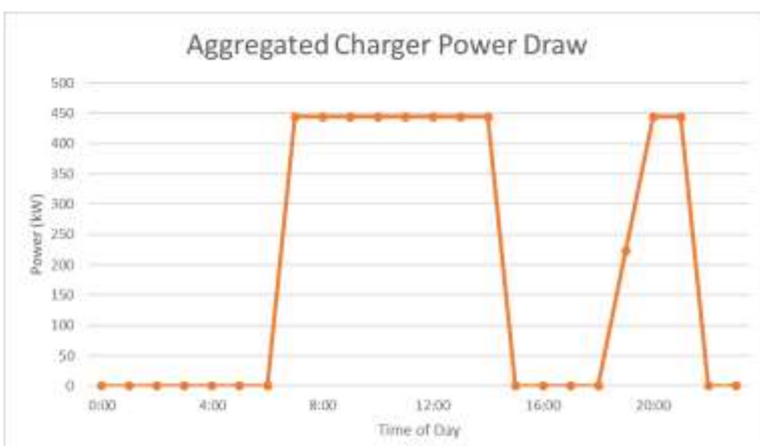



**Figure 4 Proposed On-route Charging Schedule for BSOOB's Future Fleet**

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

**Depot – 13 Pomerleau St facility**

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

Under Current IGS-S-TOU Rate Structure:

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

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

Under New B-DCFC Rate Structure:

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

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

**On-Route – Saco Transportation Center**

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

<u>Under Current IGS-S-TOU Rate Structure:</u>

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

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

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

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

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

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** | | |
| **2025** | Two long-range 35' electric 450kWh buses | Two additional dispensers for existing 150kW centralized chargers |
| **2026** | | |
| **2027** | Four long-range 35' electric 450kWh buses | Two 150kW centralized chargers with six dispensers + two further dispensers for existing 150kW centralized chargers |

| Year | Buses Procured | Infrastructure Procured |
|---|---|---|
| 2028 | | |
| 2029 | | |
| 2030 | | |
| 2031 | | |
| 2032 | | |
| 2033 | | |
| 2034 | Two 45’ electric 541kWh buses | |
| 2035 | 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

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

winter weather. Therefore, it is logical to 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 2027, 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.<br>• Cut utility cost through peak-shaving. | • Short power supply in case of outages.<br>• Batteries degrade over time yielding less available storage as the system ages.<br>• Can get expensive for high storage capacity. |
| **Generators** | • Can provide power for prolonged periods.<br>• Lower upfront cost. | • GHG emitter.<br>• Maintenance and upkeep are required and can be costly. |
| **Solar Arrays** | • Can provide power generation in the event of prolonged outages.<br>• Cut utility costs. | • Cannot provide instantaneous power sufficient to support all operations.<br>• Constrained due to real-estate space and support structures.<br>• Requires Battery Storage for resiliency usage. |

### 11.b.1. Existing Conditions

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

### 11.b.2. Outage Data and Resiliency Options

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

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

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

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

**Table 7 Resiliency Options for Worst Case Outage Scenarios**

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

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

#### 11.b.3. Solar Power

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

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

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

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


**Figure 12 13 Pomerleau Facility Proposed Solar Array**

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

**Table 8 13 Pomerleau Facility Roof**

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

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

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

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

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

# 12. Conceptual Infrastructure Design

## 12a. Conceptual Layouts

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

***Section Summary***

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

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

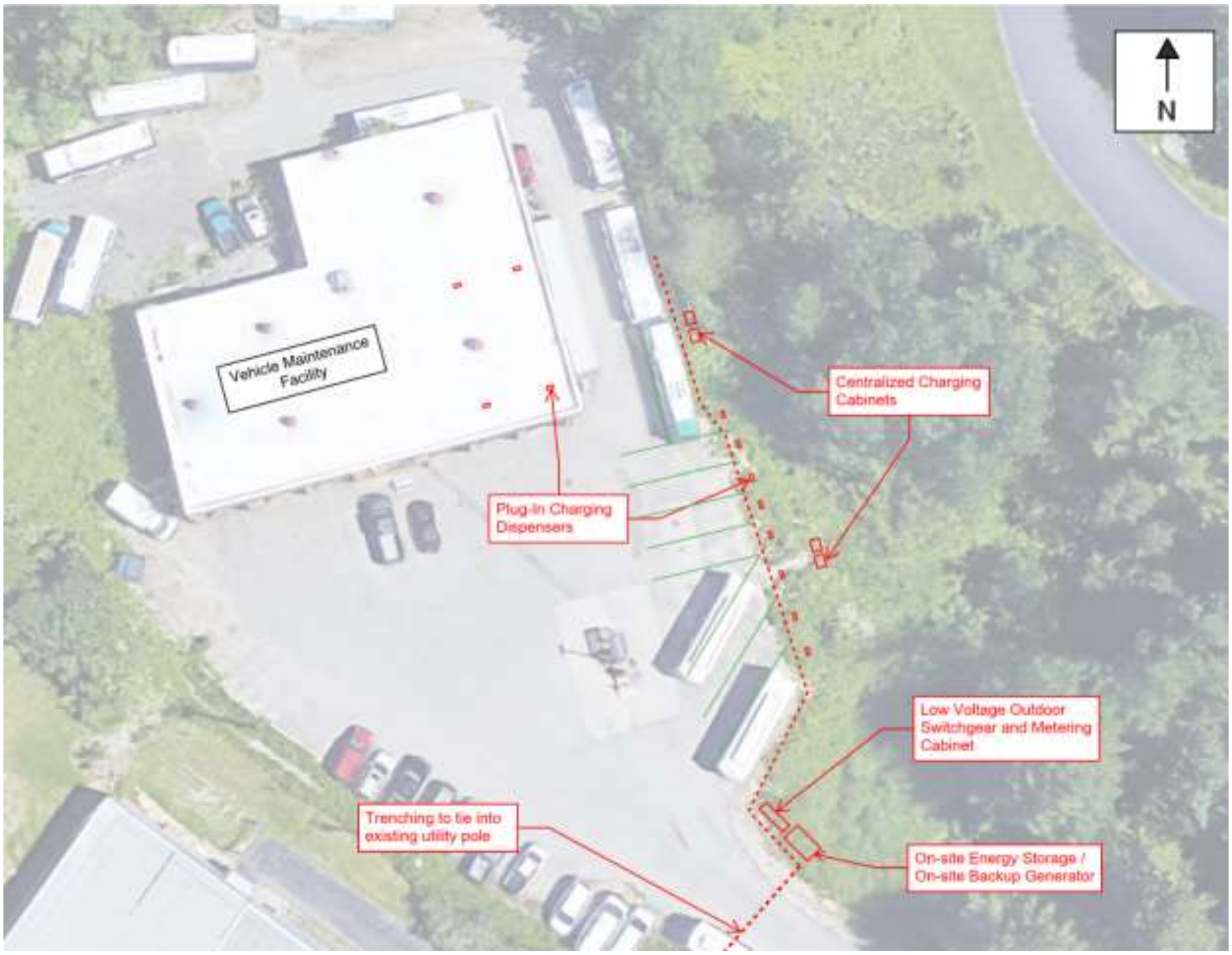



**Figure 13 13 Pomerleau St. Overnight Charger Layout Option**

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

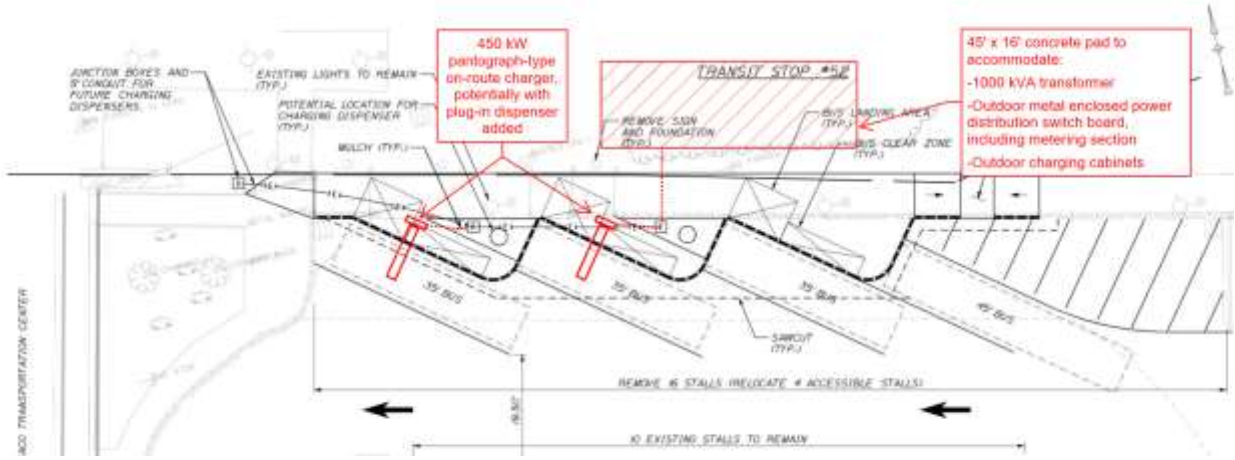



**Figure 14 Saco Transportation Center On-Charger Layout Option (Source: GPCOG)**

## 12b. Fire Mitigation

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

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

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

## 13. Policy Considerations and Resource Analysis

***Section Summary***

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

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

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

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:

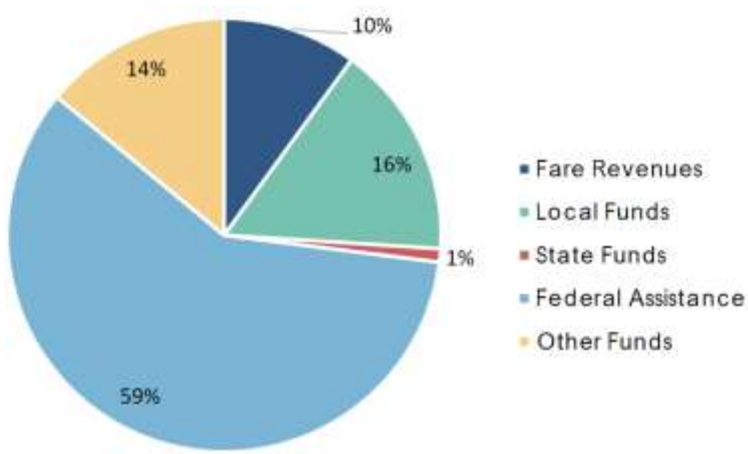



**Figure 15 Current Agency Funding Summary (Source: Maine DOT)**

- 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.<br>(*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<br>(*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.<br>(*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.<br>(*Formula funding) |

## 14. Cost Analysis

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


***Section Summary***

- Bus electrification will reduce BSOOB recurring expenses, as electric vehicles cost less to maintain and fuel
- Upfront capital costs increase by approximately 51% and annual operating cost will decrease by approximately 13%, yielding a net 1% increase in total cost of ownership


**Table 10: Life Cycle Cost Model Components**

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

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

**Capital Investment**

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

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

**Funding**

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

**Costs**

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

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

**Table 11 Cost Assumptions**

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

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

Because the electrification transition process will be gradual, life cycle cost calculations would necessarily overlap multiple bus procurement periods. Hatch addressed this issue by setting the start of the analysis period to be the year when the last diesel bus is proposed to be retired (2035), with the analysis period stretching for a full 12-year bus lifespan. For buses at midlife at the end of the analysis period, a remaining value was calculated and applied at the end of the time window.

