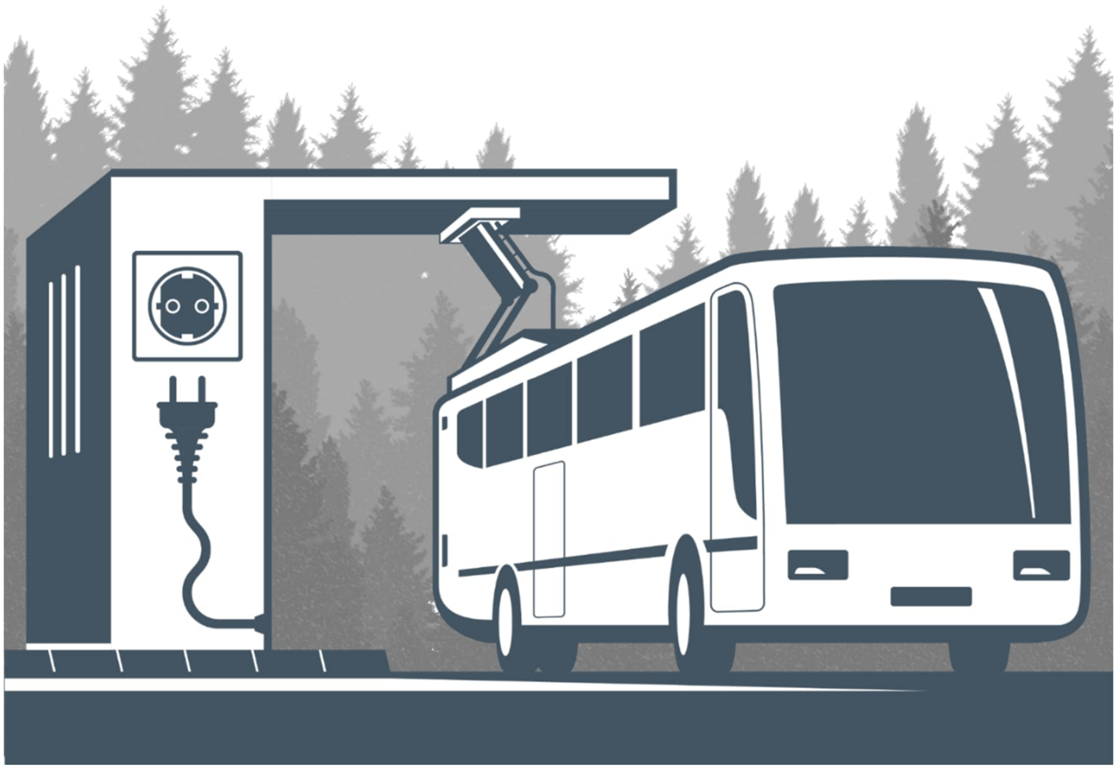

Vehicle Electrification Transition Plan for Western Maine Transportation Services (WMTS)

Western Maine Transportation Services

Prepared by:

HATCH

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Table of Contents

1. Executive Summary ... 3
2. Introduction ... 4
3. Existing Conditions ... 4
4. Vehicle Technology Options ... 5
5. Infrastructure Technology Options ... 7
6. Route Planning and Operations ... 8
6a. Operational Simulation ... 9
6b. Operational Alternatives ... 11
7. Charging Schedule and Utility Rates ... 12
8. Asset Selection, Fleet Management, and Transition Timeline ... 13
9. Building Spatial Capacity ... 16
10. Electrical, Infrastructure, and Utility Capacity ... 17
11. Risk Mitigation and Resiliency ... 18
11a. Technological and Operational Risk ... 18
11b. Electrical Resiliency ... 20
12. Conceptual Infrastructure Design ... 20
12a. Conceptual Layouts ... 20
12b. Fire Mitigation ... 21
13. Policy Considerations and Resource Analysis ... 22
14. Cost Considerations ... 27
15. Emissions Impacts ... 30
16. Workforce Assessment ... 32
17. Alternative Transition Scenarios ... 33
18. Recommendations and Next Steps ... 33

1. Executive Summary

Western Maine Transportation Services (WMTS), a nonprofit organization providing transit service in Androscoggin, Franklin, Cumberland, Sagadahoc, and Oxford Counties in Maine, is currently considering transitioning its bus and van 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, WMTS 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 50 vehicles, replacing twelve fixed-route and demand-response vehicles with EVs. Because of the limited range of today's electric vehicles and the limited supply of hybrid vehicle vendors in the van and cutaway market, the remainder of the fleet is assumed to remain diesel powered for the foreseeable future. To support the battery electric vehicles, the agency also plans to fund the procurement, installation, and commissioning of DC fast and level 2 chargers at five locations across its network. These chargers will have the capacity to support midday and overnight charging of the electric fleet.

One of the primary motivations behind WMTS's transition to battery electric drivetrain technologies is to achieve emissions reductions compared to its existing fossil fuel operations. As part of this analysis, an emissions projection was generated for the proposed future fossil fuel and battery electric fleet. The results of this emissions projection estimate that the new fleet will provide up to a 9% reduction in emissions compared to WMTS's existing fossil fuel operations. This reduction in emissions will be accompanied by a 1% reduction in lifecycle costs, albeit with a 49% increase in upfront capital spending.

