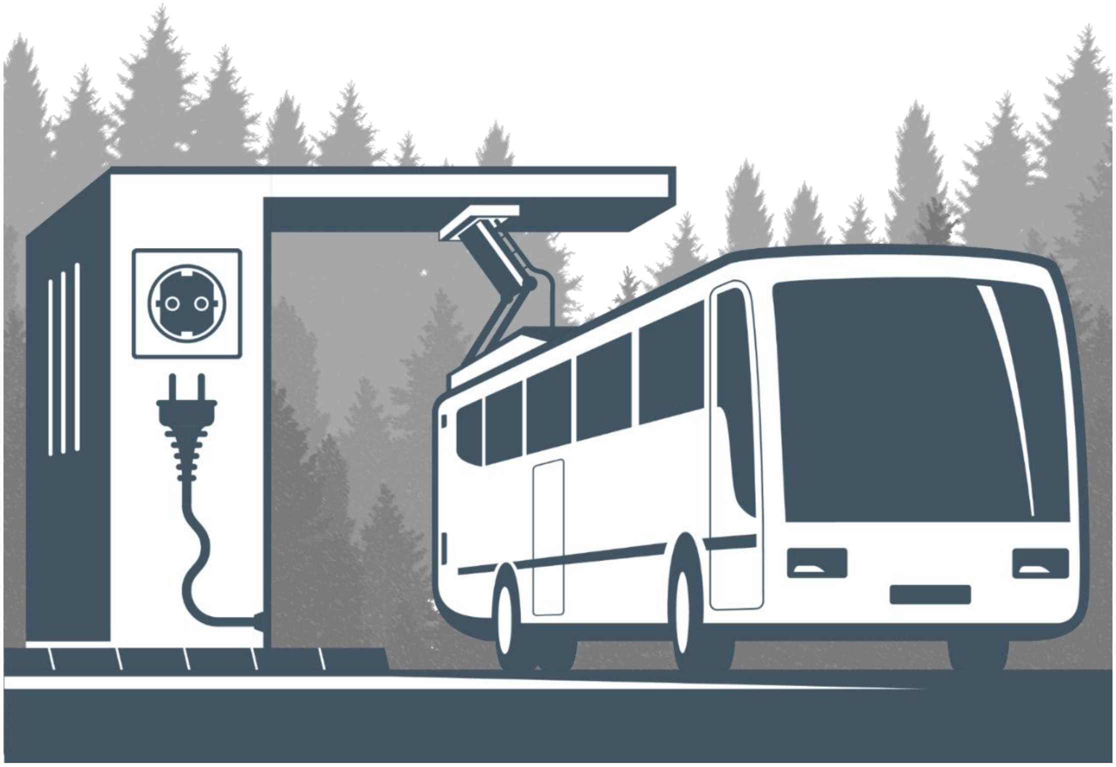

Bus Electrification Transition Plan for Bangor Community Connector

Prepared by:

HATCH

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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.

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 Bangor CC can anticipate a 39% increase in capital expenditures due to the transition. It is estimated, however, that there will be a 7% 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 Bangor CC will see a minor life cycle cost increase, of approximately 1%, by transitioning to hybrid and battery electric buses.

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 and to slightly reduce the life cycle costs required to operate its buses. 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	Projected Retirement Date
GILLIG *35'/1049-1050*	5	2	2011	2023
GILLIG *35'/1048*	5	1	2011	2025
GILLIG *35'/1046-1047*	5	2	2011	2027
GILLIG *30'/1743-1744*	5	2	2017	2027
GILLIG *30'/1858-1859*	5	2	2018	2028
GILLIG *30'/1960-1962, 1985-1989*	5	8	2019	2029
GILLIG *35'/2102-2105*	5	4	2021	2033
GILLIG *30'/2106*	5	1	2021	2031

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.