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

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

**Table 12: Net Present Value Summary**

| Category | Diesel Baseline | Future Fleet | Cost Differential (Future Fleet vs. Baseline) |
|---|---|---|---|
| Vehicle Capital Costs | $2,851,328 | $4,174,481 | +51% |
| Infrastructure Capital Costs | $0 | $118,036 | |
| Vehicle Maintenance Costs | $3,233,183 | $2,437,291 | -13% |
| Infrastructure Maintenance Costs | $0 | $47,628 | |
| Operational Cost | $7,119,275 | $6,537,309 | |
| Total Life Cycle Cost | $13,203,786 | $13,314,745 | +1% |

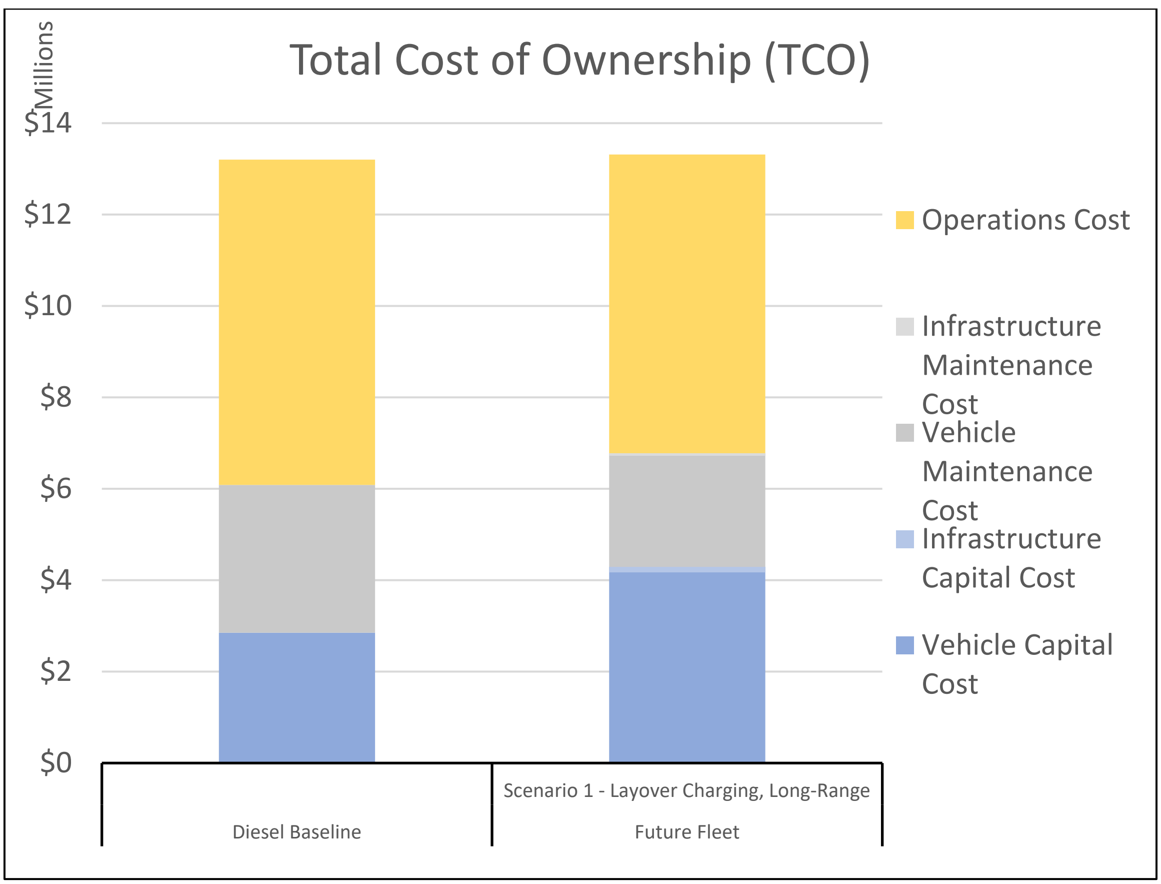



**Figure 16 Life Cycle Cost Comparison**

As shown in Figure 16, bus electrification reduces recurring cost at the expense of increasing initial capital cost. Although there is some expense related to the charging equipment at the 13 Pomerleau facility and Saco Transportation Center, the bulk of the extra capital spending is on the vehicles themselves, as electric buses are much simpler mechanically than diesel buses but command a cost premium due to their large battery systems. This yields a 51% increase in capital costs over the diesel baseline. This initial, non-recurring cost is balanced out by the maintenance and operating savings over the lifetime of the vehicles. Because electric vehicles have fewer components to maintain and are cheaper to refuel than diesels, the maintenance and operating costs of the proposed fleet are 13% lower than of the diesel baseline. However, these costs recur daily – worn parts must be replaced and empty fuel tanks must be refilled throughout the lifetime of the vehicle. This means that over the long term the operations and maintenance savings nearly outweigh the initial extra capital spending, yielding a net-present-value increase of only 1%.

The proposed fleet transition requires initial capital spending to reduce recurring cost and achieve other strategic goals. This finding is common to many transit projects and is representative of the transit industry as a whole, with nearly all bus and rail systems requiring capital investments up front to save money in other areas (traffic congestion, air pollution, etc.) and achieve broader societal benefits over the long term. By extension, just as with the transit industry at large, policy and financial commitment will be required from government leaders to achieve the desired benefits. The federal government's contribution to these goals via FTA and Low-No grants is already accounted for, leaving state and local leaders to cover the remaining 51% increase in upfront capital cost.

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

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

## 14a. Joint Procurements

The cost figures presented above assume that BSOOB independently procures its vehicles and infrastructure, instead of coordinating with other agencies and the state DOT to form a joint procurement. Shifting to a joint procurement strategy, in particular through the adoption of a state purchasing contract, has the potential to save money for BSOOB.

State purchasing contracts offer financial savings for several reasons. First, the overhead expenses associated with an order – specification development, vendor negotiation, training, and post-acceptance technical support – can be divided across several agencies. Second, the number of orders required by each agency can also be reduced. State purchasing contracts typically have a duration of five years, allowing a large portion of the agency's fleet to be replaced in one lifecycle. These two factors are estimated to reduce BSOOB's cost per bus by approximately 4%, or $40,000, for a typical BEB. Third, the increase in total order size is likely to reduce cost per vehicle as well. Like agencies, BEB vendors incur some of their costs (business development, contract negotiation, customization setup) on a per-order basis; therefore, they typically decrease the price of each bus as order size grows. Furthermore, a larger order is likely to attract additional vendors (who would be unwilling to participate in a small procurement); this is expected to drive down cost as well. In addition, technical support for the new vehicles will be more economical if it can be divided among several vehicles, or even several nearby agencies, as the expense of having an on-site vendor technician is roughly constant regardless of the size of the BEB fleet. Recent BEB orders across the US show that, on average, for each additional bus in an order the per-bus cost decreases by 0.63%. In other words, combining five two-bus orders into one ten-bus order would reduce purchase cost by 5%, or $500,000, due to order size alone.

BSOOB plans to order 24 buses over the next 15 years, and these orders can easily be allocated to purchasing contracts. The 2025 and 2027 order of 35' buses would be part of a 23-vehicle order shared with Bangor CC, Metro, and South Portland Bus Service (SPBS); 2035, 2037, and 2039 orders of 35' buses would be part of a 49-vehicle order shared with Bangor CC, Citylink, Downeast, Metro and SPBS; and the 2035 order of Trolley buses would be part of a 15-vehicle order shared with YCCAC. The 2034 order for two 45' vehicles would have to be purchased solely by BSOOB.

In summary, although this analysis assumed that BSOOB acts independently in placing its orders, the agency is encouraged to explore opportunities for joint procurements with other agencies. This will potentially save the agency money through reduced administrative expenses, increased vendor competition, and efficiencies with post-procurement technical support. Overall, this strategy will produce an 18% cost saving for the agency.

## 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 2031 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 2031 by transitioning to more renewable energy production. To account for these future grid emissions reduction goals, calculations were completed based on the most recent actual data available (2020), as well as projections that assume that the 2030 targets are met. Table 13 and Figure 17 summarize the results of the emissions calculations. These results demonstrate that the transition plan will achieve 81% emissions reduction assuming the grid mix that existed in 2020, or 91% emissions reduction assuming that Central Maine Power is able to meet the state's goals to reduce grid emissions by the year 2031. In either case, BSOOB's transition plan will achieve a reduction in emissions in excess of the 45% goal established by the State of Maine.

**Table 13 $CO_2$ Emissions Estimate Results**

| Scenario | Well-to-Tank (kg) | Tank-to-Wheel (kg) | Grid (kg) | Total (kg) | Reduction over Baseline |
|---|---|---|---|---|---|
| Diesel Baseline | 543,941 | 936,196 | --- | 1,480,137 | ---------- |
| Future Fleet (Assuming 2020 grid mix) | 25,835 | 44,466 | 212,809 | 283,111 | 81% |
| Future Fleet (Assuming 2031 grid mix) | 25,835 | 44,466 | 70,227 | 140,529 | 91% |

