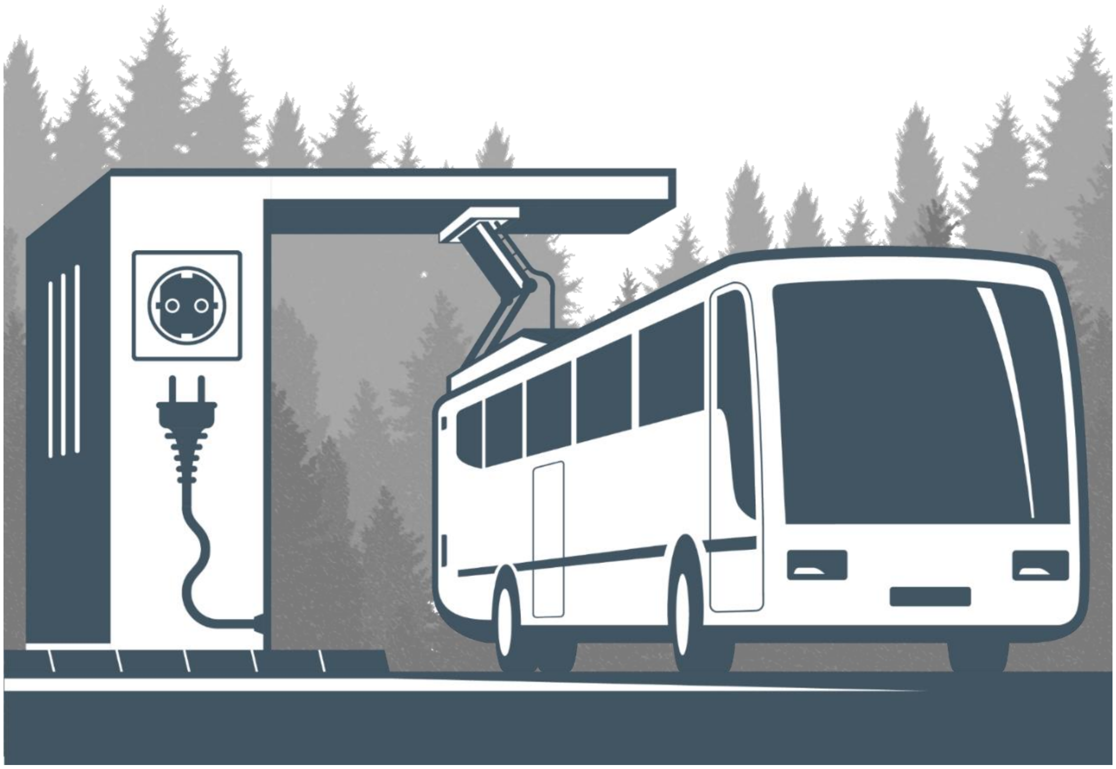

Bus Electrification Transition Plan for Lewiston-Auburn Citylink

citylink

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1. Executive Summary

Citylink, the bus agency serving the Lewiston-Auburn area in Maine, is currently considering transitioning its bus fleet to battery electric and hybrid drivetrain technologies. To effectively plan for this transition a thorough analysis was conducted to develop a feasible strategy for the agency. This report summarizes the results of the analysis for asset configuration, emissions, and the costs associated with the transition.

Through this analytical process, Citylink has expressed a preference for fleet and infrastructure asset configurations that will provide a feasible transition to battery electric drivetrain technologies while supporting the agency's operational requirements and financial constraints. The selected configuration maintains the agency's current fleet size of nine buses by replacing them with nine battery electric buses. To support the battery electric buses, the agency also plans to procure, install, and commission three charging systems at the Oak St. parking lot in downtown Lewiston that will have the capacity to support overnight charging of up to nine buses simultaneously, as well as potentially a pantograph-style charger for use during service hours.

One of the primary motivations behind Citylink's transition to battery electric drivetrain technologies is to achieve emissions reductions compared to their existing diesel operations. As part of this analysis, an emissions projection was generated for the proposed future battery electric fleet. The results of this emissions projection estimate that the new fleet will provide up to an 88% reduction in emissions compared to Citylink's existing diesel operations.

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 Citylink can anticipate a 45% increase in capital expenditures due to the transition. It is estimated, however, that there will be a 10% annual reduction in operational and maintenance costs due to the improved reliability and efficiency of battery electric drivetrain technologies. In summation, the cost estimate predicts that Citylink will see roughly 0.4% life cycle cost savings by transitioning to battery electric buses.