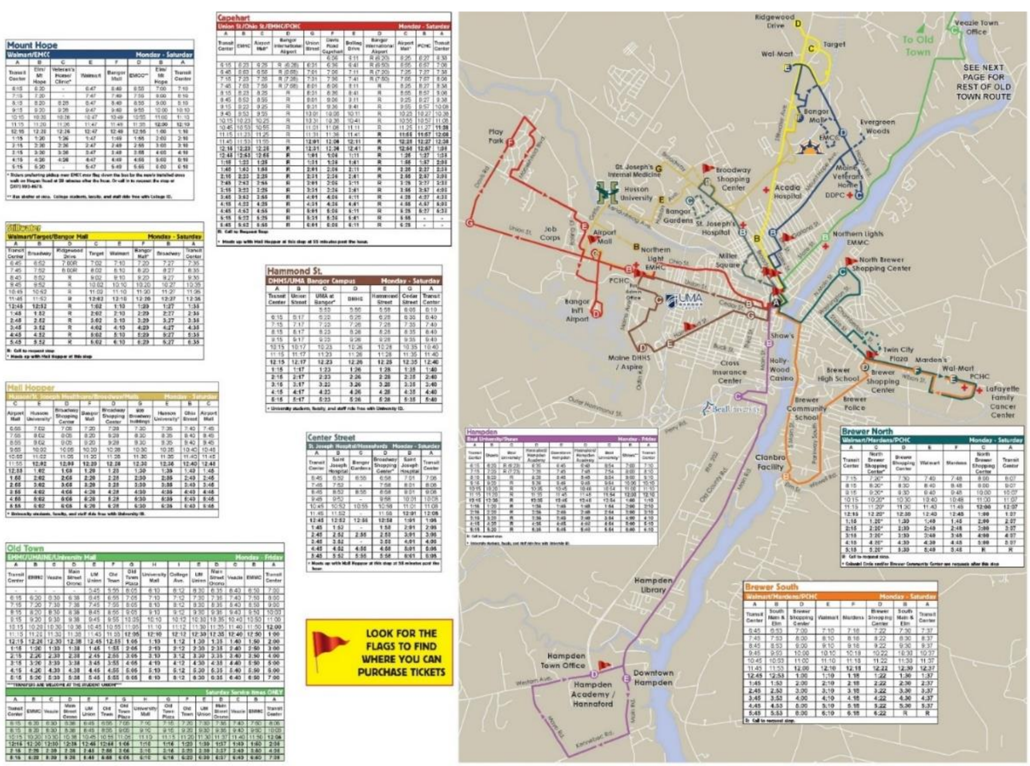

Figure 1 Bangor CC Route Map

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. 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 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

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

A centralized charger is a self-contained unit that allows charging one vehicle per charger. The charging dispenser is typically built into the charging cabinet. These are typically suited to small-scale charging applications. In contrast, in a decentralized configuration, a single high-power charger can charge multiple vehicles through separate dispensers. The power is assigned to the dispensers dynamically based on the number of vehicles that are charging at the same time. These are best applied to large charging stations, such as those that would be installed in a bus depot for overnight charging. Similarly, de-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 De-Centralized Cabinets

(Source: ABB)

Like the vehicles, charging infrastructure to support battery electric buses is available in numerous configurations. One of the primary metrics that can be customized is the charging power. For this study, it was assumed that 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. Appendix A shows additional commercially available charging system options and configurations.

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

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

needed. This assumption will remain true for hybrid buses, which have comparable range to diesels, but may not always be valid for electric vehicles, which have reduced range in comparison to diesel buses. Even when diesel heaters are installed, as was assumed in this study, icy road conditions and cold temperatures degrade electric bus performance in the winter. Therefore, battery electric buses may not provide adequate range for a full day of service, year-round, on many of 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. More information about the tradeoffs between these operating strategies is presented in Appendix B. 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.

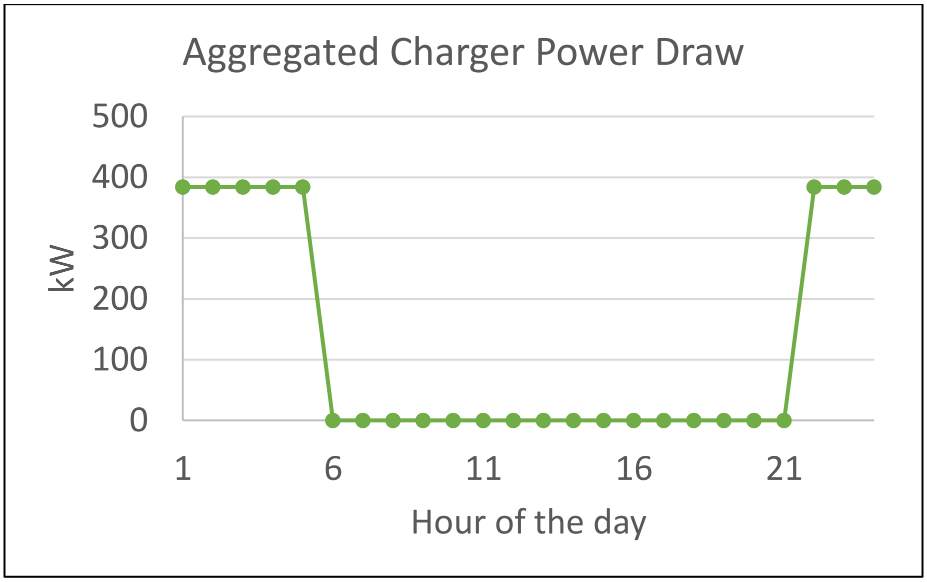

Figure 3 Proposed Charging Schedule for Bangor CC's Future Fleet

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>

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

$Monthly\ Charge$

$$= (Monthly\ Non - coincidental\ Peak\ \times Distribution\ Charge) + (Monthly\ Non - coincidental\ Peak\ \times Transmission\ Charge)$$
$$= (384\ kW\ \times \$10.51) + (384\ kW \times \$14.57)$$
$$= \$9630.72$$