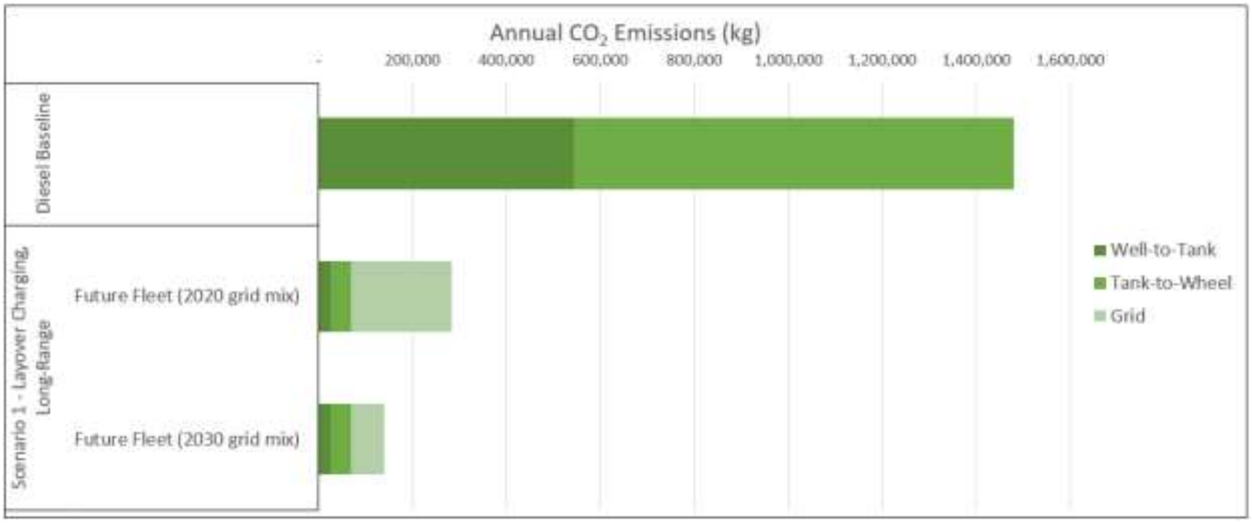



**Figure 17 Graph of $CO_2$ Emissions Estimate Results**

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

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

## 16. Workforce Assessment

**Section Summary**

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

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

**Table 14 Workforce Skill Gaps and Required Training**

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

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

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

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

## 17. Alternative Transition Scenarios

***Section Summary***

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

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

# 18. Recommendations and Next Steps

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

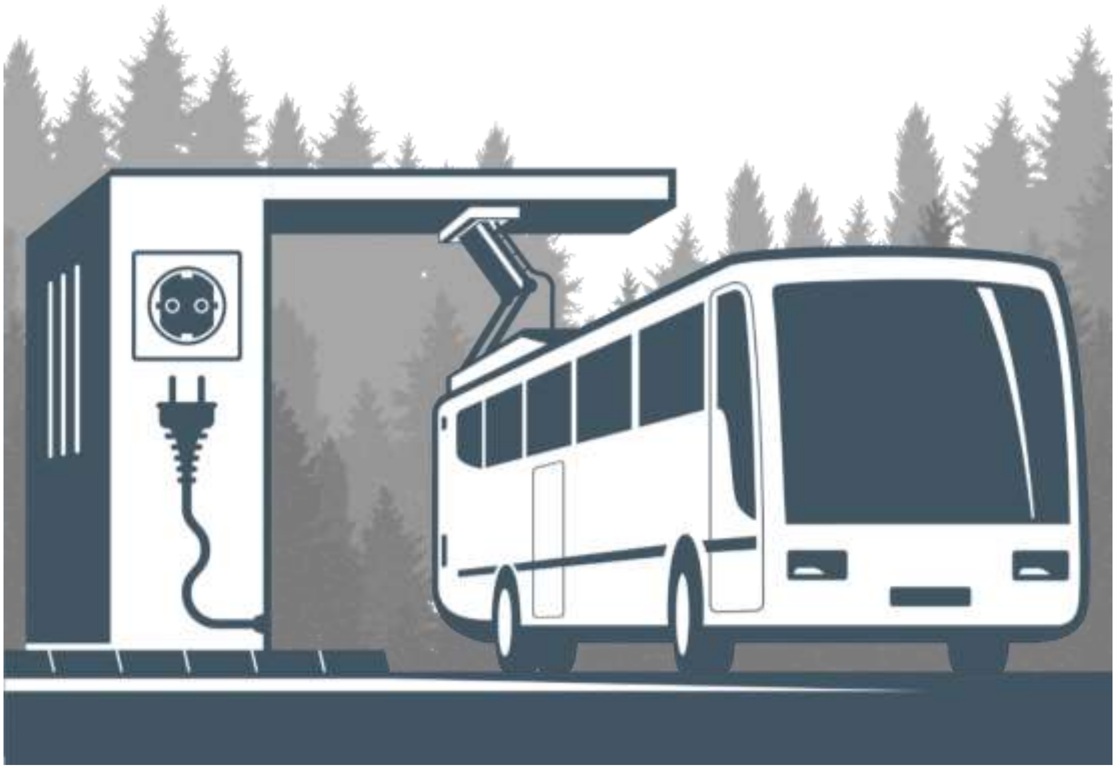
For BSOOB to achieve sustainable and economical fleet electrification, Hatch recommends the following steps:

- Proceed with transitioning the agency's buses and infrastructure in the manner described in this report.
- For the vehicles:
  - Consider ordering buses as part of larger orders or partnering with other agencies or the DOT to form large joint procurements.
  - Consider flexibility in vehicle types, particularly for commuter and trolley vehicles, to increase competition on future vehicle procurements.
  - Purchase bus batteries outright, rather than leasing them.
  - With further BEB orders, continue requiring the electric bus vendor to have a technician on site or nearby in case of problems. This is most economical when the technician is shared with several nearby agencies.
  - Reach a "mutual aid" agreement with another urban transit agency in Maine that would let BSOOB borrow spare buses in case of difficulties with its fleet.
  - Retain a small fleet of diesel backup buses to ensure they can substitute for electric buses if any incidents or weather conditions require it.
- For the infrastructure at the 13 Pomerleau facility:
  - Continue upgrading the electrical utilities to support additional charging infrastructure.
  - During the next installation of chargers, include provisions for sufficient infrastructure to electrify the entire fleet, to reduce future piecemeal work.
  - Conduct a fire safety analysis in accordance with Section 12b and standards UL9540, NFPA 70 and 230, including staff training for fire response.
- For the infrastructure at the Saco Transportation Center:

  - Add a priced option to the specification for installation of a plug-in dispenser, for use by BSOOB's trolley-style vehicles or YCCAC's Southern Maine Connector
  - Develop contingency plans in case the layover chargers fail and midday depot swapping is required.
- For other components of the transition:
  - Tweak operating schedules as required for optimal BEB operation.
  - Add requirements to future procurements for staff refresher training.
  - Participate in industry conferences and coordination with other Maine transit agencies to share best practices for staff training programs, as described in Section 16. Coordinate with local education institutions as well.
  - Coordinate transition efforts with peer transit agencies, CMP, and Maine DOT.
  - Continually monitor utility structures and peak charge rates and adjust charging schedules accordingly.
  - Develop a funding strategy to account for the 51% increase in capital expenditure.
  - Review this transition plan annually to update based on current assumptions, plans, and conditions.

## Appendices

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



# Bus Electrification Transition Plan for Greater Portland Metro

Prepared by:

Version: 1.2

April 2024

# 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.

A life cycle cost estimate was also developed as part of the analysis to assess the financial implications of the transition. The cost estimate includes the capital costs to procure the new vehicles, charging systems, and supporting infrastructure, as well as the operational and maintenance expenditures. The costing analysis indicates that Metro can anticipate a 37% increase in capital expenditures due to the transition. It is estimated, however, that there will be a 10% annual reduction in operational and maintenance costs due to the improved reliability and efficiency of battery electric drivetrain technologies. In summation, the cost estimate predicts that Metro will see roughly 3% life cycle cost savings by transitioning to an entirely battery electric bus fleet.

The conclusion of the analysis is that battery electric buses can feasibly support Metro's operations. Furthermore, these buses offer the potential for the agency to greatly reduce emissions and to slightly reduce the life cycle costs required to operate its buses. Therefore, 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.

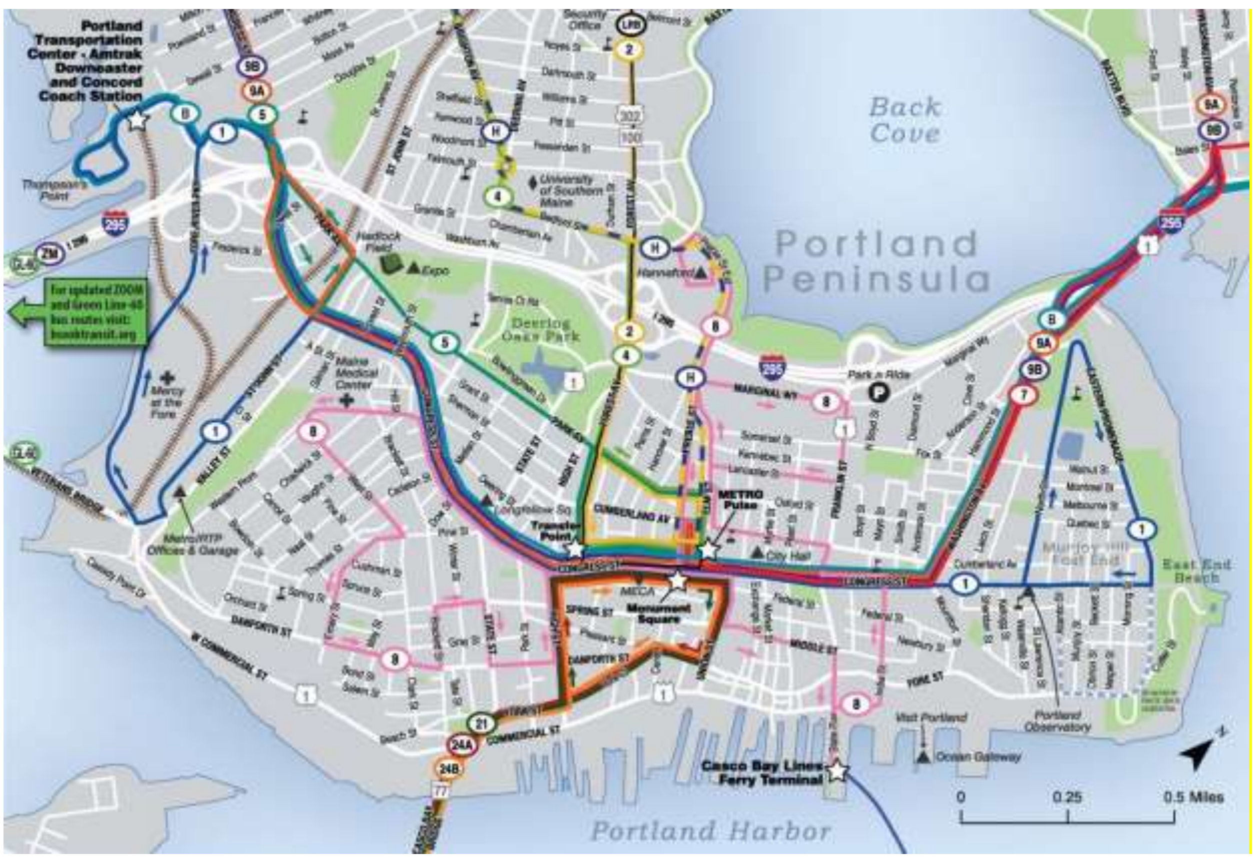



**Figure 1 Map of Metro and Other Regional Transit Services in Downtown Portland**

- **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. A summary of hybrid and battery electric vehicle models that are commercially available (provided in Appendix A) demonstrates that there is a variety of possible vehicles for 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. Appendix A shows additional commercially available charging system options and configurations.

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 |

| 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 | 88.1 | 239.6 | -16.6 | 252.8 | 47.4 |
| | 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. More information about the tradeoffs between the operating strategies below is presented in Appendix B.

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.