The conclusion of the analysis is that although battery electric vehicles are not yet ready for complete replacement of WMTS's fleet, the agency would benefit from beginning the transition with a small pilot. These vehicles offer the potential for the agency to reduce emissions, though some upfront capital spending will be required, and gain the required skillsets and operating experience for future electrification once the technology advances further. Therefore, WMTS 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 State of Maine's Roadmap and the FTA requirements, the Western Maine Transportation Services (WMTS) in association with the Maine Department of Transportation (MaineDOT) and its consultant Hatch, have developed this fleet transition plan. In addition to the FTA requirements, this transition plan also addresses details on WMTS's future route plans, vehicle technology options, building electrical capacity, emissions impacts, resiliency, and financial implications.

3. Existing Conditions

WMTS is a transit agency providing fixed- route and demand-response services throughout Androscoggin, Franklin, and Oxford Counties in Maine. The agency currently owns and operates a fleet of 50 passenger vehicles of different types, as shown in Table 1, all of which are fossil fuel powered.

Section Summary

- WMTS operates fixed-route and on-demand services with a 50 vehicle fleet and volunteer drivers' vehicles.
- Mileage of on-demand service vehicles varies widely, complicating EV transition planning.

Table 1 Current Vehicle Roster

Vehicle Type	Average Fuel Efficiency (MPG)	# of Vehicles	Nominal Useful Life
Ford F550	8.7	20	5 years
Ford E-450	7.1	21	5 years
Chevrolet Express 4500	8.5	3	5 years
Dodge Caravan with ramp	17.3	2	5 years
International School bus	7.0	1	10 years
International Thomas bus	7.0	2	10 years
Dodge Caravan	15.7	1	5 years

Fixed Routes

WMTS's fixed services consist of eight different routes. The vehicles for these routes are parked at WMTS headquarters in Auburn, Farmington Public Works in Farmington, Labonaville in Mexico, Mid Coast Hospital Parkview in Brunswick, Lisbon Public Works in Lisbon, and Bath Public Works in Bath.

- Blueline Express and Blueline Commuter
  - Connecting Lewiston, Lisbon Falls and Bath Iron works.
  - Express and Commuter are each operated with one cutaway vehicle.
- Greenline
  - Connecting Farmington to Lewiston.
  - Operated with two cutaway vehicles.
- Greenline Connector
  - Connects Rumford to Livermore.
  - Operated by one cutaway vehicle.
- Brunswick
  - Operated in Brunswick, Maine with three cutaway vehicles.
- Lisbon Connection
  - Service between Lisbon and Lewiston, operated with one cutaway vehicle.
- Bath City Bus
  - The Bath City Bus consists of a North Loop and a South Loop in Bath, Maine. The service is operated with three cutaway vehicles.

On-Demand Services

- B-link ADA
  - Services in both Bath and Brunswick between 6:30 am and 6:30 pm.
  - Operated with two vans.
- Lewiston/Auburn and L/A Worx Link
  - Services are available for approximately 18 hours a day and can be covered with any of the cutaway vehicles available.
- Oxford

  - Operates from 6 am – 3 pm
  - Typically operated with one cutaway vehicle which is kept at the driver's house in Buckfield
- Farmington
  - Operated from 6 am – 4:30 pm
  - Typically operated with three cutaway vehicles

Seasonal Routes

- Mountain Explorer and Sugarloaf Explorer
  - These are seasonal operations consisting of nine different routes.
  - Operated with a fleet of 22 cutaways and school buses.

4. Vehicle Technology Options

Section Summary

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

As discussed in Section 3, WMTS's revenue service fleet is composed primarily of wheelchair lift minibuses (cutaways) and vans, with some school buses. All three categories of electric vehicles may have limitations that the fossil fuel versions do not have. For example, because of the weight of the battery, one vendor's electric van can accommodate eight ambulatory passengers and only one wheelchair (as opposed to two on a fossil fuel van) while staying under Gross Vehicle Weight Rating (GVWR) limits. Shifting from an electric cutaway vehicle or school bus (shown in Figure 1 and Figure 2) to 30' transit buses would potentially allow greater operating range and passenger capacity; however, such a shift would have cost and maintenance implications for an agency like WMTS. In general, though, Hatch recommends that WMTS consider a broad range of vehicles in its future procurements, enabling maximum competition and potentially lowering cost.

Figure 1 Electric Cutaway Vehicle

Figure 2 Electric School Bus

There are not any hybrid cutaways, vans or school buses currently available in the US market. There are, however, a number of battery electric vehicles that are similar to what WMTS operates currently. For battery electric vehicles, battery capacity can be adjusted on many commercially available vehicle platforms to provide varying driving range. For this study, battery electric cutaways were assumed to have 125 and 160 kWh battery capacity, vans to have a 118 and 85kWh battery capacity and school buses to have 246 kWh battery capacity, which are representative values for the range of batteries offered by the industry.

5. Infrastructure Technology Options

There are two primary types of chargers that are applicable to WMTS's fleet – level 2 chargers, which are common in consumer applications, and DC fast chargers (level 3), most often applied toward heavier-duty vehicles and for faster charging. These differ in several key respects, primarily the type of power supplied.

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

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

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

DC fast chargers, which typically provide up to 80 kW of power for light- and medium-duty vehicles but can provide up to 450 kW for heavy-duty applications, typically come in two types of configurations:

1. Centralized

2. De-centralized

A de-centralized charger is a self-contained unit that allows for the charging of one vehicle per charger. The charging dispenser is typically built into the charging cabinet. In contrast, in a centralized configuration, a single high-power charger can charge multiple vehicles through separate dispensers. The power is assigned to the dispensers dynamically based on the number of vehicles that are charging at the same time. An example of a centralized charging system is shown in Figure 4.