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

2. Introduction

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

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

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

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

3. Existing Conditions

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

Section Summary

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

Table 1 Current Vehicle Roster

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

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

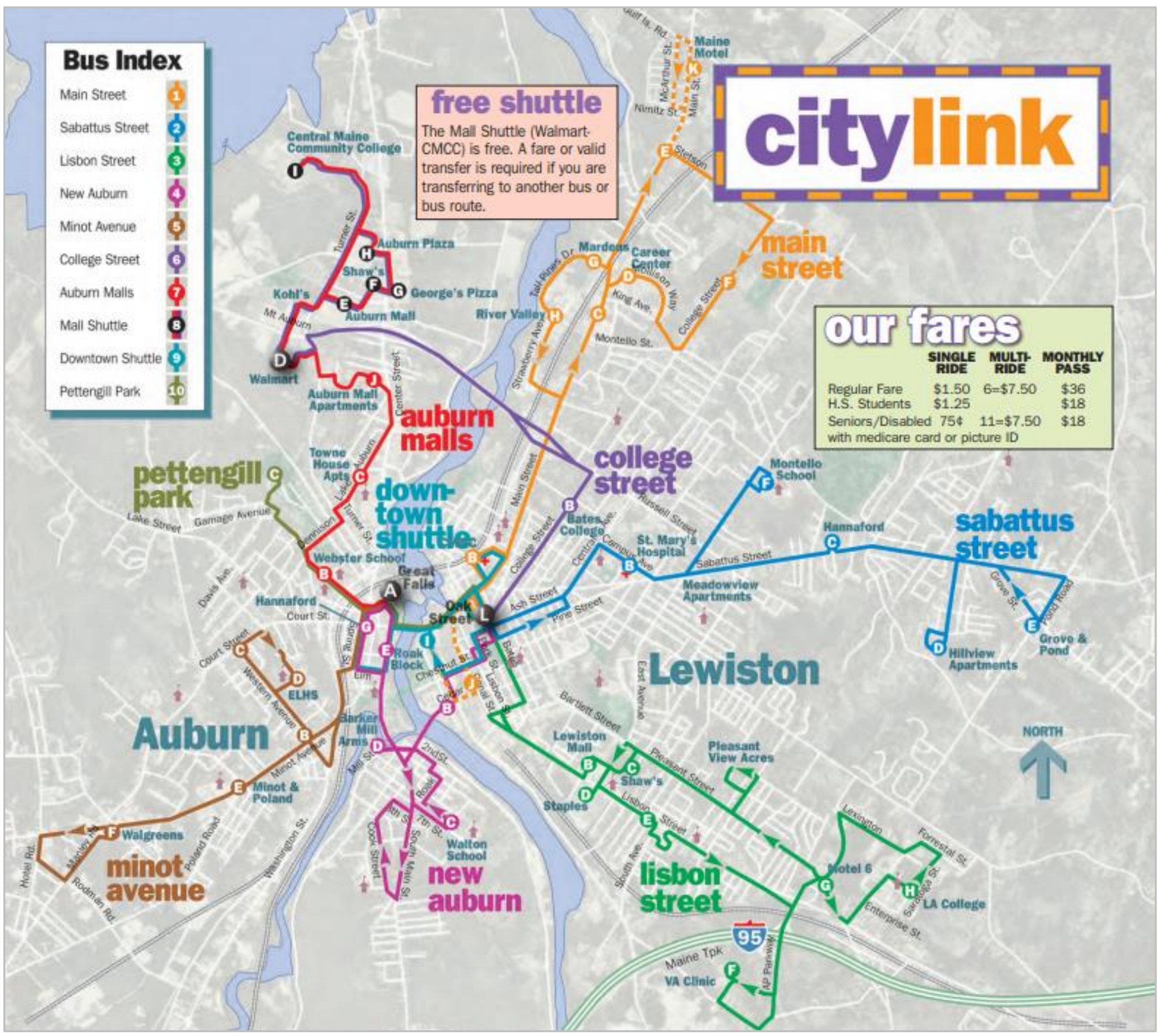

Figure 1 Citylink Route Map

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

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

3a. Stakeholder Environment

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

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

4. Vehicle Technology Options

Section Summary

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

As discussed in Section 3, Citylink's revenue service fleet is composed of 29' and 35' transit buses. 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 Citylink to utilize. For battery electric buses, battery capacity can be varied on many commercially available bus platforms to provide varying driving range. For this study, battery electric buses were assumed to have either a 'short-range' 225kWh or 'long-range' 450kWh battery capacity, which are representative values for the range of batteries offered by the industry. The buses were assumed to have diesel heaters, which minimize electrical energy spent on interior heating during the winter months. Two types of safety margins were also subtracted from the nominal battery capacities of the buses. First, the battery was assumed to be six years old (i.e. shortly before its expected replacement at the midlife of the bus). As batteries degrade over time, their capacity decreases. To account for this, the battery capacity was reduced by 20%. Second, the bus was assumed to need to return to the garage before its level of charge falls below 20%. This is both a manufacturer's recommendation – batteries have a longer life if they are not discharged to 0% – and an operational safety buffer to prevent dead buses from becoming stranded on the road. These two margins yield a usable battery capacity of 64% of the nominal value (144 or 288 kWh). Finally, as the industry is advancing quickly and technology continues to improve, a 3% yearly improvement in battery capacity was assumed.

5. Infrastructure Technology Options

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

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

1. Centralized
2. De-centralized

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

Figure 2 Example Charging Systems (Source: ABB):

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

Right – Overhead Pantograph Charger and De-Centralized Cabinets

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

6. Route Planning and Operations

> ***Section Summary***
>
> - Electric buses are typically sold in two battery capacity configurations – short and long range
> - Neither electric bus configuration offers comparable operating range to diesel buses – so detailed operations modeling is needed
> - Particularly with short-range buses, blocks should be optimized for BEB operation. This includes interlining to provide access to enroute chargers and extra layover time to allow for charging
> - Long-range electric buses can cover four of Citylink's six blocks without layover charging

Citylink's current operating model is similar to that of many transit agencies across the country. Each vehicle leaves the garage at the appropriate time in the morning, operates (typically on the same route or set of routes) for the entire day, and then returns to the garage once service has concluded in the evening. Although Citylink's schedulers must account for driver-related constraints such as maximum shift lengths and breaks, the vehicles are assumed to operate for as long as they are needed. This assumption will remain true for hybrid buses, which have comparable range to diesels, but may not always be valid for electric vehicles, which have reduced range in comparison to diesel buses. Even when diesel heaters are installed, as was assumed in this study, icy road conditions and cold temperatures degrade electric bus performance in the winter. Therefore, battery electric buses may not provide adequate range for a full day of service, year-round, on many of Citylink's routes and blocks, particularly if recommended practices like pre-conditioning the bus before leaving the garage are not always followed.

6a. Operational Simulation

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

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

As discussed in the previous section, all routes were evaluated against two common electric bus configurations: ‘short-range’ 225kWh or ‘long-range’ 450kWh battery capacity. As technology advances, Hatch assumed that these battery capacities will increase at a rate of 3% per year, allowing for additional range. Combined with the safety margins discussed in Section 4, this yielded usable battery energy of 194.4 kWh and 388.8 kWh by 2032. The year 2032 was selected as a “litmus test” because it is near the beginning of the fleet transition schedule specified in Section 8, ensuring that all feasibly electrifiable routes are accounted for without requiring future vehicle procurements to be delayed while battery technology catches up. Clearly, if battery electric bus technology advances faster than anticipated, or if the existing fleet proves reliable and can outlast its 12-year lifespan, there will be a higher operating margin in bus electrification, allowing more service expansion. Conversely, if technology develops more slowly or the existing fleet requires replacement sooner, less service expansion will be possible.

Table 2 below presents the mileage and energy requirement for each block, with green shading denoting those blocks that can be operated by the specified bus by 2032 and red shading denoting those that cannot. It should be noted that the energy requirements are slightly higher for long-range buses because of their higher weight due to the increased number of battery cells.

Table 2 Energy Requirements by Block

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

6b. Operational Alternatives

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

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

If layover charging were conducted, the operations the schedule (and perhaps even the route structure) would need to be optimized for the needs of the buses. For example, coordination of driver meal breaks with bus charging times can ensure that drivers are not waiting unproductively while the bus charges (and can even simplify scheduling, as a driver and a bus would stay together throughout the day, with meal and charging breaks happening at the same time). Careful selection of route interlines and route departure times from the hubs can help balance layover durations with the time required for charging. For example, routes that do not serve the layover charger location can be interlined with routes that do serve it, ensuring that all buses can cycle through the layover charger over the course of the day. More information about the tradeoffs between these operating strategies is presented in Appendix B. Due to the increase in fleet size that this alternative would entail, it is currently not preferred by Citylink.

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

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

7. Charging Schedule and Utility Rates

Section Summary

- The local utility has proposed a new rate structure for charging EVs which will include cost penalties for charging during peak demand periods
- As a result, a charging schedule was developed to help Citylink charge its buses economically

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

Citylink's current electricity rates are determined by Central Maine Power's 'MGS-S' rate table, as shown in Table 3. Under this rate table Citylink pays a flat "customer charge" monthly, regardless of usage. Citylink also pays a single distribution charge of $16.64 per kW for their single highest power draw (kW) that occurs during each month. This peak charge is not related to Central Maine Power's grid peak and is local to Citylink's usage. Finally, Citylink is charged an 'energy delivery charge' of $0.001745 per kWh, and an 'energy cost' of $0.12954 per kWh. These costs are recurring and are dependent on the amount of energy used by Citylink throughout the month.

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

Table 3 Utility Rates Structure Comparison

	Current MGS-S Rates	B-DCFC Rates
Customer Charge	$50.01 per month	$50.01 per month
Distribution Charge	$16.64 per non-coincidental peak kW (calculated monthly)	$4.39 per non-coincidental peak kW (calculated monthly)
Transmission Charge	$0.00 per non-coincidental peak kW (calculated monthly)	$19.35 per coincidental peak kW (calculated monthly)
Energy Delivery Charge	$0.001745 per kWh	$0.001745 per kWh
Energy Cost	$0.12954 per kWh	$0.12954 per kWh

Accordingly, a charging schedule was optimized around the operational plan developed in the previous section of the report and the above listed utility schedules. The results of this optimization are shown in Figure 3. It can be seen in the figure that the optimized charging schedule assumes buses will be charged overnight (between 9 PM and 5 AM), outside of the times when Citylink's buses are in-service, using the plug-in chargers. The optimized charging schedule also includes midday charging (at an assumed 200 kW power draw) using overhead fast chargers between 6 AM and 10 AM. This charging schedule avoids charging during the Central Maine Power grid's 'coincidental peak' (between 3 PM and 7 PM), which would allow Citylink to avoid a monthly 'transmission charge', should the agency decide to adopt the Central Maine Power's special optional 'B-DCFC' rate schedule for its charging operation.