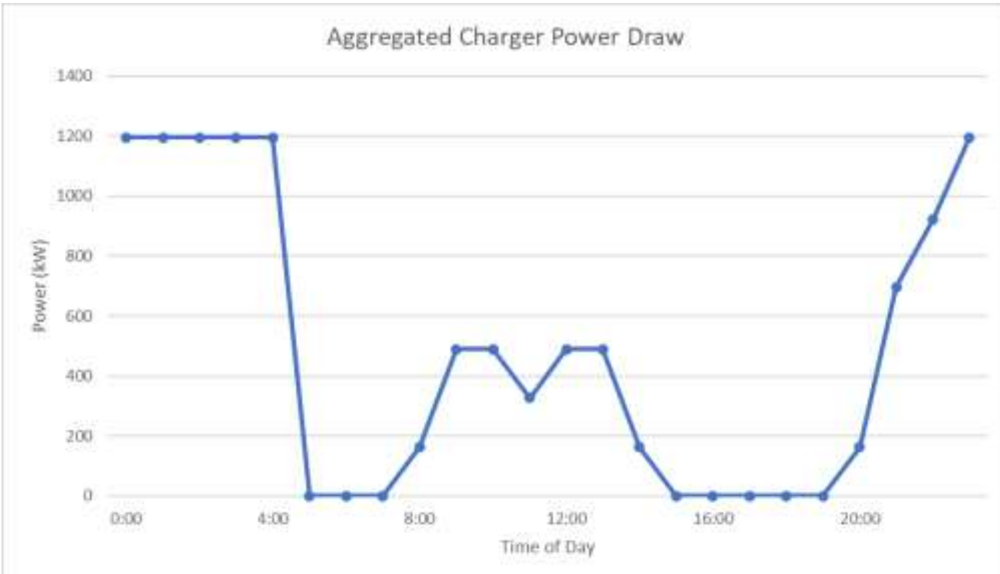



**Figure 3 Proposed Depot Charging Schedule for Metro's Future Fleet**

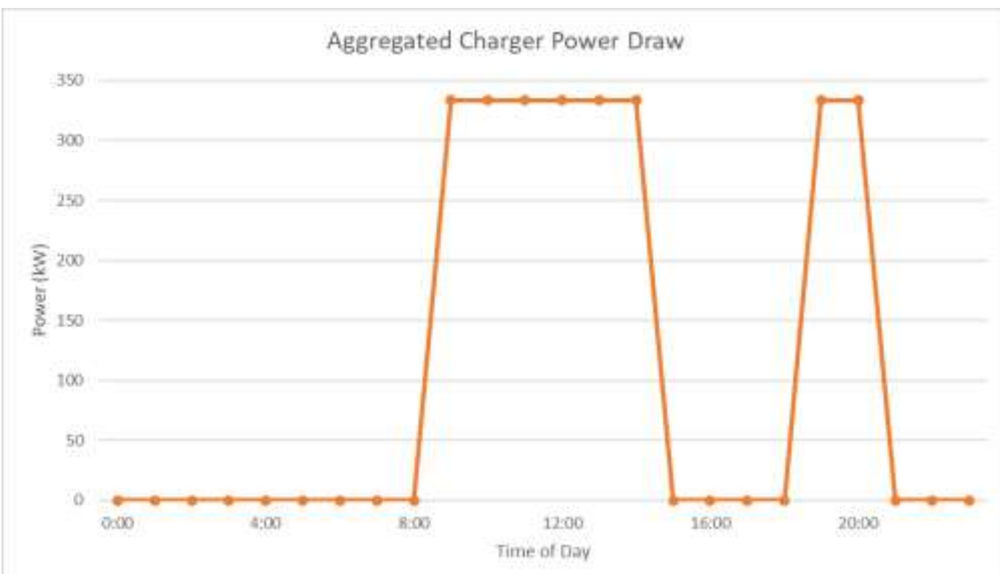



**Figure 4 Proposed On-route Charging Schedule for Metro's Future Fleet**

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 expected diesel vehicle procurement 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** | | | |
| **2025** | 3 (3 450 kWh 35') | 4 additional dispensers on existing chargers | 1101-3 |
| **2026** | | | |
| **2027** | | | |
| **2028** | 5 (5 450 kWh 35') | 4 additional dispensers on existing chargers | 1401-5 |
| **2029** | | | |
| **2030** | | | |
| **2031** | | New depot; 9 new chargers with 27 dispensers, including transformers, switchgear, and utility feed<br>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** | 7 (7 450 kWh 35') | | Replacements for 1101-7 |

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

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.

***<u>Section Summary</u>***

- 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.

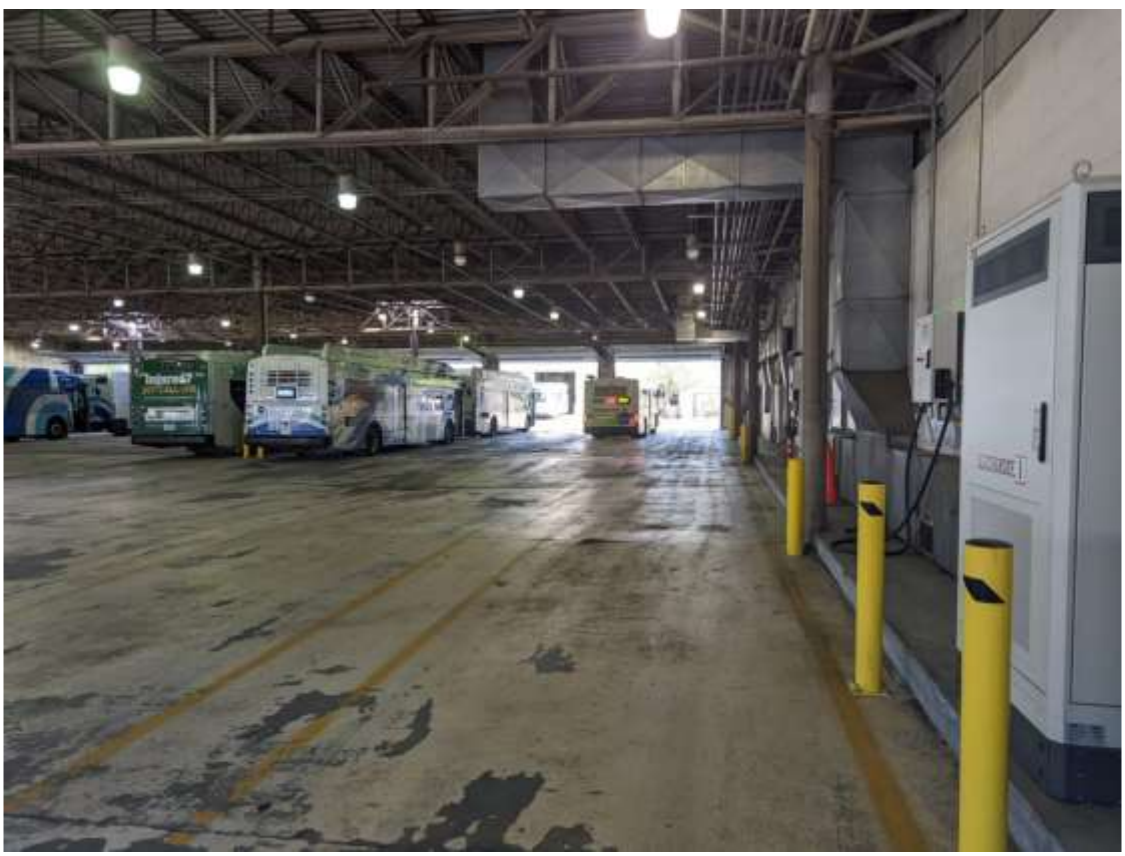


**Figure 5 Existing DC Fast Chargers at 114 Valley St Facility**

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.<br>Cut utility cost through peak-shaving. | Short power supply in case of outages.<br>Batteries degrade over time yielding less available storage as the system ages.<br>Can get expensive for high storage capacity. |
| **Generators** | Can provide power for prolonged periods.<br>Lower upfront cost. | GHG emitter.<br>Maintenance and upkeep are required and can be costly. |
| **Solar Arrays** | Can provide power generation in the event of prolonged outages.<br>Cut utility costs. | Cannot provide instantaneous power sufficient to support all operations.<br>Constrained due to real-estate space and support structures.<br>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. Appendix C shows the outage data provided by Central Maine Power for reference.

+ 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.

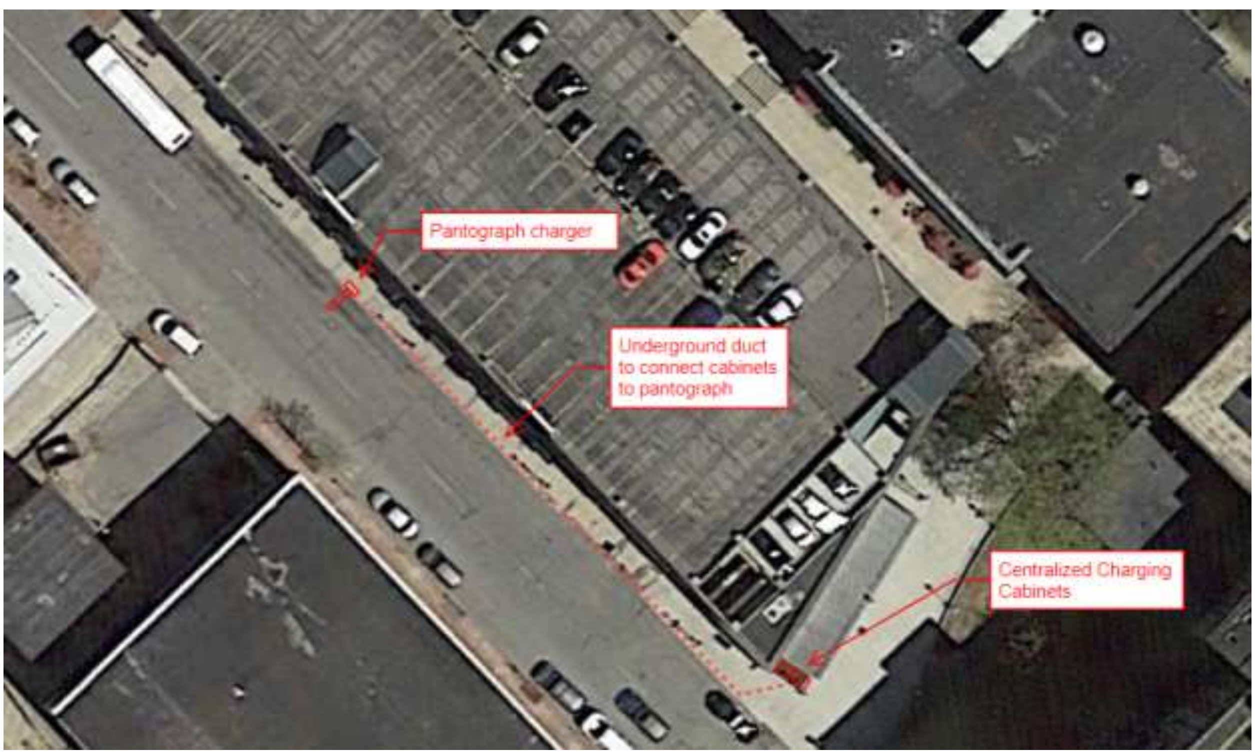



**Figure 11 Elm St Pulse On-Route Charger Layout Option**

## 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.

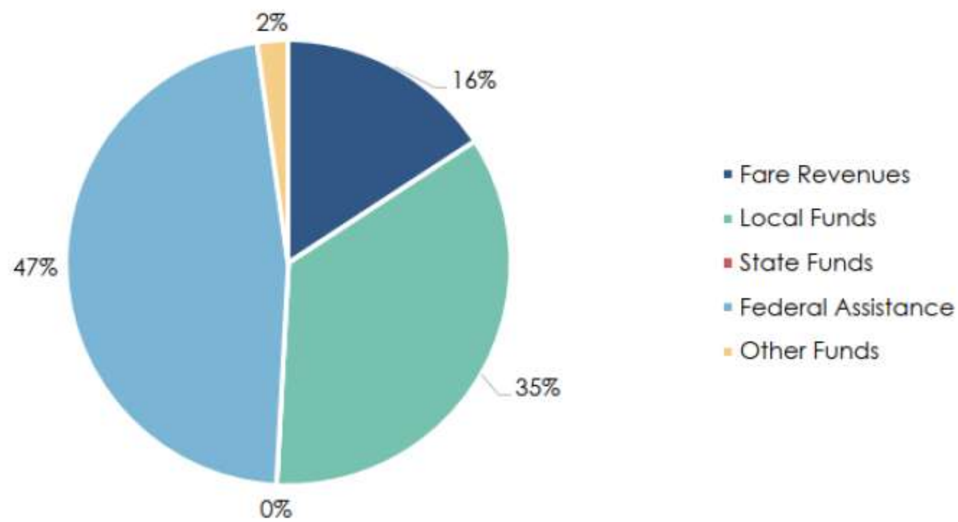



**Figure 12 Current Agency Funding Summary (Source: Maine DOT)**

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.<br>(*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.<br>(*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.<br>(*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.<br>(*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.<br>(*Competitive funding) |

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

## 14. Cost Analysis

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

***Section Summary***

- Bus electrification will save Metro money over the long term, as electric vehicles cost less to maintain and fuel
- Upfront capital costs increase by approximately 37% and annual operating cost will decrease by approximately 10%, yielding a net 3% savings in total cost of ownership

**Table 10: Life Cycle Cost Model Components**

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

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

**Capital Investment**

+ The lifespan of a bus is 14 years, in accordance with Metro practice.
+ Buses are overhauled at midlife. This is recommended for electric buses as the lifespan of a battery is approximately 6-7 years.