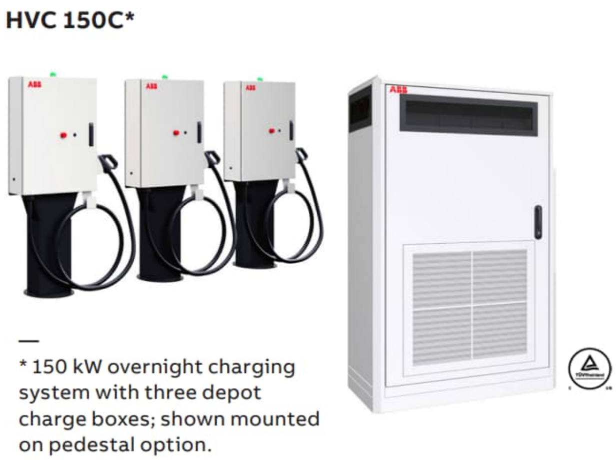

Figure 4 Example Charging Systems (Source: ABB): Charging Cabinet (System) and Three Dispensers (Charge Boxes)

6. Route Planning and Operations

Section Summary

- Electric vehicles do not offer comparable operating range to fossil fuel vehicles – so detailed operations modeling is needed.
- Shorter on-demand service runs can be electrified with available electric vans and cutaways.

WMTS's current operating model is similar to that of many transit agencies across the country. Each vehicle leaves the garage (or driver's home) at the appropriate time in the morning, operates nearly continuously for as long as necessary, and then returns to the depot / overnight parking location. Although WMTS's schedulers must account for driver-related constraints such as maximum shift lengths and breaks, the vehicles are assumed to operate for as long as they are needed. This assumption will remain true for hybrid vehicles, which have comparable range to fossil fuel vehicles, but may not always be valid for electric vehicles, which have reduced range, particularly in winter months. (Vans and cutaway shuttles typically do not have auxiliary heaters to reduce the power required for heating, like transit buses; in addition, icy road conditions and cold temperatures degrade electric vehicle performance in the winter).

Therefore, battery electric vehicles may not provide adequate range for a full day of service, year-round, particularly if recommended practices like pre-conditioning the vehicle before leaving the garage are not always followed.

WMTS's paratransit vehicles operate nearly continuously on an on-demand basis for the majority of the day, without long down-times between pick-ups. Therefore, to avoid significant impacts to operations, the electric demand-response vehicles will need to have enough range for a full day of service with minimal top-up charging. Another potential issue is that in some cases, WMTS vehicles are parked overnight at the drivers' home to avoid lengthy deadheads to the depot. Doing so with electric vehicles would pose challenges with charging compatibility and reimbursement and is best avoided, at least in the short term.

6a. Operational Simulation

To assess how battery electric vehicles' range limitations may affect WMTS'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 WMTS's operations. As mentioned above, it was not necessary to simulate hybrid operations because there are no hybrid vehicles currently available in the market, and even if there were they would offer the same range as the existing internal combustion fleet.

Hatch conducted a route-specific electric vehicle analysis for many agencies in Maine by generating drive cycles. The full geography (horizontal and vertical alignment), transit infrastructure (location of key stops), road conditions (vehicle congestion, as well as traffic lights, stop signs, crosswalks, etc.), and use of the wheelchair lift were modeled, and the performance of the vehicle was simulated in worst-case weather conditions (cold winter) to create a drive cycle. The most appropriate drive cycle previously generated by Hatch for Portland Metro, Bangor Community Connector, Citylink, and Downeast Transportation, Inc. was used to calculate energy consumption per mile for each WMTS service based on average speed, geography, and topography data.

As discussed in the previous section, the resultant runs were evaluated against a common electric cutaway with 125 or 160 kWh battery capacity, a van with 85 or 118 kWh, and a school bus with 246 kWh battery capacity. Two types of safety margins were subtracted from the nominal battery capacities of the vehicles. First, the battery was assumed to be six years old (i.e. shortly before its expected replacement). As batteries degrade over time, their capacity decreases. To account for this, the battery capacity was reduced by 20%. Second, the vehicle was assumed to need to return to the garage before its level of charge falls below 20%. This is both a manufacturer's recommendation – batteries have a longer life if they are not discharged to 0% – and an operational safety buffer to prevent dead vehicles from becoming stranded on the road. Combining these two reduction factors yields a usable battery capacity of 64% of the nominal value (80 and 102 kWh for the cutaways, 76.8 and 54.4 kWh for the vans and 157 kWh for the school bus). Finally, as the industry is advancing quickly and technology continues to improve, a 3% yearly improvement in battery capacity was assumed.

Table 2 below presents the expected worst-weather performance on an EV on each of WMTS's routes. Red cells denote services that are currently not feasible for conversion to electric vehicles, yellow denotes fixed routes that are recommend for conversion with on-route charging and demand-response routes where the average mileage can be served with an EV, and green denotes fixed routes feasible for conversion with no on-route charging required.