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 de-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 decentralized charging architecture is recommended for the Bus Barn. Decentralized 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	One (One 450 kWh Electric 35')	One 150 kW de-centralized Bus Barn charger (Three dispensers) + electrical upgrades and rough ins for future charger installations (conduit runs, concrete pads, transformers, switchgears etc.)	1048 (35', procured 2011)
2026			
2027	Four (Two 450 kWh Electric 35', Two 450 kWh Electric 30')	One 150 kW de-centralized Bus Barn charger (Three dispensers)	1046-1047 (35', procured 2011), 1743-1744 (30', procured 2017)
2028	Two (Two Hybrid 30')		1858-1859 (30', procured 2018)
2029	Eight (Four Hybrid 30', Four 450 kWh Electric 30')	Two 150 kW de-centralized Bus Barn chargers (Six dispensers)	1960-1962, 1985-1989 (all 30', procured 2019)
2030			
2031	One (One 450 kWh Electric 30')		2106 (30', procured 2021)
2032			
2033	Four (Four 450 kWh Electric 35')		2102-2105 (35', procured 2021)
2034			
2035			
2036			
2037	Two (Two Hybrid 35')		Pending replacements for 1049-1050 (30', to be procured 2023)

9. Building Spatial Capacity

Section Summary

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

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

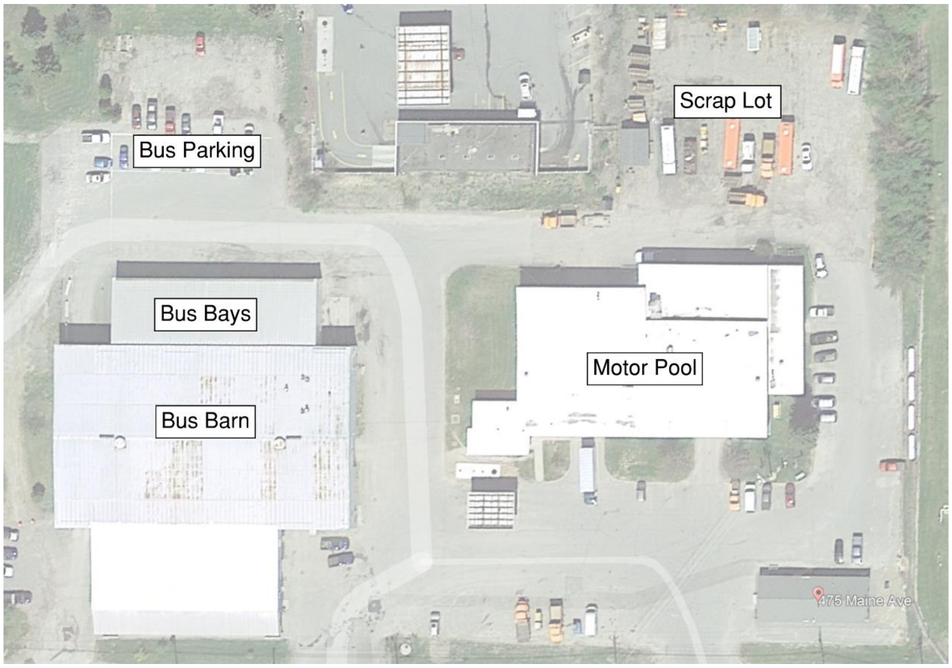

Figure 4 Bangor CC Main Facilities (475 Maine Avenue) (Source: Google Maps)

Buses and other municipal vehicles are maintained and serviced in the motor pool building, as shown in Figure 5. The motor pool building also has a storeroom which inventories parts for the fleets maintained at the facility. The motor pool facility will likely provide ample space for maintenance of electric and hybrid buses in the future, although a designated area should be established for maintaining and storing components specific to the new fleet, such as batteries. Furthermore, if the agency wishes to maintain components such as motors on-site, a back shop area will need to be established for this work.