- Buses are replaced with buses of the same length, at their expected retirement year.
- Metro purchases the batteries on its electric buses, rather than leasing them.
- The cost of the depot construction is not included as it is independent of electrification.

**Funding**

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

**Costs**

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

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

**Table 11 Cost Assumptions**

| Asset | Estimated Cost Per Unit (2022 $'s) |
|---|---|
| 35' Diesel Transit Bus | $546,000 |
| 35' CNG Transit Bus | $595,000 |
| 35' Battery Electric Transit Bus (450 kWh) | $1,009,000 |
| 40' Diesel Transit Bus | $551,000 |
| 40' CNG Transit Bus | $600,000 |
| 40' Battery Electric Transit Bus (450 kWh) | $1,050,000 |
| 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 |
| Operator salary, benefits, overhead | $36.46 / hour |
| Diesel fuel | $3.00 / gallon |
| CNG | $2.04 / gallon |

Because the electrification transition process will be gradual, life cycle cost calculations would necessarily overlap multiple bus procurement periods. Hatch addressed this issue by setting the start of the analysis period to be the year when the last diesel/CNG bus is proposed to be retired (2039), with the analysis period stretching for a full 14-year bus lifespan. For buses at midlife at the end of the analysis period, a remaining value was calculated and applied at the end of the time window.

The LCC analysis determines the relative cost difference between the baseline (diesel/CNG) case and the proposed case. Therefore, it only includes costs which are expected to be different between the two options. Costs common to both alternatives, such as bus stop maintenance, are not included as they do not have a net effect on the LCC comparison. Thus, the model indicates the most economical option but does not represent the full or true cost for either technology. Table 12 and Figure 13 summarize the NPV for both technologies by cost category.

**Table 12: Net Present Value Summary**

| Category | Diesel/CNG Baseline | Future Fleet | Cost Differential (Future Fleet vs. Baseline) |
|---|---|---|---|
| **Vehicle Capital Costs** | $6,678,290 | $8,686,047 | +37% |
| **Infrastructure Capital Costs** | $0 | $465,768 | |
| **Vehicle Maintenance Costs** | $12,532,630 | $9,441,949 | -10% |
| **Infrastructure Maintenance Costs** | $0 | $107,791 | |
| **Operational Cost** | $26,293,288 | $25,578,408 | |
| **Total Life Cycle Cost** | **$45,504,207** | **$44,279,962** | -3% |

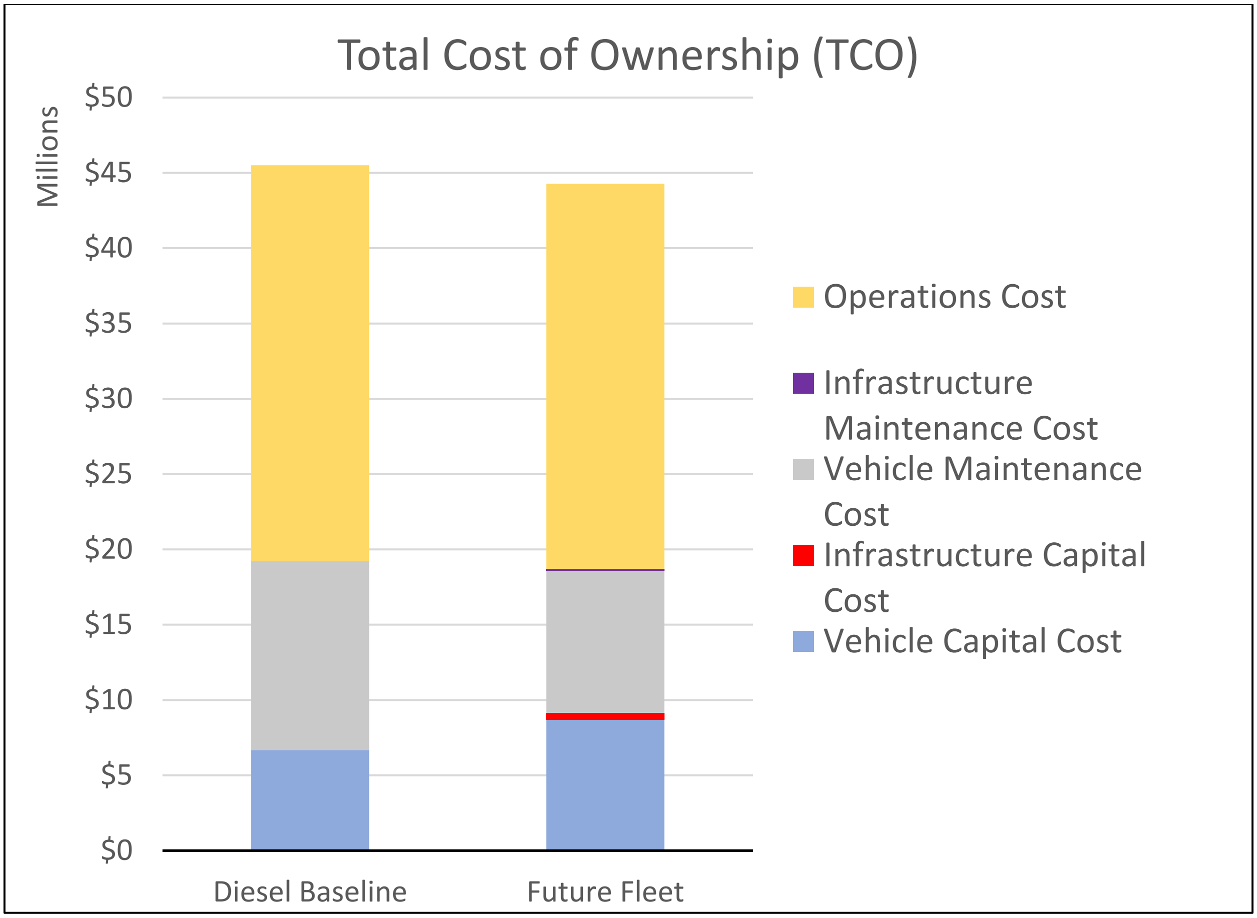



**Figure 13 Life Cycle Cost Comparison**

As shown in Figure 13, bus electrification reduces total system cost at the expense of increasing initial capital cost. Although there is some expense related to the charging equipment at the 114 Valley St facility and Elm St Pulse, the bulk of the extra capital spending is on the vehicles themselves, as electric buses are much simpler mechanically than diesel or CNG buses but command a cost premium due to their large battery systems. This yields a 37% increase in capital costs over the diesel/CNG baseline. This initial, non-recurring cost is balanced out by the maintenance and operating savings over the lifetime of the vehicles. Because electric vehicles have fewer components to maintain and are cheaper to refuel than diesels and CNG vehicles, the maintenance and operating costs of the proposed fleet are 10% lower than of the diesel/CNG baseline. However, these costs recur daily – worn parts must be replaced and empty fuel tanks must be refilled throughout the lifetime of the vehicle. This means that over the long term the operations and maintenance savings outweigh the initial extra capital spending, yielding a net-present-value savings of approximately 3%.

The proposed fleet transition requires initial capital spending to reduce life cycle cost and achieve other strategic goals. This finding is common to many transit projects and is representative of the transit industry as a whole, with nearly all bus and rail systems requiring capital investments up front to save money in other areas (traffic congestion, air pollution, etc.) and achieve broader societal benefits over the long term. By extension, just as with the transit industry at large, policy and financial commitment will be required from government leaders to achieve the desired benefits. The federal government's contribution to these goals via FTA and Low-No grants is already accounted for, leaving state and local leaders to cover the remaining 37% 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 modify vehicle procurement schedules or quantities, tweak operating schedules, or otherwise revise this report's assumed end state.

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

## 14a. Joint Procurements

The cost figures presented above assume that Metro independently procures its vehicles and infrastructure, instead of coordinating with other agencies and the state DOT to form a joint procurement. Shifting to a joint procurement strategy, in particular through the adoption of a state purchasing contract, has the potential to save money for Metro.

State purchasing contracts offer financial savings for several reasons. First, the overhead expenses associated with an order – specification development, vendor negotiation, training, and post-acceptance technical support – can be divided across several agencies. Second, the number of orders required by each agency can also be reduced. State purchasing contracts typically have a duration of five years, allowing a large portion of the agency's fleet to be replaced in one lifecycle. For example, in accordance with the procurement schedule in Table 5, Metro expects to place seven vehicle orders over the next 16 years. With five-year purchasing contracts, this number can be reduced to three, saving on many of the same per-order expenses outlined previously. These two factors are estimated to reduce Metro's cost per bus by approximately 4%, or $40,000, for a typical BEB. Third, the increase in total order size is likely to reduce cost per vehicle as well. Like agencies, BEB vendors incur some of their costs (business development, contract negotiation, customization setup) on a per-order basis; therefore, they typically decrease the price of each bus as order size grows. Furthermore, a larger order is likely to attract additional vendors (who would be unwilling to participate in a small procurement); this is expected to drive down cost as well. In addition, technical support for the new vehicles will be more economical if it can be divided among several vehicles, or even several nearby agencies, as the expense of having an on-site vendor technician is roughly constant regardless of the size of the BEB fleet. Recent BEB orders across the US show that, on average, for each additional bus in an order the per-bus cost decreases by 0.63%. In other words, combining five two-bus orders into one ten-bus order would reduce purchase cost by 5%, or $500,000, due to order size alone.

Metro plans to order 44 buses over the next 16 years and these orders can easily be allocated to purchasing contracts. The 2029 order for 35' buses can be part of a 23-vehicle order purchased together with Bangor CC, BSOOB, and South Portland Bus Service (SPBS); the 2033 and 2034 order for 35' and 40' buses can be part of a 33-vehicle order purchased together with Bangor CC and Citylink; and the 2035, 2036, 2037, and 2039 order for 35' buses can be part of a 49-vehicle order purchased together with Bangor CC, BSOOB, Citylink, and SPBS.

In summary, although this analysis assumed that Metro acts independently in placing its orders, the agency is encouraged to explore opportunities for joint procurements with other agencies. This will potentially save the agency money through reduced administrative expenses, increased vendor competition, and efficiencies with post-procurement technical support. Overall, this strategy will produce a 25% cost saving for the agency.

## 15. Emissions Impacts

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.