Table 2 Vehicle Range

Block	Mileage	Vehicle Class	EV Range (miles)	Mileage Shortage/Excess
Blueline Commuter	210	125 kWh cutaway	59	-151
Greenline Connector	255	125 kWh cutaway	59	-196
Greenline	387	125 kWh cutaway	65	-322
Blueline Express	195	125 kWh cutaway	59	-136
Brunswick 1	160	125 kWh cutaway	45	-115
Brunswick 2	135	125 kWh cutaway	45	-90
Lisbon Connection	135-170	125 kWh cutaway	55	-80 to -115
Bath 1	78	125 kWh cutaway	55	-23
Bath 2	85	125 kWh cutaway	55	-30
Sugarloaf 1	74	125 kWh cutaway	50	-24
Sugarloaf 2	120	125 kWh cutaway	62	-58
Sugarloaf 3+4	68	125 kWh cutaway	56	-12
Sugarloaf 5+5A	99	125 kWh cutaway	56	-33
Sugarloaf 6	41	125 kWh cutaway	50	9
Sugarloaf 7	114	125 kWh cutaway	50	-64
Sugarloaf 7A	72	125 kWh cutaway	50	22
Sugarloaf 8	46	125 kWh cutaway	70	-24
Sugarloaf 9	142	125 kWh cutaway	62	-80
Mountain Explorer 1	265	125 kWh cutaway	51	-214
Mountain Explorer 2	120	125 kWh cutaway	51	-69
Mountain Explorer Gould	60	125 kWh cutaway	51	-9
Mountain Express	280	125 kWh cutaway	51	-229
Paratransit				
Lewiston-Auburn	86 (24-200)	125 kWh cutaway	58	--132
L/A Worx	49 (10-79)	125 kWh cutaway	58	-21
Oxford	97 (19-137)	125 kWh cutaway	58	-79
Farmington	131 (11-220)	125 kWh cutaway	71	-149
B-link ADA	29 (10-61)	85 kWh van	53	-8

The EVs simulated as part of this study were based on vehicles available on the market as of this writing; further procurements will be governed by the performance of the initial vehicles. If battery electric technology advances faster than anticipated, or if the existing fleet proves reliable and can outlast its 7-year lifespan, more demand-response service will be available for electrification. Conversely, if technology develops more slowly or the existing fleet requires replacement sooner, a pilot deployment may remain the practical limit for the foreseeable future.

6b. Operational Alternatives

As shown in Table 2, the vast majority of WMTS runs cannot be operated by an electric vehicle without operational changes. Although the vehicles will be able to travel significantly further than the specified ranges during most conditions, as discussed above, the resulting operating plan must remain achievable during all seasons and weather conditions. Accordingly, below are several strategies for operating electric vehicles with range limitations most effectively.

The first is to recharge the vehicle periodically (e.g. during a layover or lunch break) using a fast charger. For fixed-route vehicles, this would be achieved during already-scheduled or additional layovers, assuming that on-time performance is sufficient to allow the charging time to be reliably achieved. For demand-response vehicles, approximately one hour of charging time during a lunch break is most practical. Though these options may require introducing additional vehicle downtime, a well-optimized daily schedule could combine vehicle charging time and driver meal break time, maximizing efficiency. The chargers would need to be located near the vehicle's location to minimize deadheading. Therefore, this analysis recommends installation of chargers at the Bath Public Works facility (to support Bath City Bus vehicles), the Brunswick train station (for Brunswick area fixed-route and demand-response service), the Lisbon Public Works facility (for the Lisbon Connection vehicles), and the Sugarloaf maintenance building, as well as a small charger for maintenance use at the main WMTS depot in Auburn.

Another possible service pattern is to revise and interline the timetables of different routes, for example the Green Line, Blue Line, and Lisbon Connection routes at Lewiston/Auburn, to swap freshly charged vehicles between routes and allow other vehicles to be sent to the depot for charging. For example, a bus could return to the depot after a Green Line trip, charge for approximately an hour to replenish its battery, then enter Blue Line service while the vehicle previously serving that route begins charging. Although this strategy would minimize the number of additional vehicles and chargers required for full electrification, it would complicate operations and would require changes to passenger-facing schedules, which are largely beyond the scope of this study. Therefore, although WMTS is encouraged to consider this strategy for further electrification, it is not analyzed further here.

A third option involves using a transit bus rather than a cutaway vehicle. Because transit buses have more room for batteries on the roof and under the floor, they typically have longer range than cutaway vehicles. In this case, a transit-style bus would likely be able to operate for the majority of the day before needing to recharge. Adopting a transit bus would also allow WMTS to increase capacity on its services. However, transit buses are significantly more expensive than cutaways, are less maneuverable on narrow streets, and would require additional training for WMTS staff to operate and maintain. Further, given the recent elimination of fixed-route service, transit buses are likely too large a vehicle for WMTS's demand-response operations. Because of these drawbacks, this option is currently not being considered.

Hybrid vehicles would provide a good balance between the advantages of lower-emission vehicles and the range required for longer routes. Operations would be able to remain exactly as they are today, since hybrid vehicles have comparable range to fossil fuel-powered ones. Unfortunately, as of this writing there are no hybrid vans or cutaways available on the market. Hatch recommends that WMTS continue to monitor the industry to determine if a new vendor enters the market, as hybrid vehicles would substantially reduce WMTS's carbon emissions without posing challenges with vehicle range.

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 WMTS charge its vehicles economically.

For WMTS's pilot operations, Hatch recommends installing one DC fast (80 kW) and one level 2 (19.2 kW) charger at the Bath Public Works facility, one DC fast and one level 2 charger at Brunswick train station, one DC fast charger in Lisbon, and two level 2 chargers at the Sugarloaf maintenance depot. As mentioned previously, the main WMTS facility in Auburn will also need a level 2 maintenance charger to test and repair the new electric vehicles. This draws a balance between the advantages of lower-power charging (reduced capital cost, longer battery lifespan) and the requirements of keeping vehicles operating all day with short lunch breaks for recharging.