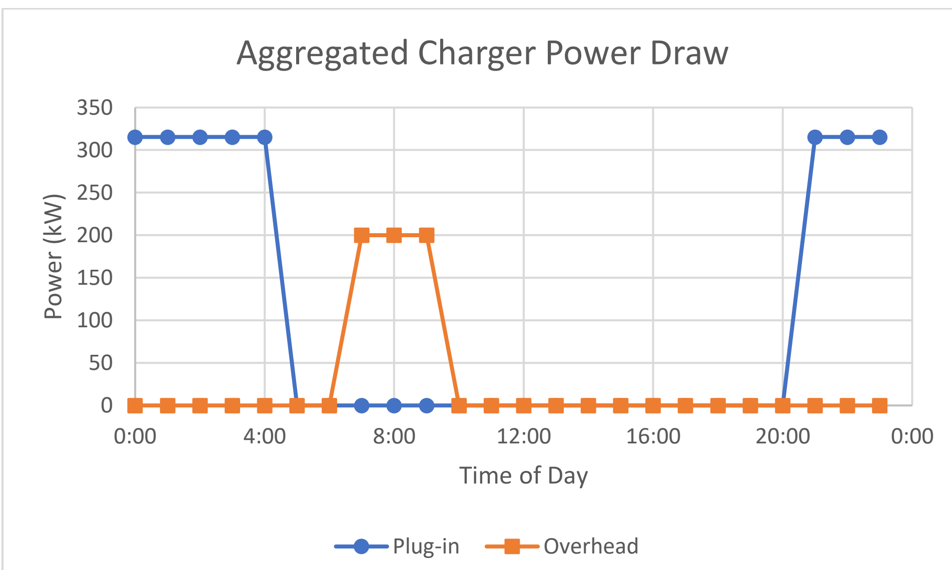

Figure 3 Proposed Charging Schedule for Citylink's Future Fleet

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

Daily kWh consumption = 2613 kWh

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

Under Current MGS-S Rate Structure:

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

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

Under New B-DCFC Rate Structure:

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

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

As this estimate shows, the optional ‘B-DCFC’ rate structure would save Citylink \$3,858.75 per month. These savings are, again, achieved by avoiding charging during the coincidental peak between 3 PM and 7 PM, and the reduced monthly ‘distribution’ charges under the “B-DCFC” rate structure. If the charging schedule were adjusted to charge during the coincidental peak, it could lead to an increase of up to \$6,095 per month from a ‘transmission charge’. Therefore, it is critical that Citylink only charges the buses, whether using plug-in or overhead pantograph, outside the coincidental peak window between 3 PM and 7 PM or procures a smart charging management system which is programmed to avoid charging during the coincidental peak. Furthermore, it is also important that Citylink monitors changes in Central Maine Power’s coincidental peak window and adjusts its charging schedule accordingly.

It should also be noted that the above charges are calculated based on a typical weekday load. Weekend and holiday calculation would follow a similar calculation for daily charges. The typical weekday and weekend/holiday charges are combined with monthly charges to calculate the annual utility cost for Citylink’s operation.

8. Asset Selection, Fleet Management and Transition Timeline

> ***Section Summary***
>
> - Hatch recommends ordering more 35’ buses to allow greater vendor competition
> - Hatch recommends installing decentralized chargers at the Oak St hub

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

As an additional complication, Citylink currently operates a mix of 29’ and 35’ buses. This is done to provide additional capacity on the busier routes (such as College Street) while minimizing inefficient use of larger vehicles on the less ridden routes (such as Minot Avenue). The drawback to this decision, in the context of electric buses, is that it may pose a constraint on the number of possible vendors. Many electric bus manufacturers (such as Proterra and New Flyer) do not offer a 29’ or 30’ bus, with the smallest available being 35’. The vendors that do (such as BYD) are likely to have more limited options, partly because of the smaller space available for batteries and partly because of the smaller market for 29’ / 30’ buses. Although the market is changing quickly, and within the next few years more 30’ models are likely to be introduced, Hatch recommends that Citylink consider shifting to a higher proportion of 35’ buses for greater flexibility in ordering. To maintain a fair comparison, however, this analysis assumes that the existing fleet will be replaced during its expected retirement year with the same bus length as operated now.

With respect to infrastructure procurements, the Oak St. parking lot will eventually need to have enough chargers to accommodate all of Citylink’s electric buses. Although the cost of one charger itself is more or less constant regardless of how many are being purchased, the additional costs such as utility feed upgrades, duct installation, structural modifications, and civil work make it economical to install all the support infrastructure at once. When additional electric buses arrive and more chargers are required, the only work that should be necessary is installation of the chargers themselves.

To serve the charging requirements described in the previous section for the proposed electric fleet, a decentralized charging architecture is recommended for the Oak St. parking lot.

Decentralized chargers will give Citylink the most flexibility in its charging operation by providing a minimum of 50kW per vehicle but allowing for charging power of up to 150 kW when other dispensers on the same charger are not in use. Because each charger typically has three dispensers, Citylink will require a minimum of three chargers (for a total of nine dispensers) to ensure there is a dedicated dispenser for each of its seven electric buses needed for pre-COVID peak service. A dedicated dispenser per vehicle allows overnight charging without requiring a staff member to move buses or plug in chargers overnight. This will also provide the recommended one or two spare dispensers to accommodate dispenser cable failures, "hot standby" buses, and possible future expansion. As discussed previously, this procurement schedule assumes that the pantograph charger at the Oak St. bus bays is procured several years after electric bus operation begins. As several Citylink blocks can be operated without layover charging, this delay will let Citylink staff gain operating experience and determine whether a layover charger is necessary or if, for example, battery technology has advanced quickly enough that it is no longer required. 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
2031	Three (two 35' electric 450kWh, one 30' electric 450kWh)	One 150kW de-centralized charger (three dispensers) + electrical upgrades and rough-ins for future charger installations (conduit runs, concrete pads, transformers, switchgears, etc.)	1901, 1902, 1904
2032			
2033			
2034	Three (one 35' electric 450kWh, two 30' electric 450kWh)	Two 150kW de-centralized chargers + one pantograph charger at Oak St. transit hub (if warranted)	2201 – 2203
2035	Three (three 35' electric 450kWh)		Pending replacements for 1101, 1102, 1401

Hatch recommends that the first (2031) order of electric buses is operated across all the routes. This experience will help Citylink understand electric bus operations and make any scheduling or routing adjustments that may be needed. As discussed above, the experience Citylink will gain will inform the decision on whether an enroute charger is required. Finally, spreading electric buses out across the network will ensure that the benefits of electric vehicles (elimination of tailpipe emissions, reduced noise, etc.) are distributed equitably across the city. This may also prove valuable from a Title VI perspective, particularly as city demographics continue to change over the coming years. Rotating the electric vehicles across the routes will ensure that no area is disproportionately negatively impacted by Citylink operations.