**_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%

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 13 and Figure 14 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 13 $CO_2$ 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% |

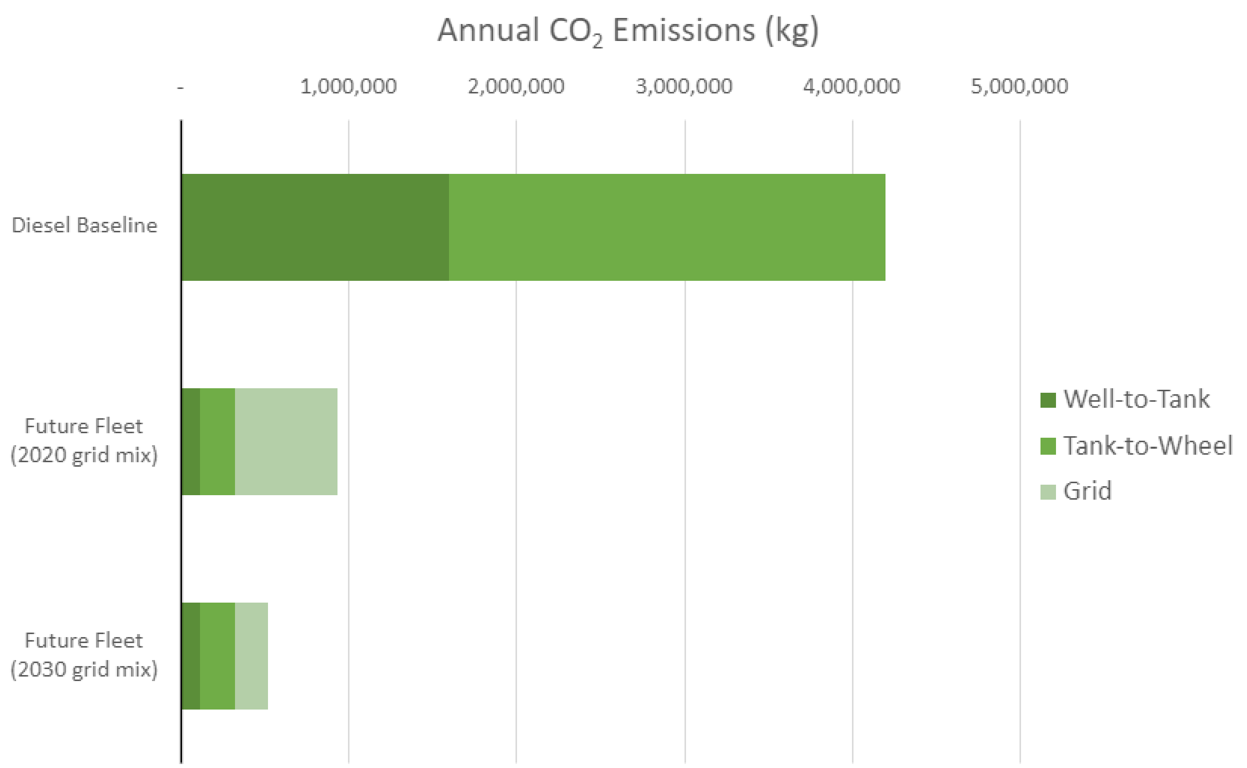



**Figure 14 Graph of $CO_2$ Emissions Estimate Results**

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

**Table 14 Workforce Skill Gaps and Required Training**

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

To address these training requirements Hatch recommends that 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. Details on the alternative plans are presented in Appendix B and D. 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.

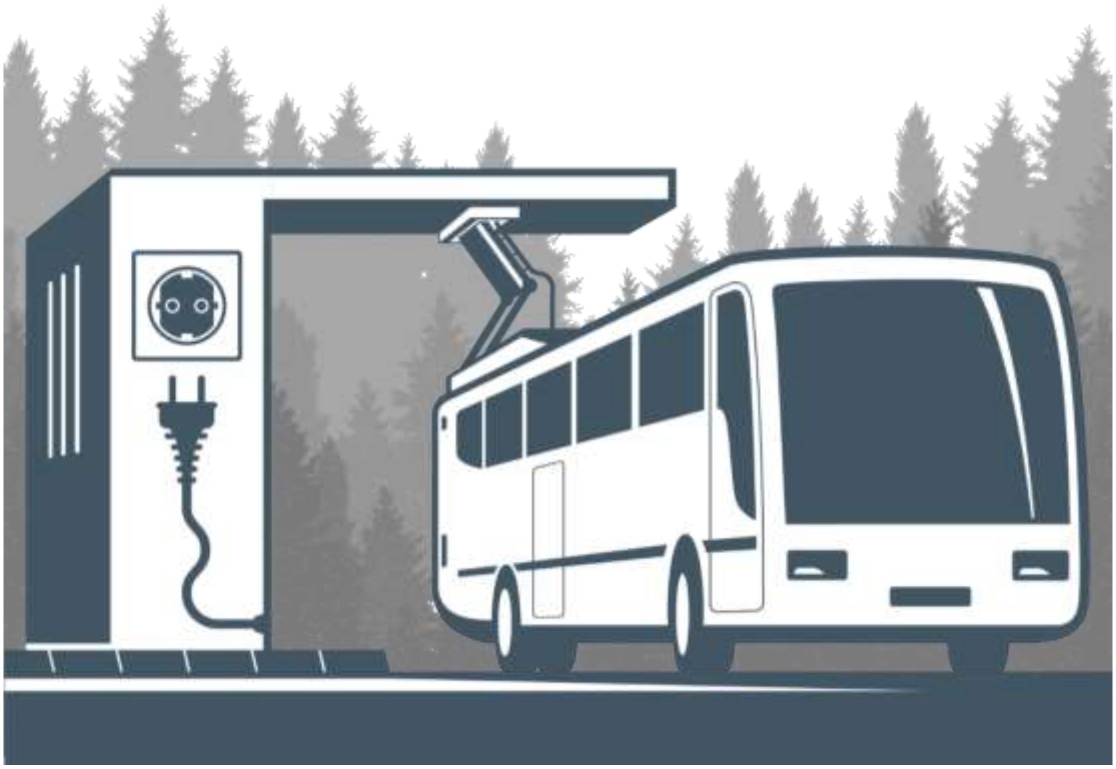
For Metro to achieve sustainable and economical fleet electrification, Hatch recommends the following steps:

- 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 2034 – 2037.

  - 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.
  - Develop a funding strategy to account for the 37% increase in capital expenditure.
  - Review this transition plan annually to update based on current assumptions, plans, and conditions.

## Appendices

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



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

York County COMMUNITY ACTION Corporation

**Prepared by:**

HATCH

**Version: 1.2**
**April 2024**

# Table of Contents

# 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.

A life cycle cost estimate was also developed as part of the analysis to assess the financial implications of the transition. The cost estimate includes the capital costs to procure the new vehicles, charging systems, and supporting infrastructure, as well as the operational and maintenance expenditures. The costing analysis indicates that YCCAC can anticipate a 126% increase in capital expenditures due to the transition, primarily due to the acquisition of electric trolley vehicles which are not a widely available product, and as a result are far more expensive than gasoline trolleys. It is estimated, however, that there will be a 6% annual reduction in operational and maintenance costs due to the improved reliability and efficiency of battery electric and hybrid drivetrain technologies. In summation, the cost estimate predicts that YCCAC will see a life cycle cost increase of roughly 6% by transitioning to hybrids and electric vehicles.

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**

A summary of hybrid and battery electric vehicle models that are commercially available (provided in Appendix A) demonstrates that there is a variety of possible vehicles for 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; Appendix A shows commercially available charging system options and 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 and presented in additional detail in Appendix B.

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).

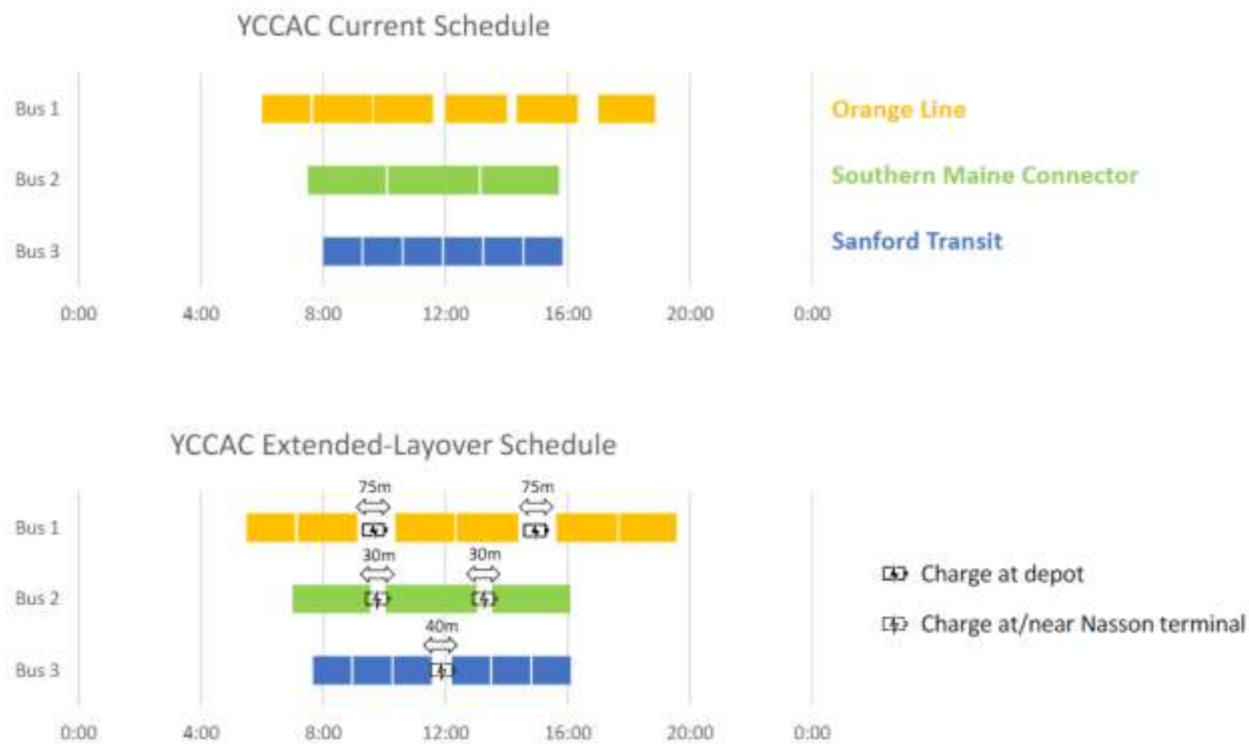



**Figure 5 Comparison of Current and Conceptual Electric-Vehicle Schedules**

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 1$^{st}$, 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.