Developing a charging schedule for the proposed charger installations is recommended practice while developing a transition plan as charging logistics can have significant effects on fleet operations and costs incurred by the agency. From an operational perspective, charging vehicles during regular service hours introduces operational complexity by requiring a minimum downtime for charging that – unlike a driver lunch break – cannot be deferred or relocated. WMTS's operating practices and fleet composition dictate that vehicles will be charged only overnight, with the exception of once-daily mid-day charge windows to prolong range.

WMTS's current electricity rates are determined by Central Maine Power's 'MGS-S' rate table, as shown in Table 3. Under this rate table WMTS pays a flat "service charge" monthly, regardless of usage. WMTS also pays a single demand charge per kW for the single highest power draw (kW) that occurs during each month. Finally, WMTS is charged a recurring 'kWh charge' dependent on the amount of energy used throughout the month.

To discourage demand during times when the utility experiences highest demand, CMP also offers an 'MGS-S-TOU' (time-of-use) rate. As shown in Table 3, demand charges are adjusted depending on the time of day, with peak periods (7am-12pm and 4pm-8pm, weekdays) incurring the highest charges, shoulder periods (12pm-4pm, weekdays, as well as 7am-12pm and 4pm-8pm on winter weekends) incurring lesser charges, and off peak periods (other times) incurring no charges. Accordingly, if using the TOU rate, it is in WMTS's best interest to minimize the amount of electricity used during peak times.

Table 3 Utility Rates Structure Comparison

	Current MGS-S Rates, per Month	MGS-S-TOU Rates, per Month
Service Charge (three-phase)	$297.90	$271.62
Demand Charge (July-August)	$15.79/kW	$12.49/kW (peak) $4.15/kW (shoulder) $0.00/kW (off-peak)
Demand Charge (September-June)	$14.55/kW	$11.80/kW (peak) $3.46/kW (shoulder) $0.00/kW (off-peak)
kWh Charge	$0.011418/kWh	$0.011418/kWh

8. Asset Selection, Fleet Management, and Transition Timeline

Section Summary

- Hatch recommends procuring twelve electric vehicles to replace a quarter of WMTS's fleet on a one-for-one basis, with the remainder of the fleet being diesel-powered.
- Hatch recommends installing chargers at five locations to support this EV deployment.

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

As an additional complication, WMTS currently operates a mix of cutaways, vans, and school buses across its services. The market in these vehicle classes is small, and most manufacturers do not offer electric versions; the vendors that do often have range, passenger capacity, or vehicle availability limitations. Although alternatives like 30' transit buses are more expensive and require significant maintenance skills, keeping a wide range of options open will help WMTS procure vehicles as efficiently as possible. To maintain a fair comparison, however, this analysis assumes that the existing fleet will be replaced approximately as expected by WMTS with vehicles of the same class (either cutaways, vans, or school buses, as appropriate).

With respect to infrastructure procurements, choosing suitable locations for the chargers is critical to optimizing EV operation. WMTS's broadly distributed route network, and common use of third-party overnight vehicle storage locations, complicates this selection. Charger installation at a WMTS-owned location – such as the main depot in Auburn – would make installation and funding much simpler. However, because the fixed-route vehicles stored overnight in Lewiston/Auburn are scheduled for very long blocks, for a pilot project it may be most feasible to convert vehicles stored at other locations first, and to use the results of this pilot as input for the design of eventual conversion of the WMTS facility for full electrification. In the meantime, to install chargers at third party locations, the agency would either need to obtain an easement to install the chargers directly, or would need to reach an agreement with the property owner for installation and maintenance of the chargers on its behalf.

As a collection of small charger installations, with few immediate next steps for further electrification at those locations, the project can proceed without many of the future-proofing mitigations (spare conduits, oversized transformers, etc.) typically recommended for larger facilities. For example, although the cost of one charger itself is more or less constant regardless of how many are being purchased, the additional costs such as utility feed upgrades, duct connections, structural modifications, and civil work make it economical to install all the support infrastructure at once if larger deployments are expected in the near future. However, as they are not, keeping the project scope small will help reduce cost and complexity, with the possible drawback of requiring additional investment when more of WMTS's fleet is electrified. A detailed engineering design will be required to develop an accurate estimate of the costs.

As discussed earlier, Hatch recommends installing a mix of DC fast and level 2 chargers in Bath, Brunswick, Lisbon, Carrabassett Valley, and Auburn. The number of chargers at each location is generally equal to the number of electric vehicles charging there for the first-stage EV deployment. Some agencies prefer installing additional chargers to provide spare capacity and allow for charger maintenance outages; given the number of locations in the pilot deployment, this additional expense would likely not be justified. If the pilot is successful and WMTS pursues further vehicle electrification, a more detailed planning study would be needed to determine the correct number of charger redundancy, ensuring that some spares are available for resiliency while avoiding over-investment in infrastructure. Table 4 provides a summary of the proposed vehicle and infrastructure procurement schedule for the first pilot phase:

Table 4 Proposed Fleet and Charging System Transition Schedule

Year	Vehicles Procured	Infrastructure Procured
2025	11 (3 Electric Vans, 1 Diesel School Bus, 7 Electric Cutaways)	3 80 kW DC fast chargers (1x Bath Public Works, 1x Brunswick Station, 1x Lisbon Public Works) 3 19.2 kW level 2 chargers (1x Bath Public Works, 1x Brunswick Station, 1x WMTS facility)
2026	5 (2 Electric Cutaways, 3 Diesel Cutaways)	2 19.2 kW level 2 chargers (Sugarloaf)
2027	3 (1 Diesel School Bus, 2 Diesel Cutaways)	
2028		
2029	17 (17 Diesel Cutaways)	
2030	8 (8 Diesel Cutaways)	
2031	5 (2 Diesel School Buses, 3 Diesel Cutaways)	