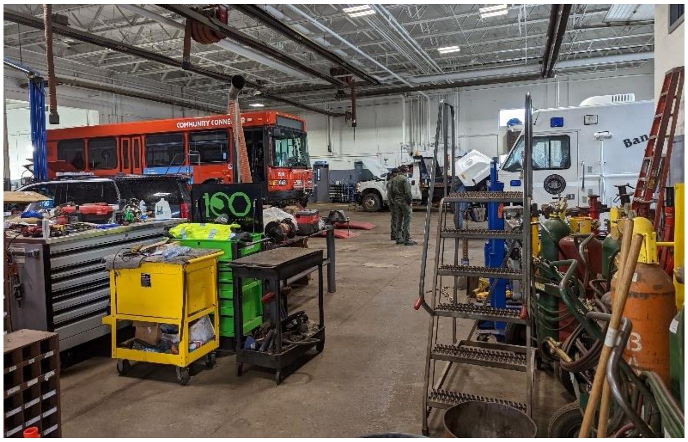

Figure 5 Motor Pool Maintenance Area

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

Figure 6 Bus Bay "Warm Storage" Area

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

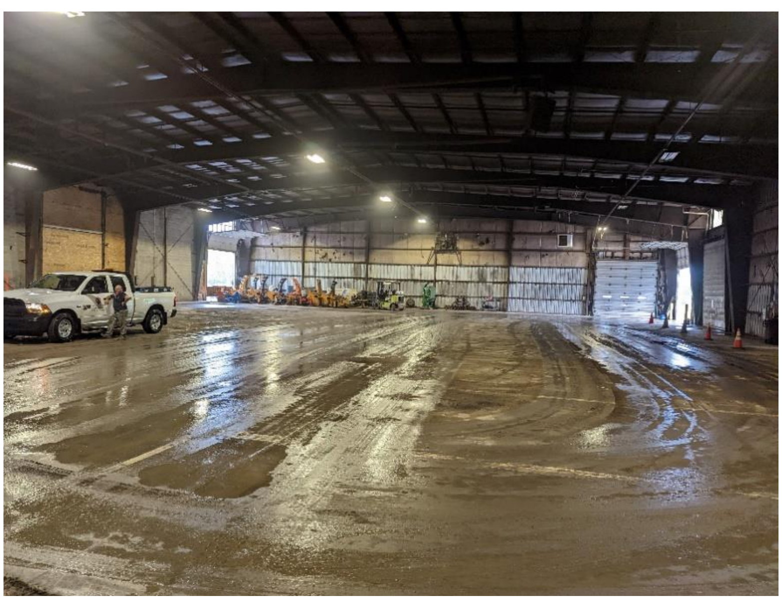

Figure 7 Bus Barn "Cold Storage" Area

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

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

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

10. Electrical, Infrastructure, and Utility Capacity

Section Summary

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

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

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

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

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

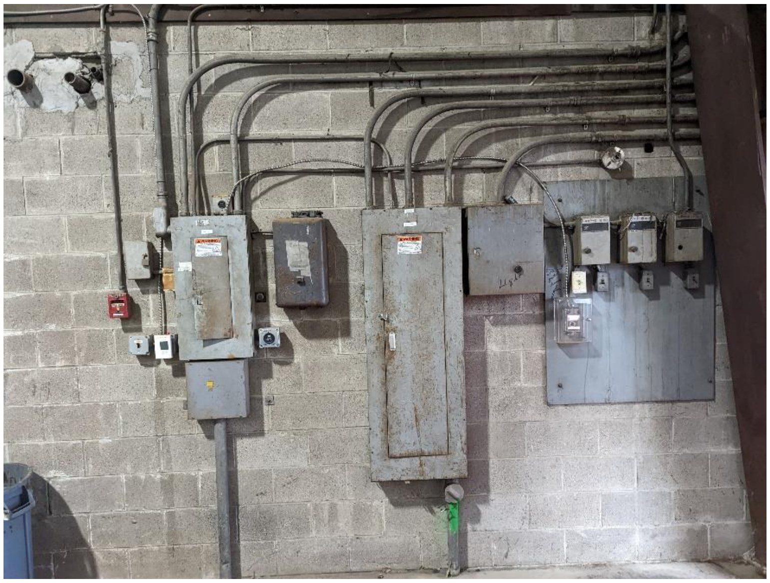

Figure 10 Bus Barn Electrical Room

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

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

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

11. Resiliency

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

> ***Section Summary***
>
> - Power outages have occurred rarely, but resiliency options should be considered
> - Solar in conjunction with on-site energy storage system can be a viable option for resiliency, reducing GHG and offsetting electricity cost

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

Table 5 summarizes the advantages and disadvantages of on-site storage and on-site generation systems. The most ideal solution for Bangor CC will need to be determined based on a cost benefit analysis.

Table 5 Comparison of the resiliency options

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

11a. Existing Conditions

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

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

11b. Outage Data and Resiliency Options

After noting no viable resiliency systems in place currently, Hatch assessed potential resiliency options. The first step in that assessment was to analyze the power outage data for the utility feeds that supply power to the Community Connector's Bus Barn and at the Pickering Square Transit Center location to determine the requirements for backup power. Following is a summary of the outages at each of the locations in the last five years. Appendix C shows the outage data provided by Versant Power for reference.

- 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 de-centralized chargers with three dispensers each, as specified in this report, two chargers would be required to support five buses. Assuming that all chargers Bangor CC would purchase would be rated at a minimum 150kW, would have an efficiency of 90%, and a 20% space capacity, the resulting on-site generation capacity required would be approximately 420 kVA.

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

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

Hatch next generated cost estimates associated with the four resiliency system options for the two sites. Table 6 summarizes the requirement for the first two resiliency options for each site and the associated approximate project cost for implementing each option. Note that as these are conceptual proposals on which no decision has been made, these costs are not included in the lifecycle costs in Section 14.

Table 6 Resiliency Options for Worst Cast Outage Scenarios

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

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

11c. Solar Power

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

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

Table 7 Bus Barn Rooftop Solar Analysis

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

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

However, solar power generation is not recommended as a primary resiliency system as power outages are likely to occur due to winter storms during the time of the year when the least amount of solar energy is available due to cloud cover.

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

If solar is considered for the site, the on-site storage system should be sized according to the full solar production rather than to only support outage scenarios. A more detailed study should be conducted to determine the battery energy requirements, which are likely to be more than 2.5 MWh for the Bus Barn based on the above solar estimates.