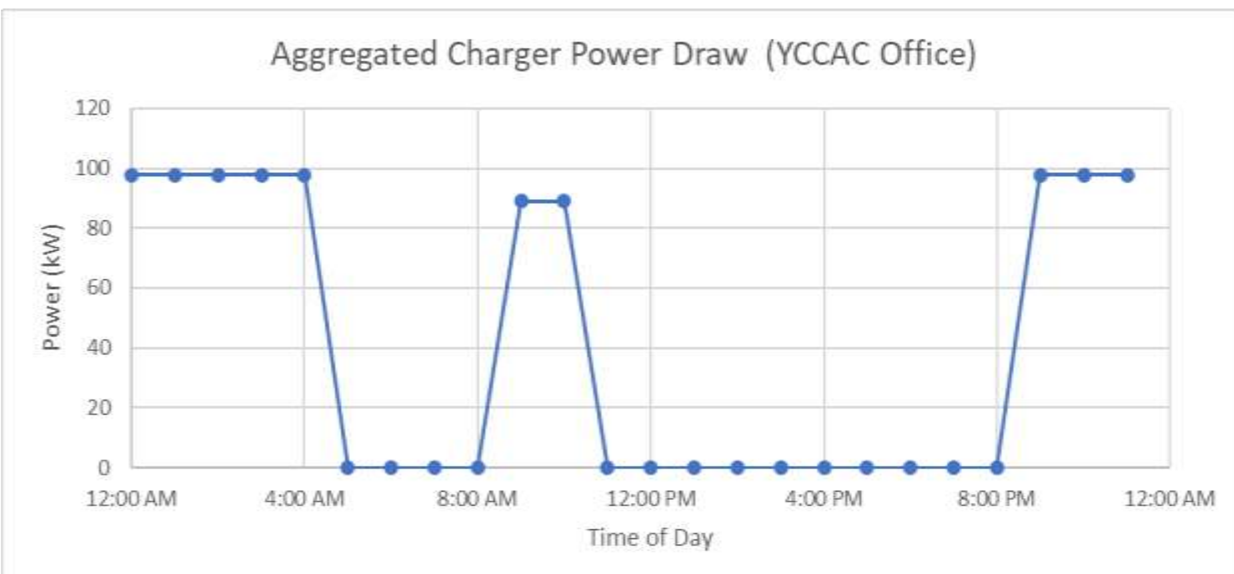



**Figure 6 Proposed Overnight Charging Schedule for YCCAC's Flex-Route and Demand Response Vehicles**

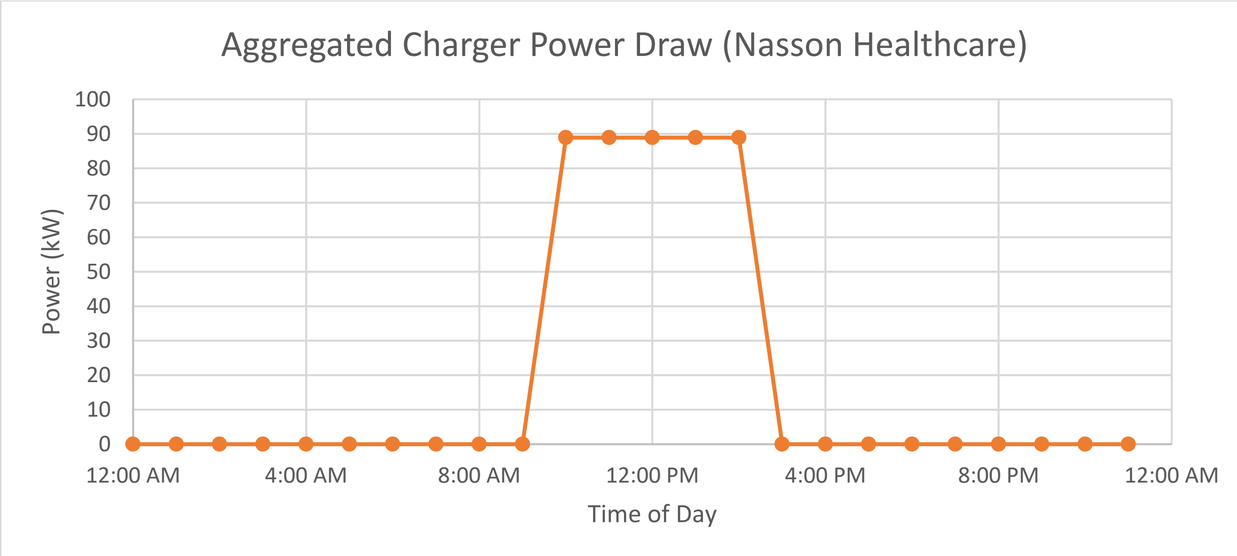



**Figure 7 Proposed On-Route Charging Schedule for YCCAC's Flex Route Vehicles**

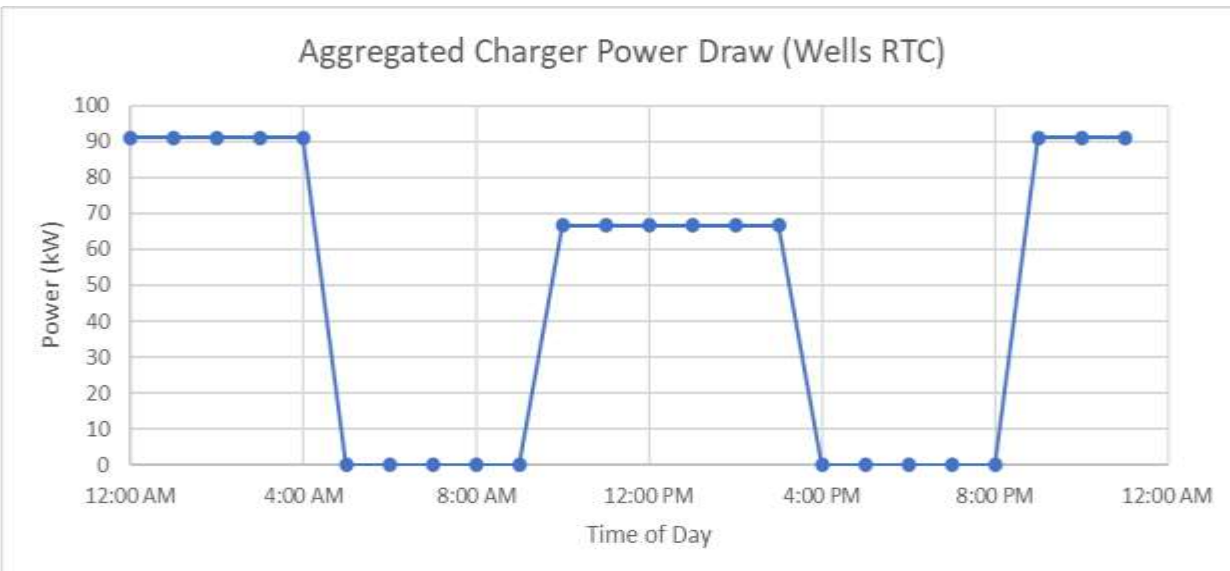



**Figure 8 Proposed Overnight and Mid-day Charging Schedule for YCCAC's Trolley Buses**

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 eight 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, the Orange Line's midday layovers will be too short for the low level of power provided by a level 2 charger; therefore, fast-charging capability is required as well. Although this could be accommodated by a single DC fast charger, for redundancy and future expansion possibility 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., seven 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 |
|---|---|---|---|
| **2025** | 7 (7 Hybrid Transit Vans) | | 147-9, 151-3, 201 |
| **2026** | 13 (7 Electric Trolleys, 4 Electric Transit Vans, 2 Hybrid Transit Vans) | Spruce St.: 7 level 2 chargers, 1 centralized 150 kW charger<br>Wells TC: 2 centralized 150 kW chargers<br>Nasson HC: 1 80 kW DCFC | 83-4, 86, 154-6, all trolleys |
| **2027** | | | |
| **2028** | 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

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 this area is likely infeasible because it is

***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

**Figure 10 Unpaved Storage Lot**

**Figure 9 Paved Storage Lot**


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

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.<br>Cut utility cost through peak-shaving. | Short power supply in case of outages.<br>Batteries degrade over time yielding less available storage as the system ages.<br>Can get expensive for high storage capacity. |
| **Generators** | Can provide power for prolonged periods.<br>Lower upfront cost. | GHG emitter.<br>Maintenance and upkeep are required and can be costly. |
| **Solar Arrays** | Can provide power generation in the event of prolonged outages.<br>Cut utility costs. | Cannot provide instantaneous power sufficient to support all operations.<br>Constrained due to real-estate space and support structures.<br>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. Appendix C shows the outage data provided by Central Maine Power for reference.

+ 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

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.

***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

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.

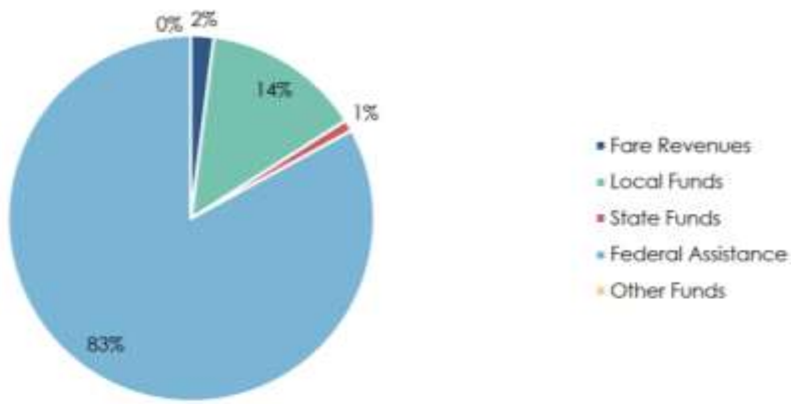



**Figure 19 Current Agency Funding Summary (Source: Maine DOT)**

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.<br>(*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.<br>(*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.<br>(*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.<br>(*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.<br>(*Competitive funding) |

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

## 14. Cost Analysis

Section Summary

- Vehicle electrification will save YCCAC money over the long term, as electric vehicles cost less to maintain and fuel
- Upfront capital costs increase by approximately 126% and annual operating cost will decrease by approximately 6%, yielding a net 6% increase in total cost of ownership

Hatch calculated the life cycle cost (LCC) of the proposed transition strategy and compared it to maintaining YCCAC's current gasoline operations as a baseline, using a net present value (NPV) model. This allows all costs incurred throughout the fleet transition to be considered in terms of today's dollars. The costs, which are based on the summer weekday service levels analyzed above and scaled to account for weekends, holidays, and the off-season, include initial capital as well as operations and maintenance costs of the vehicles and supporting infrastructure for gasoline, hybrid, and battery electric vehicles. Table 9 outlines the LCC model components, organized by basic cost elements, for gasoline and battery electric vehicle technologies.

**Table 9 Life Cycle Cost Model Components**

| Category | Gasoline (Base case) | Hybrid | Battery-Electric Vehicles |
|---|---|---|---|
| Capital | Purchase of the vehicles | Purchase of the vehicles | Purchase of the vehicles |
| | | | EV charging Infrastructure |
| | | | Electrical infrastructure upgrades |
| | | | Utility feed upgrades |
| Operations | Gasoline fuel | Gasoline fuel | Electricity |
| | Operator's Cost | Operator's cost | Operator's Cost |
| | | | Demand charges for electricity |
| Maintenance | Vehicle maintenance costs | Vehicle maintenance costs | Vehicle maintenance costs |
| | | | Charging infrastructure maintenance costs |
| Financial Incentives | Grants | Grants | Grants |

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

**Capital Investment**

- The lifespan of trolleys is 14 years and of other vehicles is 7 years, in accordance with YCCAC practice.

- All demand response vehicles are replaced with vans at their expected retirement year.
- YCCAC will make capital investment on the installation of charging infrastructure at all locations described previously; partnerships with other entities are not considered.

**Funding**

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

**Costs**

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

Table 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 2022 dollars where necessary, with capital costs estimated based on industry references as specified in Appendix D.