9. Building Spatial Capacity

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

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

Section Summary

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

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

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

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

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

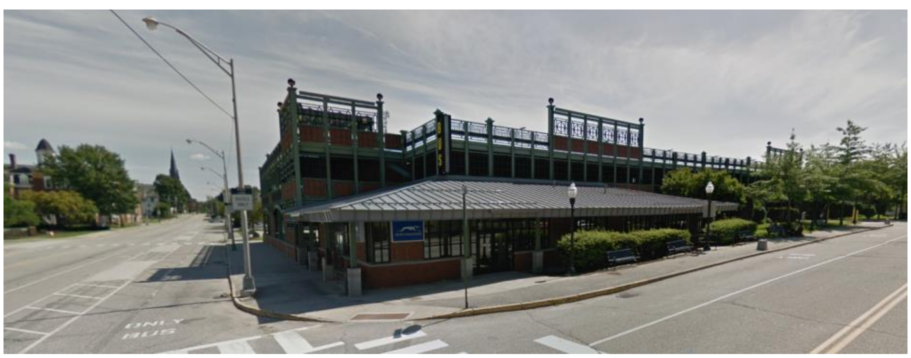

Figure 5 Oak St. Transit Hub (Source: Google Maps)

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

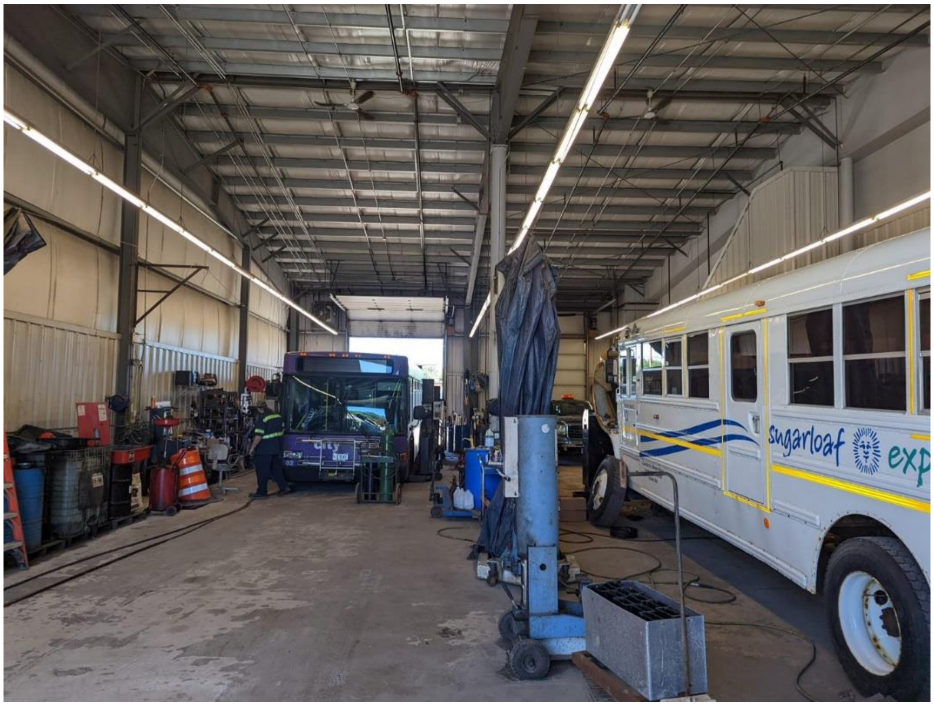

Figure 6 WMTS Facility Existing Maintenance Bay

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

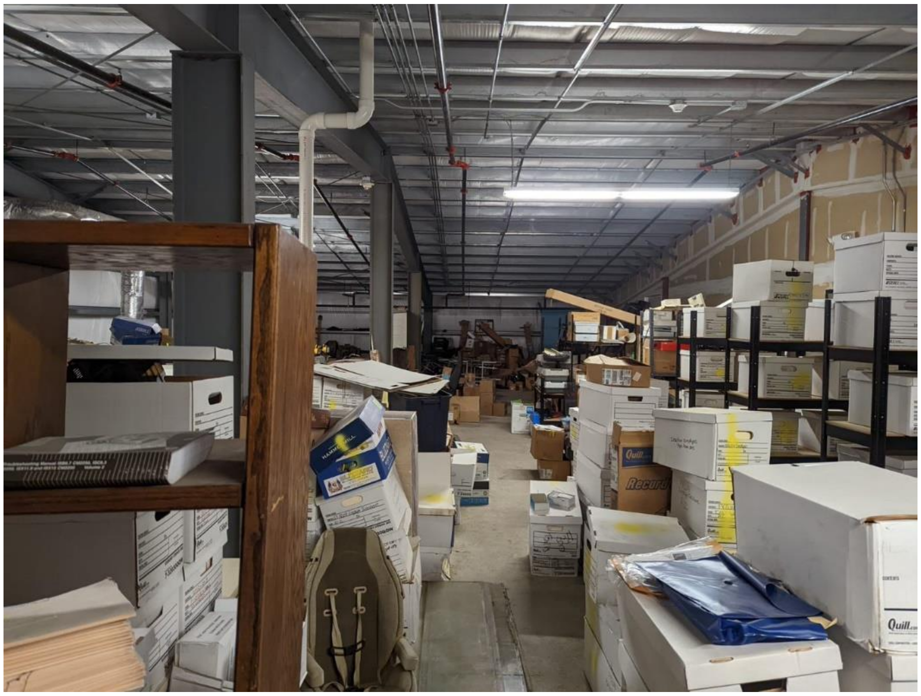

Figure 8 WMTS Facility Upstairs Storage Area (Potential Location for Backshop)

10. Electrical, Infrastructure, and Utility Capacity

Section Summary

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

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

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

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

Figure 9 Oak St. Municipal Parking Lot Electrical Distribution Assets

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

11. Risk Mitigation and Resiliency

Section Summary

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

Every new vehicle procurement brings about a certain degree of operational risk to the agency. Even when the existing fleet is being replaced 'in-kind' with new diesel buses, there are new technologies to contend with, potential build quality issues that must be uncovered, and maintenance best practices that can only be learned through experience with a particular vehicle. Bus electrification makes some failure modes impossible – for example by eliminating the diesel engine – but introduces others. For example, the ability to provide service becomes dependent on the continuous supply of electricity to the charging location. Understanding these risks and the best ways to mitigate them is key to successful electric bus operation.

11a. Technological and Operational Risk

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

- Technological robustness: By their nature as newer technology, many electric vehicles and chargers have not had the chance to stand the test of time. Although many industry vendors have extensive experience with diesel buses, and new vehicles are required to undergo Altoona testing, some of the new designs will inevitably have shortcomings in reliability.
- Battery performance: The battery duty cycle required for electric buses – intensive, cyclical use in all weather conditions – is demanding, and its long-term implications on battery performance are still being studied. Though manufacturers have recommended general principles like battery conditioning, diesel heater installation, and preferring lower power charging to short bursts of high power, best practices in bus charging and battery maintenance will become clearer in coming years.
- Supply availability: Compared with other types of vehicles, electric buses are particularly vulnerable to supply disruptions due to the small number of vendors and worldwide competition for battery raw materials such as lithium. As society increasingly shifts to electricity for an ever-broader range of needs, from heating to transportation, both the demand and the supply will need to expand and adapt.
- Lack of industry standards: Although the market has begun moving toward standardization in recent years – for example through the adoption of a uniform bus charging interface – there are many areas (e.g. battery and depot fire safety) in which best practices have not yet been developed. This may mean that infrastructure installed early may need to be upgraded later to remain compliant.
- Reliance on wayside infrastructure: Unlike diesel buses, which can refuel at any publicly fueling station, electric buses require DC fast chargers for overnight charging and specialized pantograph chargers for midday fast charging. Particularly early on, when there is not a widespread network of public fast chargers, this may pose an operating constraint in case of charger failure.
- Fire risk: The batteries on electric buses require special consideration from a fire risk perspective (see Section 12b).

All these risks are likely to be resolved as electric bus technology develops. Citylink is in a good position in this regard, as its fleet replacement timeline allows it to wait for the technology to mature before placing an order. Nevertheless, it will be prudent for Citylink to begin its transition to electric vehicles with an eye toward operating robustness in case of unexpected issues. Hatch recommends several strategies to maximize robustness:

+ Require the electric bus vendor to have a technician on site or nearby in case of problems. This is most economical when the technician is shared with several nearby agencies.
+ Reach a "mutual aid" agreement with WMTS, or another urban transit agency in Maine, that would let Citylink borrow spare buses in case of difficulties with its fleet
+ Retain diesel buses for at least two years after they are retired to ensure they can substitute for electric buses if any incidents or weather conditions require it
+ Work with the city of Lewiston to develop contingency plans in case the layover charger fails and midday use of the plug-in chargers is required (see Section 12).