This timeline assumes that, in line with current practice, WMTS generally replaces vehicles once they have reached twice their expected lifetime. (Because of the low annual mileage associated with the seasonal nature of many of WMTS's services, and funding and market challenges associated with fleet replacement, WMTS typically retains vehicles for longer than their nominal lifespan). This acquisition timeline also assumes that WMTS pays for construction of chargers at each of the relevant locations. If possible, negotiating a partnership or a charger use agreement with the owners of these locations may save WMTS money and encourage deployment of additional EVs for the Bath or Lisbon municipal fleets, allowing economies of scale in vehicle maintenance as well. If some downtime in vehicle operation is available, WMTS can also consider using local public charging infrastructure; the knowledge gained about charger location and reliability/availability will let WMTS better plan for vehicle range extension and operational resiliency. This will also allow the demand-response EVs to be spread out (within the range constraints as outlined above), which will ensure that the benefits of electric vehicles (elimination of tailpipe emissions, reduced noise, etc.) are distributed equitably across the WMTS service area. This may also prove valuable from a Title VI perspective, particularly as county demographics continue to change over the coming years. Rotating the electric vehicles across the region will ensure that no area is disproportionately negatively impacted by WMTS operations.

9. Building Spatial Capacity

WMTS has a number of facilities used for vehicle parking and maintenance. The ones recommended for EV charger installation are as follows:

> ***Section Summary***
>
> - The existing facilities are suitable for installation of DCFC and level 2 chargers.
> - If WMTS chooses to electrify additional vehicles, more detailed spatial planning would be needed to ensure a cohesive charging layout.

- Auburn: 76 Merrow Road, WMTS headquarters, WMTS owned.
- Lisbon: 14 Capital Avenue, Lisbon Public Works facility.
- Brunswick: 16 Station Avenue, train station. Recommended to move overnight storage/charging here to consolidate locations in Brunswick.
- Sugarloaf: 5002 Iron Brook Road, Carrabassett Valley.
- Bath: 450 Oak Grove Avenue, Bath Public Works Facility

Each of these facilities has ample space for both overnight and midday vehicle charging, as shown in the figures below.

Figure 5 WMTS Facility

Figure 6 Lisbon Public Works Facility (Source: Google Maps)

Figure 7 Brunswick Station (Source: Google Maps)

Figure 8 Sugarloaf Maintenance Facility (Source: Google Maps)

Figure 9 Bath Public Works Facility (Source: Google Maps)

10. Electrical, Infrastructure, and Utility Capacity

Section Summary

- At most charging locations, the utility grid has ample capacity to allow charger installation.
- At Lisbon and Sugarloaf, coordination with CMP will be needed for sufficient capacity.

Central Maine Power is the utility provider for WMTS's service area. As shown in the table below, the existing utility lines in the area of some proposed charging locations have ample capacity to support charger installation for the pilot deployment; in other locations, based on publicly available information, there is insufficient capacity and further coordination with CMP will be needed before charger installation can begin. The table below assumes that all chargers are used at once and have an efficiency of 90%.

Although detailed information for each location was not reviewed for this study, as a general principle, electrical connections from the utility line to each building will likely be insufficient for EV charging and will need to be upgraded. This will likely require the installation of a new 480V three-phase service to the building. WMTS may choose to install this as a separately metered service as a future-proofing measure in case any future utility rates are tailored to electrical services that exclusively serve EV chargers (as the now-defunct B-DCFC utility rate was).

Table 5 Power Demand by Location for Pilot Deployment

Location	Expected Peak Charge Rate	CMP Available Capacity	Sufficient Capacity?
Auburn	21.3 kW	12,459.4 kW	Yes
Lisbon	88.9 kW	0.0 kW	No
Brunswick	110.2 kW	604.4 kW	Yes
Sugarloaf	42.6 kW	55.8 kW	Marginal
Bath	110.2 kW	1,174.7 kW	Yes

11. Risk Mitigation and Resiliency

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 fossil fuel vehicles, there are new technologies to contend with, potential build quality issues that must be uncovered, and maintenance best practices that can only be learned through experience with a particular vehicle. Vehicle electrification makes some failure modes impossible – for example by eliminating the fossil fuel engine – but introduces others. For example, the ability to provide service becomes dependent on the continuous supply of electricity to the charging location. Understanding these risks and the best ways to mitigate them is key to successful electric vehicle operation.

11a. Technological and Operational Risk

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

- Technological robustness: By their nature as newer technology, many electric

Section Summary

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

vehicles and chargers have not had the chance to stand the test of time. Although many industry vendors have extensive experience with fossil fuel vehicles, and new vehicles are required to undergo Altoona testing, some of the new designs will inevitably have shortcomings in reliability.