**Table 10 Cost Assumptions**

| Asset | Estimated Cost Per Unit (2022 $'s) |
|---|---|
| Gasoline Transit van | $40,000 |
| Hybrid Transit van | $55,000 |
| Electric Transit van | $180,000 |
| Gasoline Cutaway | $70,000 |
| Hybrid Cutaway | $125,000 |
| Electric Cutaway | $280,000 |
| Gasoline Trolley | $325,000 |
| Hybrid Trolley | $375,000 |
| Electric Trolley | $800,000 |

| Expense | Estimated Cost (2022 $'s) |
|---|---|
| Gasoline Vehicle maintenance | $0.84 / mile |
| Hybrid Vehicle maintenance | $0.84 / mile |
| Electric Vehicle maintenance | $0.63 / mile |
| Operator salary, benefits, overhead | $26.38 / hour |
| Gasoline fuel | $3.25 / gallon |

Because the electrification transition process will be gradual, life cycle cost calculations would necessarily overlap multiple vehicle procurement periods. Hatch addressed this issue by setting the start of the analysis period to be the year when the last non-hybrid gasoline vehicle is proposed to be retired (2028), with the analysis period stretching for a full 14-year vehicle lifespan for trolleys and 7-year lifespan for other vehicles. For vehicles at midlife at the end of the analysis period, a remaining value was calculated and applied at the end of the time window.

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

Table 11 and Figure 20 summarize the NPV for both technologies by cost category.

**Table 11 Net Present Value Summary**

| Category | Gasoline Baseline | Future Fleet | Cost Differential (Future Fleet vs. Baseline) |
|---|---|---|---|
| Vehicle Capital Costs | $1,020,889 | $2,115,545 | +126% |
| Infrastructure Capital Costs | $0 | $197,743 | |
| Vehicle Maintenance Costs | $2,667,706 | $2,220,570 | -6% |
| Infrastructure Maintenance Costs | $0 | $101,227 | |
| Operational Cost | $7,652,358 | $7,397,596 | |
| **Total Life Cycle Cost** | **$11,340,953** | **$12,032,681** | +6% |

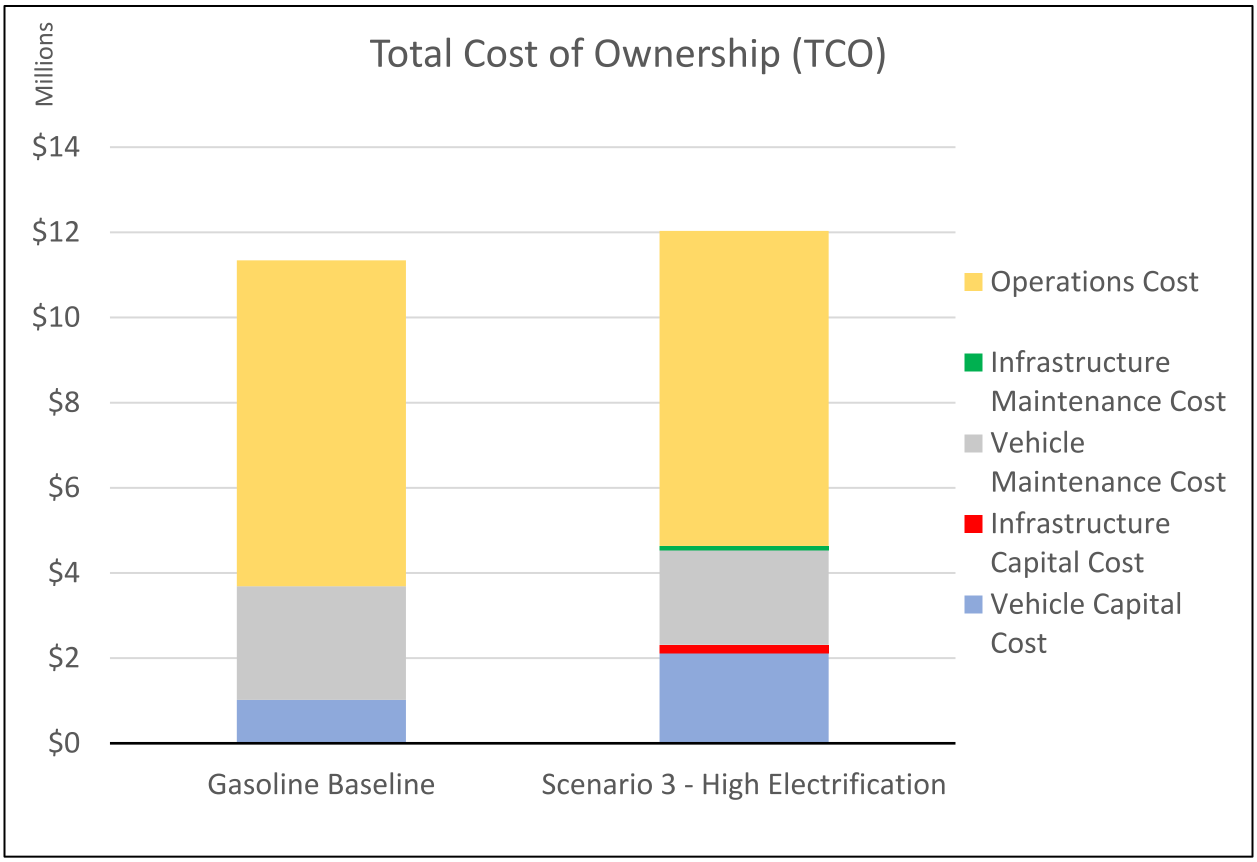



**Figure 20 Life Cycle Cost Comparison**

As shown in Figure 20, vehicle electrification reduces total system cost at the expense of increasing initial capital cost. Although there is some expense related to the charging equipment at the three charging locations, the bulk of the extra capital spending is on the vehicles themselves. Hybrid vehicles are more complex than gasoline vehicles, and while electric vehicles are much simpler mechanically they command a cost premium due to their large battery systems. This is particularly true for uncommon vehicle types, such as electric trolleys, which do not benefit from manufacturer economies of scale. These factors yield a 126% increase in capital costs over the gasoline baseline. This initial, non-recurring cost is mostly balanced out by the maintenance and operating savings over the lifetime of the vehicles. Because electric vehicles have fewer components to maintain and are cheaper to refuel than gasoline, and even hybrid vehicles experience less wear on certain components, the maintenance and operating costs of the proposed fleet are 6% lower than of the gasoline baseline. However, these costs recur daily – worn parts must be replaced and empty fuel tanks must be refilled throughout the lifetime of the vehicle. This means that over the long term the operations and maintenance savings offset much of the initial extra capital spending, yielding a net-present-value increase of approximately 6%.

The proposed fleet transition requires initial capital spending to reduce operating cost and achieve other strategic goals. This finding is common to many transit projects and is representative of the transit industry as a whole, with nearly all bus and rail systems requiring capital investments up front to save money in other areas (traffic congestion, air pollution, etc.) and achieve broader societal benefits over the long term. By extension, just as with the transit industry at large, policy and financial commitment will be required from government leaders to achieve the desired benefits. The federal government's contribution to these goals via FTA and Low-No grants is already accounted for, leaving state and local leaders to cover the remaining 126% increase in upfront capital cost.

The electric vehicle 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 tweak operating schedules, or otherwise revise this report's assumed end state.

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

## 14a. Joint Procurements

The cost figures presented above assume that YCCAC independently procures its vehicles and infrastructure, instead of coordinating with other agencies and the state DOT to form a joint procurement. Shifting to a joint procurement strategy, in particular through the adoption of a state purchasing contract, has the potential to save money for YCCAC.

State purchasing contracts offer financial savings for several reasons. First, the overhead expenses associated with an order – specification development, vendor negotiation, training, and post-acceptance technical support – can be divided across several agencies. Second, the number of orders required by each agency can also be reduced. State purchasing contracts typically have a duration of five years, allowing a large portion of the agency's fleet to be replaced in one lifecycle. These two factors are estimated to reduce YCCAC's cost per vehicle by approximately 4%. Third, the increase in total order size is likely to reduce cost per vehicle as well. Like agencies, EV vendors incur some of their costs (business development, contract negotiation, customization setup) on a per-order basis; therefore, they typically decrease the price of each vehicle as order size grows. Furthermore, a larger order is likely to attract additional vendors (who would be unwilling to participate in a small procurement); this is expected to drive down cost as well. In addition, technical support for the new vehicles will be more economical if it can be divided among several vehicles, or even several nearby agencies, as the expense of having an on-site vendor technician is roughly constant regardless of the size of the EV fleet. Recent BEB orders across the US show that, on average, for each additional bus in an order the per-vehicle cost decreases by 0.63%. In other words, combining five two-bus orders into one ten-bus order would reduce purchase cost by 5% due to order size alone.

YCCAC plans to order 80 vehicles over the next 17 years and their orders can easily be allocated to purchasing contracts. The 2024, 2025, and 2027 order for vans can be part of a 42-vehicle order purchased together with RTP; the 2031, 2032 and 2034 order for vans can be part of a 46-vehicle order purchased together with RTP and Downeast; the 2038, 2039, and 2041 order for vans can be part of a 42-vehicle order purchased together with RTP; the 2027 order for cutaways can be part of a 16-vehicle order purchased together with RTP and Downeast; the 2034 order for cutaways can be part of a 16-vehicle order purchased together with RTP and Downeast; and the 2037 order for trolleys can be part of a 15-vehicle order purchased together with BSOOB. The 2025 order for trolleys will have to be purchased solely by YCCAC.

In summary, although this analysis assumed that YCCAC acts independently in placing its orders, the agency is encouraged to explore opportunities for joint procurements with other agencies. This will potentially save the agency money through reduced administrative expenses, increased vendor competition, and efficiencies with post-procurement technical support. Overall, this strategy will produce a 10% cost saving for the agency.

## 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.

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.

***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%

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 12 and Figure 21 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 12 $CO_2$ 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% |

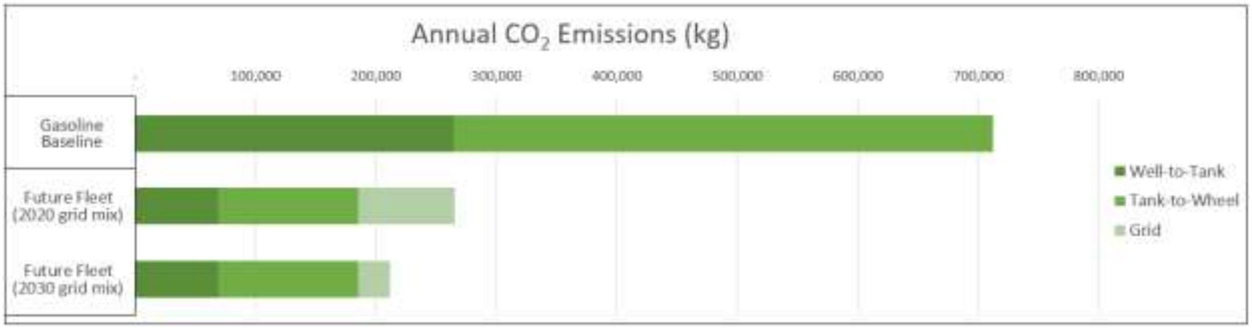



**Figure 21 Graph of $CO_2$ Emissions Estimate Results**

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 13 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 YCCAC success
- Hatch recommends partnering with local colleges and other transit agencies to share skills

**Table 13 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. Details on the alternative plans are presented in Appendix B and D. 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 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 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.
  - Develop a funding strategy to account for the 126% increase in capital spending.
  - Review this transition plan annually to update based on current assumptions, plans, and conditions.

# Appendices

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