11b. Electrical Resiliency

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

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

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

Table 5 Comparison of the resiliency options

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

11.b.1. Existing Conditions

The Oak St. facility currently does not have resilient systems in place that would be able to support battery electric bus operations should there be an electrical service interruption. This would mean that a prolonged power outage would deprive Citylink of the ability to operate service once it has transitioned to electric bus operations.

11.b.2. Outage Data and Resiliency Options

After noting no viable resiliency systems in place, Hatch assessed potential resiliency options. The first step in that assessment was to analyze the power outage data for the utility feeds that supply power to the Oak St. Parking lot to determine the requirements for backup power. There were only two outages at this location in the last five years (2017 and 2018). Of the two outages, the one in 2017 was insignificant and only lasted for two mins. The second outage that occurred in 2018 lasted for an hour and ten minutes. Appendix C shows the outage data provided by Central Maine Power for reference.

The resiliency system requirements are determined below based on the worst outage instance outlined above and the charging needs for the full fleet during this type of outage scenario. The on-site energy storage requirement to charge the fleet during that outage period would be 365 kWh. Assuming a 20% safety factor on top of the required energy, the size of the on-site energy storage system would need to be approximately 460 kWh. The power requirement for a generator was determined by the power draw of the number of chargers required to charge the peak service fleet of six vehicle. Assuming Citylink purchases the centralized chargers with three dispensers each, as recommended in this report, two chargers would be required to charge the fleet. Assuming that all chargers Citylink would purchase would be rated at a minimum 150kW, would have an efficiency of 90%, and a 20% spare capacity, the resulting on-site generation capacity required would be approximately 420 kVA.

Hatch next generated cost estimates associated with the two resiliency system options for the Oak St. Parking lot. Table 6 summarizes the approximate project cost for implementing each option. Note that as these are conceptual proposals on which no decision has been made, these costs are not included in the life cycle costs in Section 14.

Table 6 Resiliency Options for Worst Cast Outage Scenarios

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

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

11.b.3. Solar Power

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

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

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

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

Figure 10 Oak St. Municipal Garage Proposed Solar Array

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

Table 7 Oak Street Station Parking Garage

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

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

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

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

If solar is considered for the site, the on-site storage system should be sized according to the full solar production rather than to only support outage scenarios. A more detailed study should be conducted to determine the battery energy requirements, which are likely to be more than 365 kWh based on the above solar estimates.

12. Conceptual Infrastructure Design

12a. Conceptual Layouts

Section Summary

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

To assist Citylink with visualizing the required infrastructure transition, conceptual plans were next developed based on the previous information established in this report. As outlined previously, Hatch recommends that the charging infrastructure – for both enroute and overnight charging – be placed at the Oak St. transit hub / municipal parking lot in downtown Lewiston. As this is the property of the city of Lewiston rather than LATC / Citylink, municipal approval would be required.

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

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

Of these options, the overhead structure would allow the most layout flexibility, but would also be the most expensive, maintenance-intensive, and difficult to adapt for daytime use. The two ground-level alternatives would offer comparable utility; buses would be able to park adjacent to the dispensers to charge overnight, and cars would be able to use the same spaces to charge during the daytime (generating revenue for the city). Figure 11 and Figure 12 illustrate possible layouts for these two alternatives. Hatch recommends that the city of Lewiston selects the wall-mounted alternative, to minimize the capital and operational impacts of charger installation. Aside from the charging infrastructure itself, the city of Lewiston would also need to invest in security measures to deter overnight bus vandalism (such as fences, cameras, and lighting), install fire detection measures as outlined in Section 12b, and develop snow-clearing procedures to ensure that the plow operators clear the areas adjacent to the chargers without damaging the chargers themselves.