+ Battery performance: The battery duty cycle required for electric vehicles – intensive, cyclical use in all weather conditions – is demanding, and its long-term implications on battery performance are still being studied. Though manufacturers have recommended general principles like battery conditioning, avoiding full depletion, and preferring lower power charging to short bursts of high power, best practices in vehicle charging and battery maintenance will become clearer in coming years.
+ Supply availability: Compared with other types of vehicles, electric vans are particularly vulnerable to supply disruptions due to the small number of vendors and worldwide competition for battery raw materials such as lithium. As society increasingly shifts to electricity for an ever-broader range of needs, from heating to transportation, both the demand and the supply will need to expand and adapt.
+ Lack of industry standards: Although the market has begun moving toward standardization in recent years – for example through the adoption of a uniform vehicle charging interface – there are many areas (e.g. battery and depot fire safety) in which best practices have not yet been developed. This may mean that infrastructure installed early may need to be upgraded later to remain compliant.
+ Reliance on wayside infrastructure: Unlike fossil fuel vehicles, which can refuel at any public fueling station, electric vehicles require level 2 chargers for overnight charging and specialized DCFC chargers for midday fast charging. Particularly early on, when there is not a widespread network of public chargers, this may pose an operating constraint in case of charger failure.
+ Fire risk: The batteries on electric vehicles require special consideration from a fire risk perspective (see Section 12b).

Most of these risks are likely to be resolved as electric vehicle technology develops. Although WMTS will have a twelve-vehicle pilot EV fleet, the short lifespan of the vehicles means that any electrification decision does not present a long-term financial commitment. Nevertheless, it will be prudent for WMTS to begin its transition to electric vehicles with an eye toward operating robustness in case of unexpected issues. Hatch recommends several strategies to maximize robustness:

+ Require the electric vehicle vendor to have a technician nearby in case of problems. This is most economical when the technician is shared with nearby agencies such as Portland Metro.
+ Retain fossil fuel vehicles for at least two years after they are retired to ensure they can substitute for electric vehicles if any incidents or weather conditions require it.
+ Develop contingency plans in case of charger failure, particularly for high-speed chargers required for midday use. This may include using another charger in the area, swapping vehicles more often than planned, or borrowing a vehicle from a nearby operator.

+ Conduct a fire detection, suppression and mitigation study of the 76 Merrow Road and Sugarloaf locations (as these will have indoor storage) to understand the risk associated with using chargers and housing electric vehicles (see section 12b).

11b. Electrical Resiliency

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

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

Table 6 summarizes the advantages and disadvantages of on-site storage and on-site generation systems. The most ideal solution for WMTS will need to be determined based on a cost benefit analysis.

Table 6 Comparison of the resiliency options

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

12. Conceptual Infrastructure Design

12a. Layout Selection

Although detailed site-specific engineering will be needed to choose the best location for chargers at each location, the following general principles affect the optimal placement of chargers:

- Snow Clearance
  - In a snowy environment like Maine, it is critical for chargers to be easily

Section Summary

- Charger layout and facility design needs to consider a variety of safety, operations, and maintenance factors.

accessible year-round. This is especially important in winter months, when batteries deplete quickly and more charging will therefore be needed. If snowbanks are piled up in front of the charger, vehicles will be unable to access it; furthermore, there is a risk of damage to the chargers from the snow (or snowplow) hitting it. To mitigate this risk, it is recommended to place the chargers on concrete islands slightly offset from the rear curb of the parking area, allowing space for snowbank buildup without interfering with the chargers. An overhead canopy, if installed, may reduce the amount of snowfall near the chargers.

- Vehicle Access
  - Particularly for the DCFC unit, which will be used for fast charging during the midday period, each minute of charging is important to maximize range and minimize vehicle downtime. Therefore, the charger should be positioned in an easily-accessed area close to the entrance of the charging area. Longer cable reels on the charger are also helpful because they reduce the required parking precision to access the charger. Finally, as vehicles will be required to dwell near chargers (particularly overnight level 2 chargers) for hours at a time, chargers should not be placed near entrances/exits to maintenance bays or other areas where a parked vehicle could interfere with the turning radius of other traffic.
- Ease of Maintenance
  - There are two broad categories of chargers available: ground- or wall-mounted, which constrain vehicle circulation the most but are easiest to access and repair, and ceiling- or canopy-mounted, which allow vehicles to be parked anywhere within range of their suspended reels but are more difficult to maintain. Ground- or wall-mounted chargers are most typical in outdoor applications, largely because of their lower cost and ease of maintenance, but the vehicle circulation advantages of a canopy-mounted charger should also be considered.

12b. Fire Mitigation

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

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 WMTS's risk is relatively low because of the high proportion of outdoor storage of the electric fleet, the agency should nevertheless monitor any development of standards for fire suppression and mitigation of facilities housing battery electric vehicles (which currently do not exist). There are partially relevant standards for the storage of high-capacity batteries indoors for backup power systems, such as UL9540, NFPA 70, and NFPA 230, and the primary components of any fire mitigation strategy are well understood. These include detectors for immediate discovery of a fire, sprinklers to extinguish it as much as possible, and barriers to prevent it from spreading to other vehicles or the building structure. To aid emergency response, the fire detectors should also be designed to automatically notify the fire department to ensure response even if no WMTS staff are able to respond. Further, WMTS should commission a fire safety study as part of detailed design work for the new charger installation to consider other mitigation measures.

13. Policy Considerations and Resource Analysis

As of 2021, WMTS's current operating budget is roughly $5.6 million per year. The agency's funding sources are summarized in Figure 10. As can be seen in the figure, WMTS's largest source of funding comes from federal assistance, such as the Formula Grants for Rural Areas program (49 U.S.C. 5311), and the Buses and Bus Facilities Competitive Program (49 U.S.C. 5339(b)) through the FTA.