12. Conceptual Infrastructure Design

12a. Conceptual Layouts

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

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

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

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

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

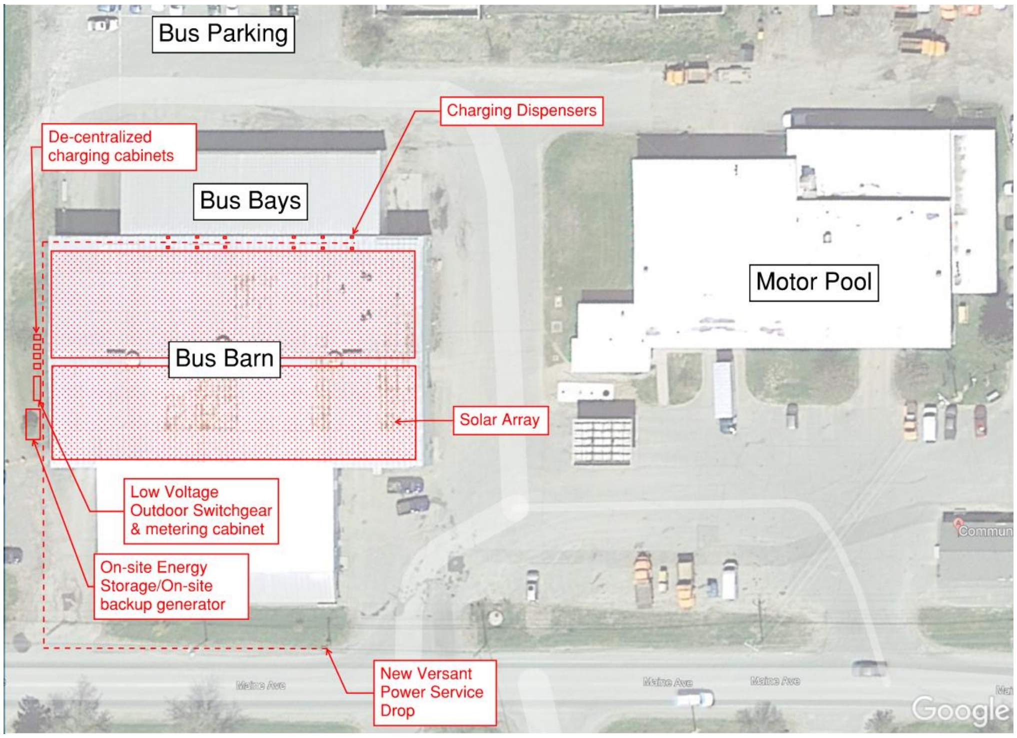

Figure 12 Bus Barn Infrastructure Conceptual Layout (Source: Google Maps)

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

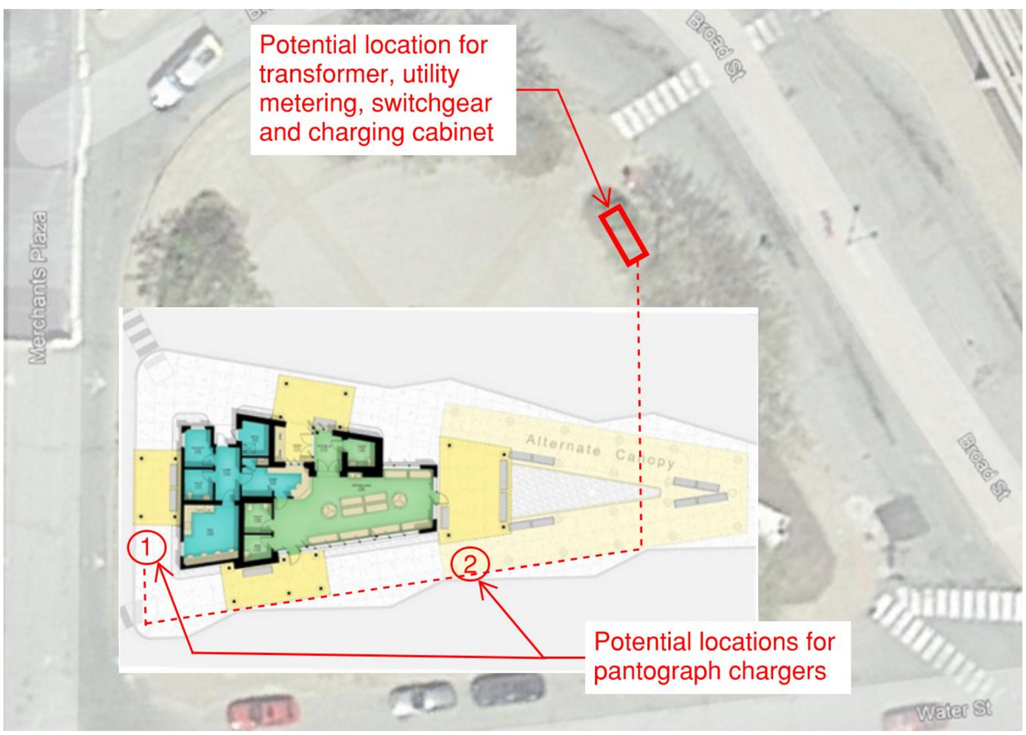

Figure 13 Pickering Square Transit Center Charger Location Concept (Source: Google Maps)