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

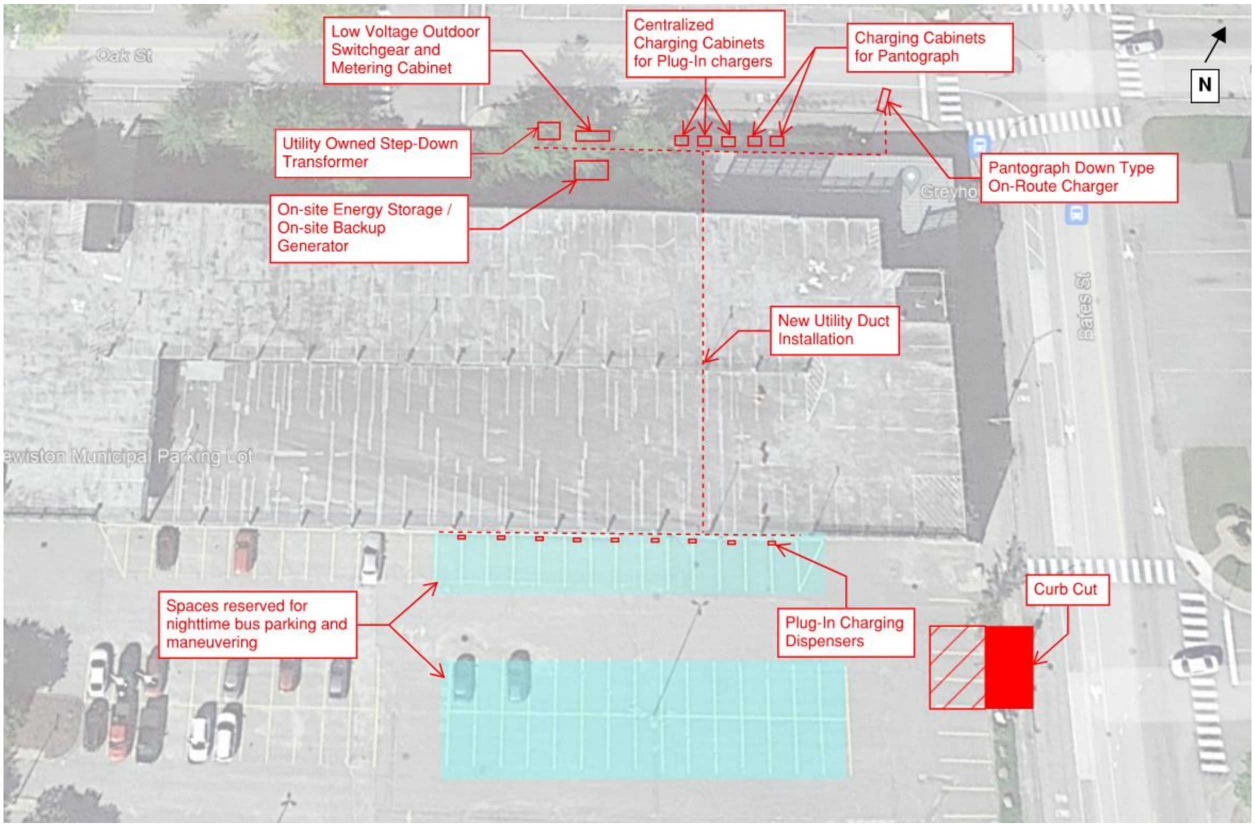

Figure 11 Wall-Mounted Charger Layout Option

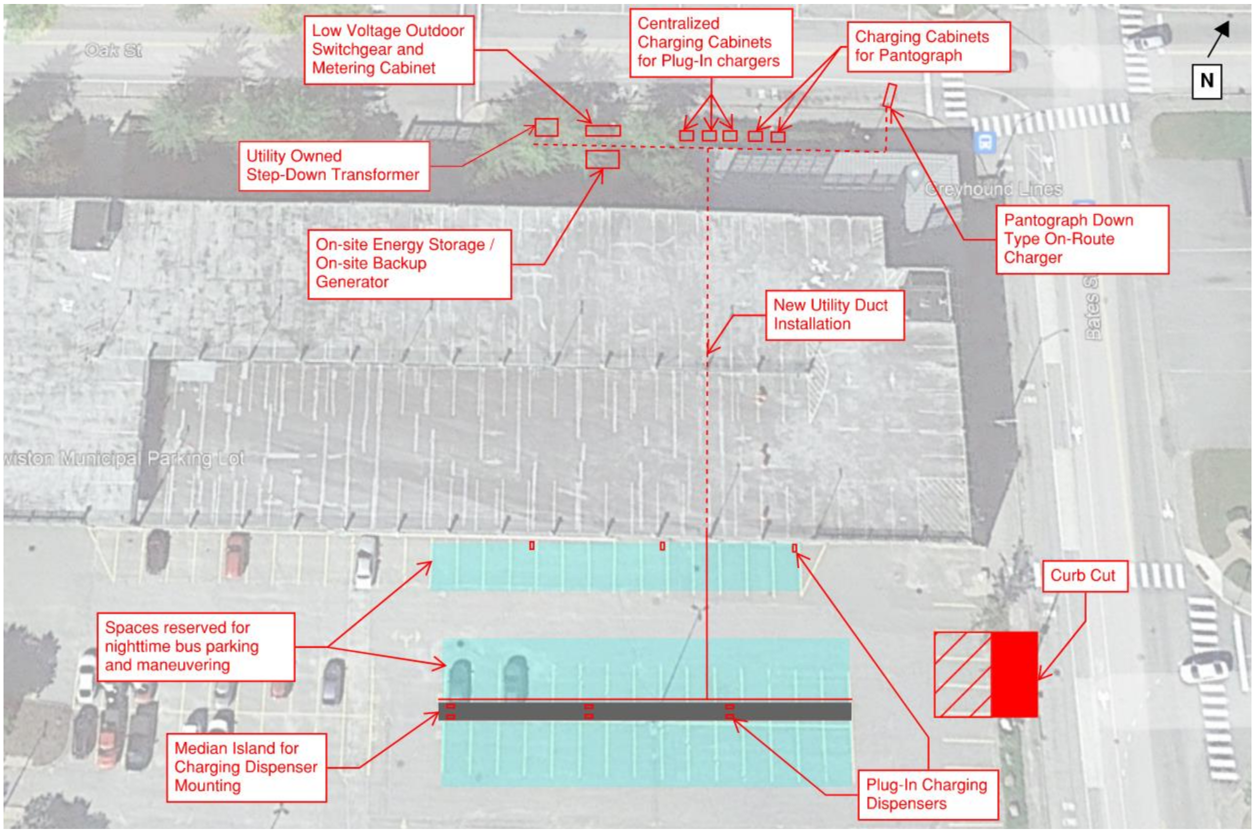

Figure 12 Mid-Lot Island Charger Layout Option

12b. Fire Mitigation

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

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

The infrastructure best practices for preventing fire spread with electric vehicles are still being developed. Although Citylink's risk is partially mitigated because the buses will be stored outdoors while charging, Hatch still recommends that Citylink monitor any development of standards for fire suppression and mitigation of facilities housing battery electric vehicles (which currently do not exist). There are partially relevant standards for the storage of high-capacity batteries indoors for backup power systems, such as UL9540, NFPA 70, and NFPA 230, and the primary components of any fire mitigation strategy are well understood. These include detectors for immediate discovery of a fire, sprinklers to extinguish it as much as possible, and barriers to prevent it from spreading to other buses or the adjacent garage structure. In terms of staffing, it is recommended that staff be located nearby to respond in case of a fire and move unaffected buses out of harm's way. Each of these requires specific consideration with respect to Citylink's operations; for example, the staff presence can likely be provided by appropriately trained personnel at the fire station across the street from Oak St. Hatch recommends that Citylink commission a fire safety study as part of detailed design work for the charger installation to consider these factors.

13. Policy Considerations and Resource Analysis

Section Summary

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

Citylink's current operating budget is roughly $2.0 million per year. The agency's funding sources are summarized in Figure 13. As can be seen in the figure, Citylink's largest source of funding comes from federal assistance. For bus, facility, and infrastructure costs the agency's primary federal funding comes from the Urbanized Area Formula Funding program (49 U.S.C. 5307), and the Buses and Bus Facilities Competitive Program (49 U.S.C. 5339(b)) through the FTA.

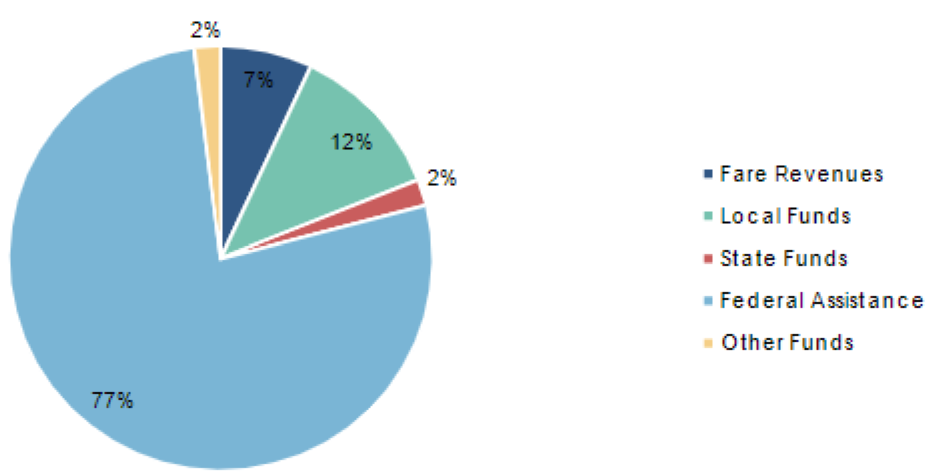

Figure 13 Current Agency Funding Summary (Source: MaineDOT)

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

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

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

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

Table 8 Policy and Resources Available to Citylink

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

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

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

14. Cost Analysis

Section Summary

- Bus electrification will save Citylink money over the long term, as electric vehicles cost less to maintain and fuel
- Upfront capital costs increase by approximately 45% and annual operating cost will decrease by approximately 10%, yielding a net 0.4% savings in total cost of ownership

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

Table 9: Life Cycle Cost Model Components

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

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

Capital Investment

- The lifespan of a bus is 12 years, in accordance with Citylink practice.
- Buses are overhauled at midlife. This is recommended for electric buses as the lifespan of a battery is approximately 6-7 years.
- Buses are replaced with buses of the same length, at their expected retirement year.

- Citylink will not pay for any capital investment at the WMTS facility, although it (or a comparable garage) will be used for vehicle maintenance.

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 Citylink'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' Battery Electric Transit Bus (225 kWh)	$782,000
30' Battery Electric Transit Bus (450 kWh)	$978,000
35' Diesel Transit Bus	$546,000
35' Battery Electric Transit Bus (225 kWh)	$813,000
35' Battery Electric Transit Bus (450 kWh)	$1,009,000
DC Fast Charger – Plug-in Garage (de-centralized unit and 3 dispensers)	$270,000
DC Fast Charger – Pantograph Overhead	$630,000

Expense	Estimated Cost (2022 $'s)
Diesel bus maintenance	$1.57 / mile
Electric bus maintenance	$1.18 / mile
Operator salary, benefits, overhead	$32.08 / hour
Diesel fuel	$3.15 / gallon

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

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

Table 11 and Figure 14 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	$1,744,671	$2,331,415	+45%
Infrastructure Capital Costs	$0	$194,913	
Vehicle Maintenance Costs	$2,448,611	$1,836,458	-10%
Infrastructure Maintenance Costs	$0	$45,847	
Operational Cost	$5,424,002	$5,173,873	
Total Life Cycle Cost	**$9,617,284**	**$9,582,507**	-0.4%

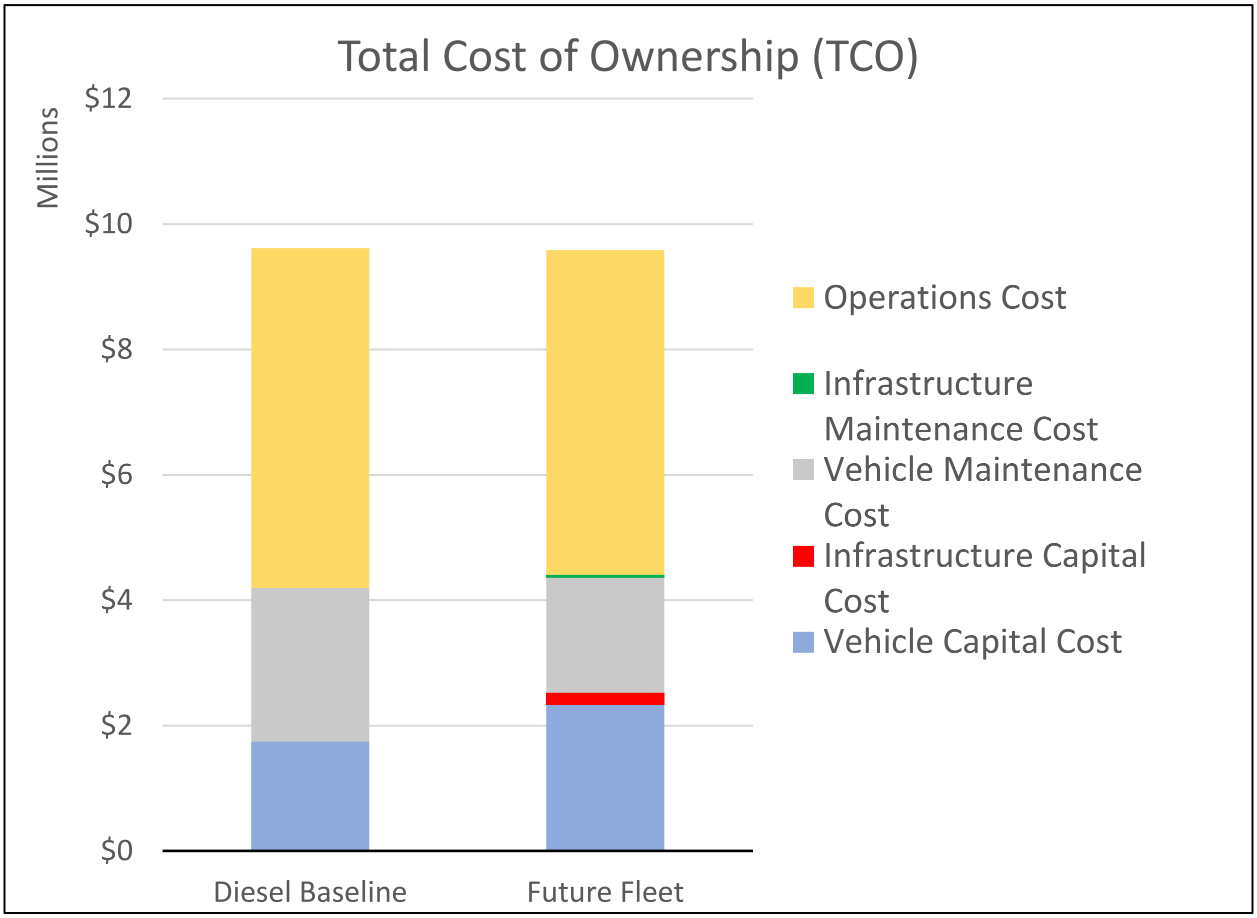

Figure 14 Life Cycle Cost Comparison

As shown in Figure 14, bus electrification reduces total system cost at the expense of increasing initial capital cost. Although there is some expense related to the charging equipment at Oak St., the bulk of the extra capital spending is on the vehicles themselves, as electric buses are much simpler mechanically than diesel buses but command a cost premium due to their large battery systems. This yields a 45% 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 10% lower than of the diesel baseline. However, these costs recur daily – worn parts must be replaced and empty fuel tanks must be refilled throughout the lifetime of the vehicle. This means that over the long term the operations and maintenance savings outweigh the initial extra capital spending, yielding a net-present-value savings of approximately 0.4%.

The proposed fleet transition requires initial capital spending to reduce life cycle cost and achieve other strategic goals. This finding is common to many transit projects and is representative of the transit industry as a whole, with nearly all bus and rail systems requiring capital investments up front to save money in other areas (traffic congestion, air pollution, etc.) and achieve broader societal benefits over the long term. By extension, just as with the transit industry at large, policy and financial commitment will be required from government leaders to achieve the desired benefits. The federal government's contribution to these goals via FTA and Low-No grants is already accounted for, leaving state and local leaders to cover the remaining 45% increase in upfront capital cost.

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

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

14a. Joint Procurements

The cost figures presented above assume that Citylink 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 Citylink.

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, Citylink expects to place three vehicle orders over the next 12 years. With five-year purchasing contracts, this number can be reduced to two, saving on many of the same per-order expenses outlined previously. These two factors are estimated to reduce Citylink'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.

Citylink plans to order 9 buses over the next 12 years, and these orders can easily be allocated to purchasing contracts. The 2031 order for 30' and 35' vehicles would be part of a 33-vehicle order shared with Bangor CC and Metro; and the 2034 and 2035 order can be part of a 49-vehicle order shared with Bangor CC, BSOOB, Downeast, Metro and South Portland Bus Service (SPBS).

In summary, although this analysis assumed that Citylink 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 29% cost saving for the agency.

15. Emissions Impacts

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

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

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

Section Summary

- Bus electrification will be critical to helping meet State emission goals
- Forecasted grid conversion to clean energy will maximize the benefit of bus electrification
- The transition is expected to reduce emissions by 77-88%

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

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

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

Battery electric vehicles have a third emissions source: grid electricity generation. The local utility, Central Maine Power, was not able to provide specific details on the emissions associated with its electricity production as part of this project. Therefore, the emissions calculations assumed an EPA and EIA average grid mix for Maine. Similar to the state's overall goals to reduce emissions, the state has also set the goal of reducing grid emissions by roughly 67% by 2030 by transitioning to more renewable energy production. To account for these future grid emissions reduction goals, calculations were completed based on the most recent actual data available (2020), as well as projections that assume that the 2030 targets are met. Table 12 and Figure 15 summarize the results of the emissions calculations. These results demonstrate that the transition plan will achieve 77% emissions reduction assuming the grid mix that existed in 2020, or 88% emissions reduction assuming that Central Maine Power is able to meet the state's goals to reduce grid emissions by the year 2030. In either case, Citylink's transition plan will achieve a reduction in emissions in excess of the 45% goal established by the State of Maine.