12b. Fire Mitigation

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

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

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

13. Policy Considerations and Resource Analysis

Section Summary

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

Bangor CC's current operating budget is roughly $3.5 million per year. The agency's funding sources are summarized in Figure 14. As can be seen in the figure, Bangor CC's largest source of funding comes from federal assistance. For bus, facility and infrastructure costs the agency's primary federal funding comes from the Urbanized Area Formula Funding program (49 U.S.C. 5307), and the Buses and Bus Facilities Competitive Program (49 U.S.C. 5339(b)) through the FTA.

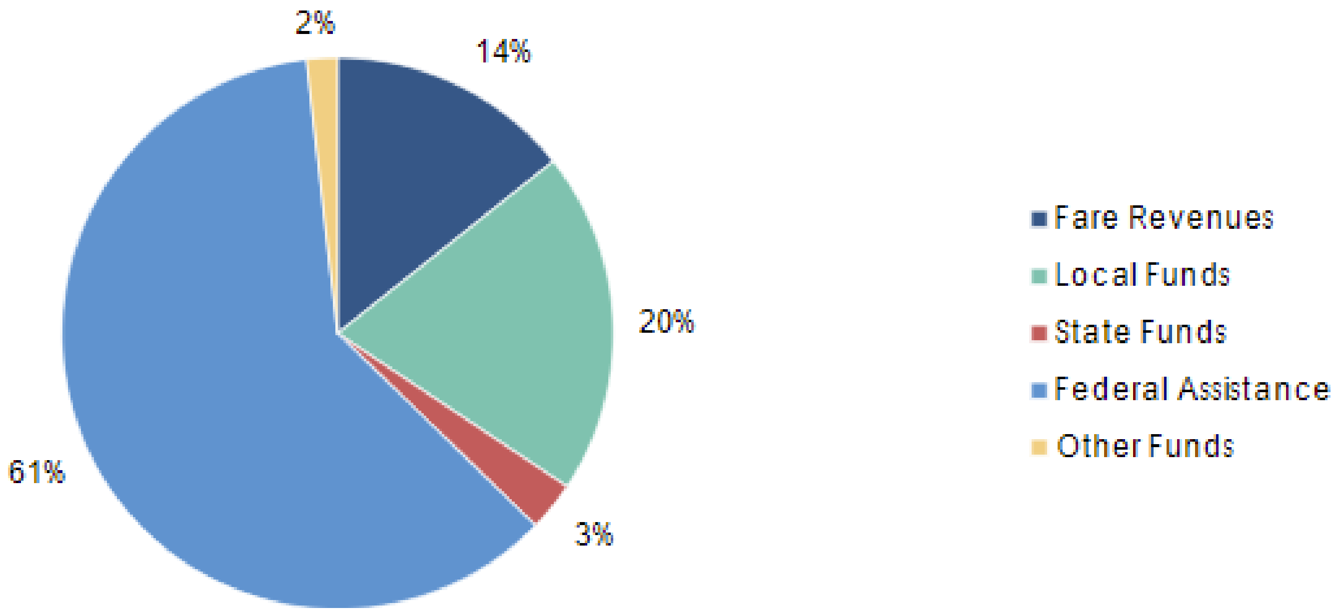

Figure 14 Current Agency Funding Summary (Source: MaineDOT)

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

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

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

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

Table 8 Policy and Resources Available to Bangor CC

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

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

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

14. Cost Analysis

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

Section Summary

- Bus electrification will reduce Bangor CC recurring expenses, as electric vehicles cost less to maintain and fuel
- Upfront capital costs increase by approximately 39% and annual operating cost will decrease by approximately 7%, yielding a net 1% increase in total cost of ownership

Table 9: Life Cycle Cost Model Components

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

Like any complex system, Bangor CC 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 FTA guidelines.
+ Buses are overhauled at midlife. This is recommended for electric buses as the lifespan of a battery is approximately 6-7 years.
+ Buses are replaced with buses of the same length, at their expected retirement year.
+ The existing fueling infrastructure will not require replacement.

Funding

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

Costs

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

Table 10 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 2022 dollars where necessary.

Table 10 Cost Assumptions

Asset	Estimated Cost Per Unit (2022 $'s)
30' Diesel Transit Bus	$531,000
30' Hybrid Transit Bus	$814,000
30' Battery Electric Transit Bus (450 kWh)	$978,000
35' Diesel Transit Bus	$546,000
35' Hybrid Transit Bus	$821,000
35' Battery Electric Transit Bus (450 kWh)	$1,009,000
DC Fast Charger – Plug-in Garage (de-centralized unit and 3 dispensers)	$270,000

Expense	Estimated Cost (2022 $'s)
Diesel and hybrid bus maintenance	$1.11 / mile
Electric bus maintenance	$0.83 / mile
Operator salary, benefits, overhead	$31.29 / hour
Diesel fuel	$2.90 / 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

(2037), 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) 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 11 and Figure 15 summarize the NPV for both technologies by cost category.

Table 11: Net Present Value Summary

Category	Diesel Baseline	Future Fleet	Cost Differential (Future Fleet vs. Baseline)
Vehicle Capital Costs	$3,163,719	$4,265,992	+39%
Infrastructure Capital Costs	$0	$143,997	
Vehicle Maintenance Costs	$4,062,561	$3,454,796	-7%
Infrastructure Maintenance Costs	$0	$34,898	
Operational Cost	$10,567,724	$10,127,907	
Total Life Cycle Cost	**$17,794,004**	**$18,027,590**	+1%

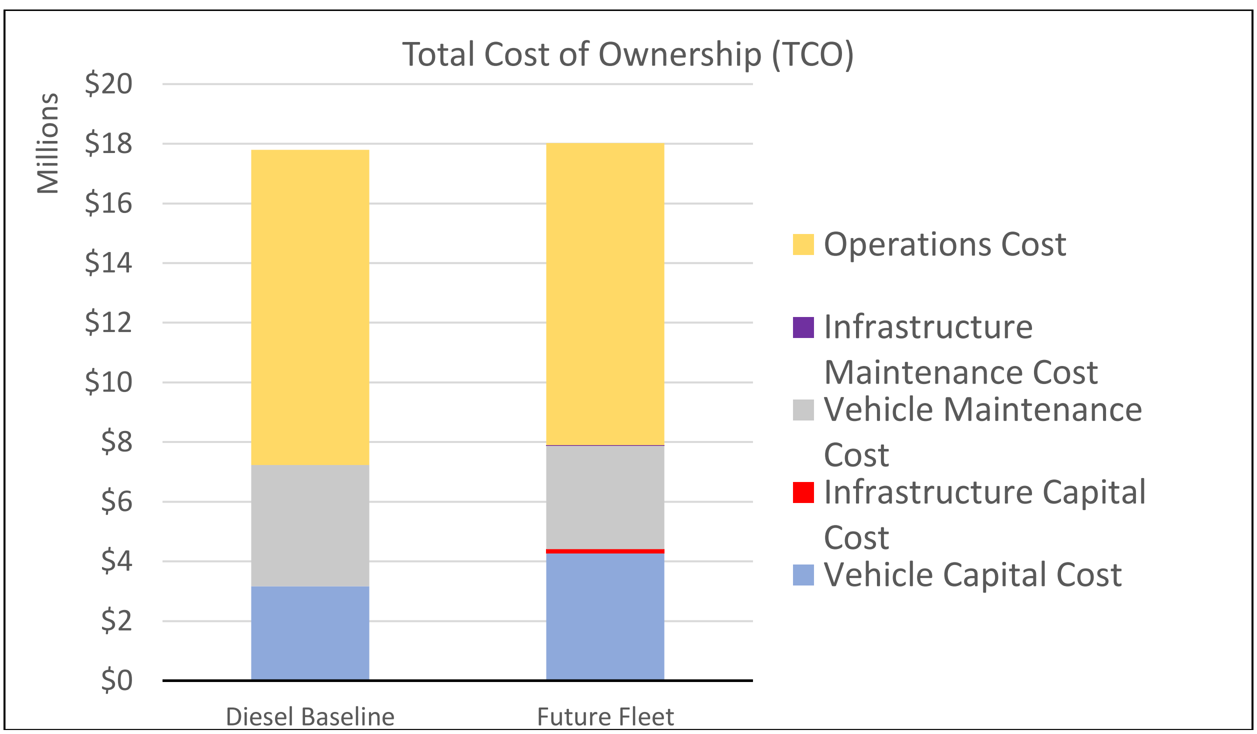

Figure 15 Life Cycle Cost Comparison

As shown in Figure 15, bus electrification reduces recurring cost at the expense of increasing initial capital cost. Although there is some expense related to the charging equipment in the garage, the bulk of the extra capital spending is on the vehicles themselves. Hybrid buses are pricier than diesels because of their increased complexity and higher number of components; electric buses are much simpler mechanically but command a cost premium due to their large battery systems. Even though the proposed fleet is only two-thirds electric, with the balance being hybrid vehicles, these factors yield a 39% increase in capital costs over the diesel baseline. This initial, non-recurring cost is balanced out by the maintenance and operating savings over the lifetime of the vehicles. Because electric vehicles have fewer components to maintain and are cheaper to refuel than diesels, the maintenance and operating costs of the proposed fleet are 7% lower than of the diesel baseline. However, these costs recur daily – worn parts must be replaced and empty fuel tanks must be refilled throughout the lifetime of the vehicle. This means that over the long term the operations and maintenance savings 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 39% 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.

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

14a. Joint Procurements

The cost figures presented above assume that Bangor CC 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 Bangor CC.