Table 12 CO_2 Emissions Estimate Results

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

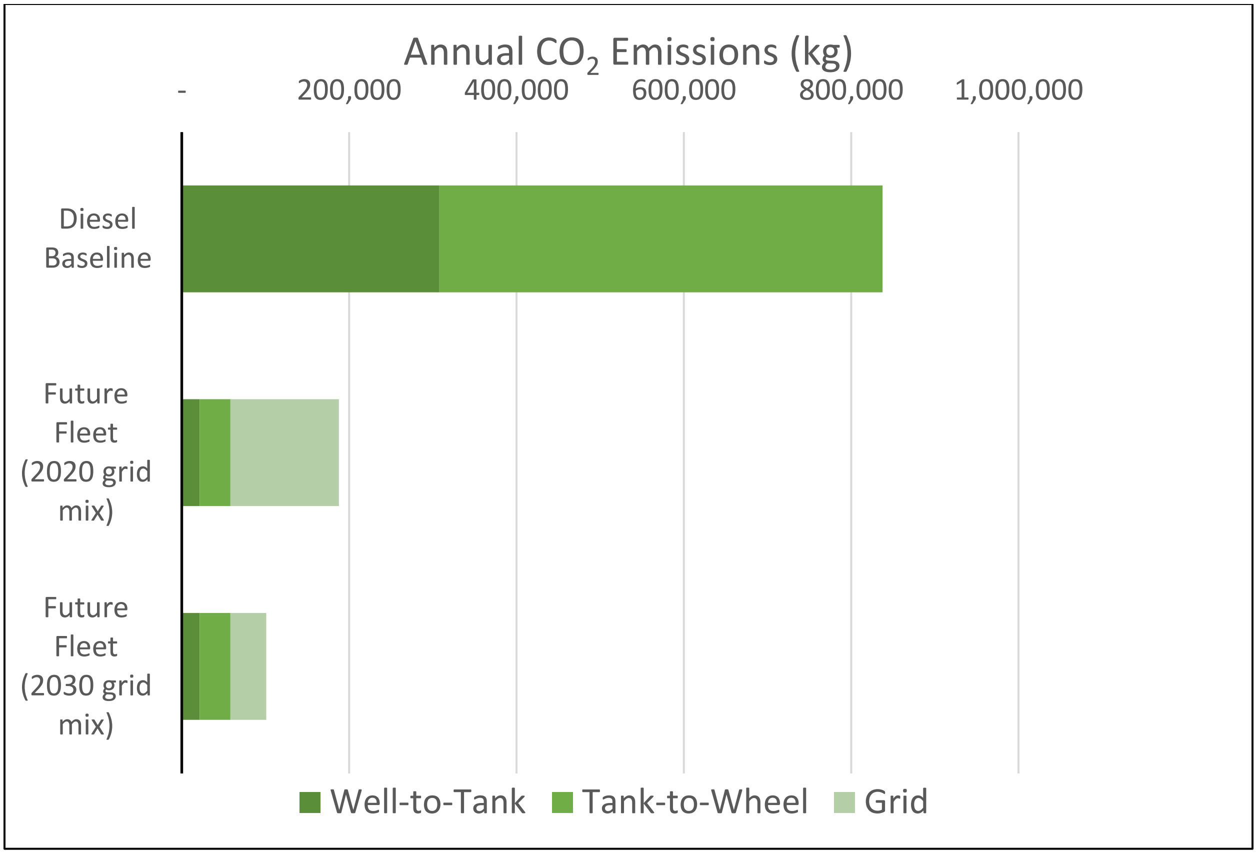

Figure 15 Graph of CO_2 Emissions Estimate Results

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

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

16. Workforce Assessment

WMTS staff currently operate a revenue fleet composed entirely of diesel vehicles. As a result, the staff have skill gaps related to battery electric vehicle and charging infrastructure technologies that will be operated in the future. To ensure that both existing and future staff members (whether at WMTS or elsewhere) can operate Citylink's future system a workforce assessment was conducted. Table 13 details skills gaps for the workforce groups within the agency and outlines training requirements to properly prepare the staff for future operations.

Section Summary

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

Table 13 Workforce Skill Gaps and Required Training

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

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

+ Add requirements to the operations contract for the system operator to train its staff on the safe operation and maintenance of electric vehicles.
+ Add requirements to vehicle and infrastructure specifications to require contractors to deliver training programs to meet identified skill gaps as part of capital projects.
+ Coordinate with other peer transit agencies, especially within the state of Maine, to transfer 'lessons learned'. Send staff to transit agency properties that have already deployed battery electric buses to learn about the technology.
+ Coordinate with local vocational and community colleges to learn about education programs applicable to battery electric technologies, similar to the one Southern Maine Community College recently introduced. If no nearby programs are available, consider partnering with a school to develop a curriculum.

As electric vehicles become increasingly widespread, contracted operators such as WMTS will likely take the initiative to train their own personnel on the new technology, both for electrification of services operated in-house and for increased competitiveness on procurements. In the long term, Hatch does not expect this new training requirement to limit LATC's ability to competitively bid out the Citylink operations and maintenance contract. As the electrification transition timeline approaches, it is recommended that Citylink partner with its contract operator at that time to begin training staff and other stakeholders on these technologies ahead of the delivery of the first vehicles and charging systems.

17. Alternative Transition Scenarios

As part of this study, Citylink was presented with alternative fleet and infrastructure transition scenarios that would also satisfy the agency's operational requirements. These alternatives considered other vehicle battery configurations, different fleet sizes, other

Section Summary

- Hatch recommends reviewing this report annually for comparison with technology development and Citylink operations charging locations, and different operational plans. Through discussions, however, Citylink currently favors the transition plan presented in this report. Details on the alternative plans are presented in Appendix B and D. Should Citylink's plans or circumstances change in the future, it is possible that one of the alternative transition plans presented may become more advantageous. Hatch recommends that Citylink review this transition plan on an annual basis to reevaluate the assumptions and decisions made at the time this report was authored.

18. Recommendations and Next Steps

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

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

- Proceed with transitioning the agency's buses and infrastructure in the manner described in this report.
- For the vehicles:
    - Consider ordering buses as part of larger orders or partnering with other agencies or the DOT to form large joint procurements. In particular, consider combining the procurements in 2034 and 2035.
    - Consider shifting to a higher proportion of 35' buses to increase competition on future vehicle procurements.
    - Before or as part of the first electric bus order, conduct a pilot program with a small number of electric buses to test the technology and validate the results of the analyses presented in this transition plan. During this pilot program, operate the electric buses on all routes.
    - Require the electric bus vendor to have a technician on site or nearby in case of problems. This is most economical when the technician is shared with several nearby agencies.
    - Develop specifications for battery electric buses.
    - Reach a "mutual aid" agreement with WMTS, or another urban transit agency in Maine, that would let Citylink borrow spare buses in case of difficulties with its fleet.
    - Retain diesel buses for at least two years after they are retired to ensure they can substitute for electric buses if any incidents or weather conditions require it.
- For the infrastructure at Oak St.:
    - Coordinate with the city of Lewiston on required upgrades to the Oak St. lot.

    - Upgrade the electrical utilities to support charging infrastructure.
    - Conduct a fire safety analysis in accordance with Section 12b and standards UL9540, NFPA 70 and 230.
    - Consider omitting the Oak St. layover charger, should early procurements and operations perform acceptably.
    - Develop specifications for chargers and other required infrastructure.
    - Work with the city of Lewiston to develop contingency plans in case the layover charger fails and midday use of the plug-in chargers is required (see Section 12).
    - Conduct a study with the city of Lewiston to predict revenue from public daytime use of the chargers at Oak St.
- For other components of the transition:
    - Work with WMTS to plan for staff training programs, as described in Section 16.
    - Coordinate transition efforts with peer transit agencies, CMP, and Maine DOT.
    - Continually monitor utility structures and peak charge rates and adjust charging schedules accordingly.
    - Develop a funding strategy to account for the 45% increase in capital expenditure.
    - Review this transition plan annually to update based on current assumptions, plans, and conditions.

Appendices

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