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 4, Bangor CC expects to place seven vehicle orders over the next 14 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 Bangor CC'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.

Because Bangor CC's vehicles are all transit-style buses, the agency's orders can be easily allocated to purchasing contracts. The 2025, 2027, and 2028 orders would be part of a 23-vehicle order shared with BSOOB, Metro, and South Portland Bus Service (SPBS); 2029, 2031, and 2033 orders would be part of a 33-bus purchase together with Citylink and Metro, and the 2037 order would be included in a 49-bus procurement shared with BSOOB, Citylink, Downeast, Metro, and SPBS. This analysis assumes that hybrid and battery-electric buses, of both 30' and 35' length, are included in a single contract. As the industry expands, an increasing number of vendors is likely to offer all of these permutations for purchase under a single contract; if this does not occur, Bangor CC may revisit its preferred vehicle types, for example by ordering more-common 35' buses in place of 30' ones.

In summary, although this analysis assumed that Bangor CC 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 21% cost saving for the agency.

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 12 and Figure 16 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 12 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%

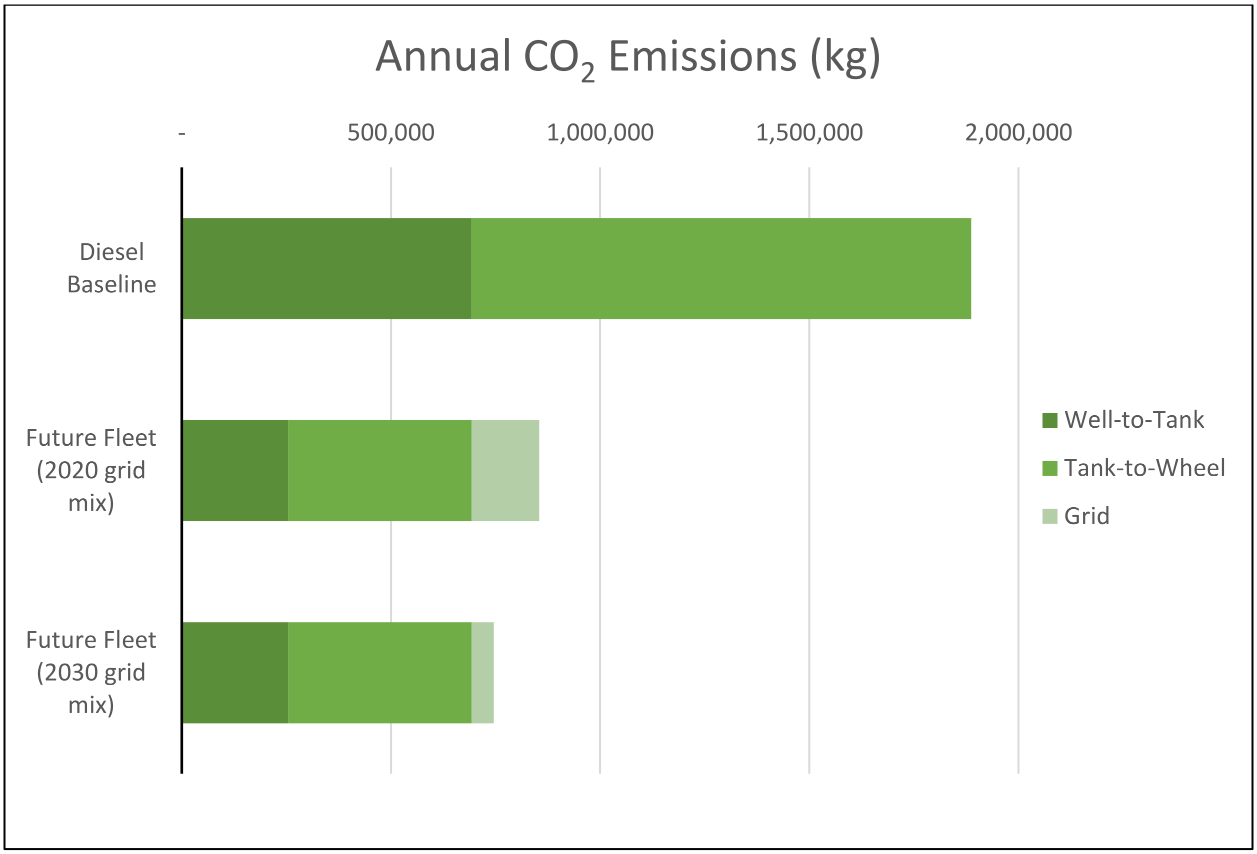

Figure 16 Graph of CO_2 Emissions Estimate Results

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 13 details skills gaps for the workforce groups within the agency and outlines training requirements to properly prepare the staff for future operations.

Table 13 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. Details on the alternative plans are presented in Appendix B, D, and E. 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. In particular, consider

revising the procurement schedule to receive multiple electric buses as part of the first order in 2025.
    - 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.
- Develop a funding strategy to account for the 39% increase in capital expenditure.
- Review this transition plan annually to update based on current assumptions, plans, and conditions.

Appendices

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