Section Summary

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

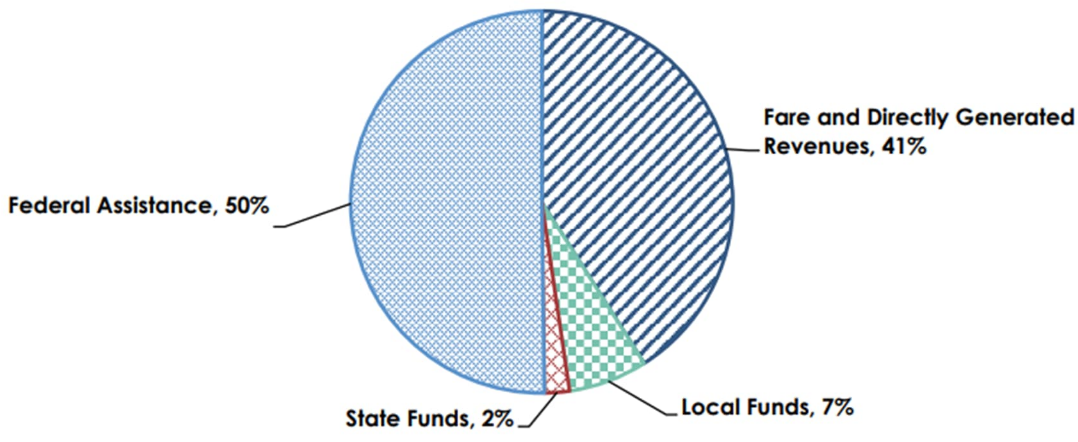

Figure 10 Current Agency Funding Summary (Source: Maine DOT)

As the agency transitions to battery electric technology, additional policies and resources will become applicable to WMTS. Table 7 provides a summary of current policies, resources and legislation that are relevant to WMTS'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 WMTS with guaranteed funding sources. Therefore, this analysis assumes that WMTS will only receive funding through the largest grant programs that provide the highest likelihood of issuance to the agency. Specifically, this analysis assumed that WMTS will receive 80% of the capital required to complete the vehicle, charging system, and supporting infrastructure procurements outlined in this transition plan through the following major grant programs:

+ Formula Grants for Rural Areas (49 U.S.C. 5311),
+ Low or No Emission Grant Program (FTA 5339 (c)
+ Buses and Bus Facilities Competitive Program (49 U.S.C. 5339(b))

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

Table 7 Policy and Resources Available to WMTS

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

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

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

14. Cost Considerations

> ***Section Summary***
>
> - The electrification pilot is expected to increase fleetwide capital cost by 49%.
> - However, reduced recurring expenses are expected, as electric vehicles cost less to maintain and fuel; this will lead to a 1% reduction in total cost of ownership.

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

The upfront purchase cost of battery electric vehicles is higher than for fossil fuel ones. This is largely due to the high cost of the propulsion batteries. Although the cost of batteries is declining each year it is still very high. Because transit agencies prefer high-capacity batteries to extend vehicle range, the additional price of the batteries overshadows the cost savings from eliminating the engine and associated components on a fossil fuel vehicle. The vehicle purchase cost increases are often significant, as shown below.

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

These upfront capital costs are expected to be balanced out by recurring savings on operations and maintenance cost. For operations, EVs are cheaper to recharge than fossil fuel vehicles are to refuel. This is especially true if a charge management system is used to avoid electricity demand charges. In addition to operations spending, maintenance costs are expected to decline as well. EVs have many fewer drivetrain parts, especially moving parts, than fossil fuel vehicles. Therefore, components will wear out less often, meaning that less time has to be spent maintaining them and spare parts can be bought less frequently.

Table 8 lists the operating and capital costs that Hatch assumed for this study. These are based on WMTS's figures and general industry trends and have been escalated to 2024 dollars where necessary.

Table 8 Cost Assumptions

Asset	Estimated Cost Per Unit (2024 $'s)
Fossil Fuel Transit van	$50,000
Fossil Fuel Cutaway	$80,000
Fossil Fuel School Bus	$150,000
Electric Transit van	$180,000
Electric Cutaway	$280,000

Expense	Estimated Cost (2024 $'s)
Fossil Fuel Vehicle maintenance	$0.97 / mile
Electric Vehicle maintenance	$0.73 / mile

The financial analysis outlined below makes the following assumptions:

Capital Investment

- Taking into account the range of vehicle types and the maintenance of some vehicles past their nominal useful life, this analysis assumed an average lifespan of a vehicle of 7 years.
- All vehicles are replaced with minivans, vans, or cutaways, as appropriate, at or shortly after their expected retirement year.

Funding

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

Costs

- Discount rate (hurdle rate) of 7%
- Inflation rate of 3%

Because the electrification transition process will be gradual, life cycle cost calculations would necessarily overlap multiple vehicle procurement periods. Hatch addressed this issue by setting the start of the analysis period to be the year after the pilot electric fleet is procured (2026), with the analysis period stretching for a full 7-year vehicle lifespan. For vehicles at midlife at the end of the analysis period, a remaining value was calculated and applied at the end of the time window.

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

Table 9 Lifecycle Cost Comparison

Category	Fossil Fuel Baseline	Future Fleet	Cost Differential (Future Fleet vs. Baseline)
Vehicle Capital Cost	$663,054	$948,937	+49%
Infrastructure Capital Cost	$0	$38,505	
Vehicle Maintenance Cost	$10,401,420	$10,141,385	-2%
Infrastructure Maintenance Cost	$0	$55,328	
Operations Cost	$15,445,242	$15,044,158	
Total	**$26,509,717**	**$26,228,312**	-1%

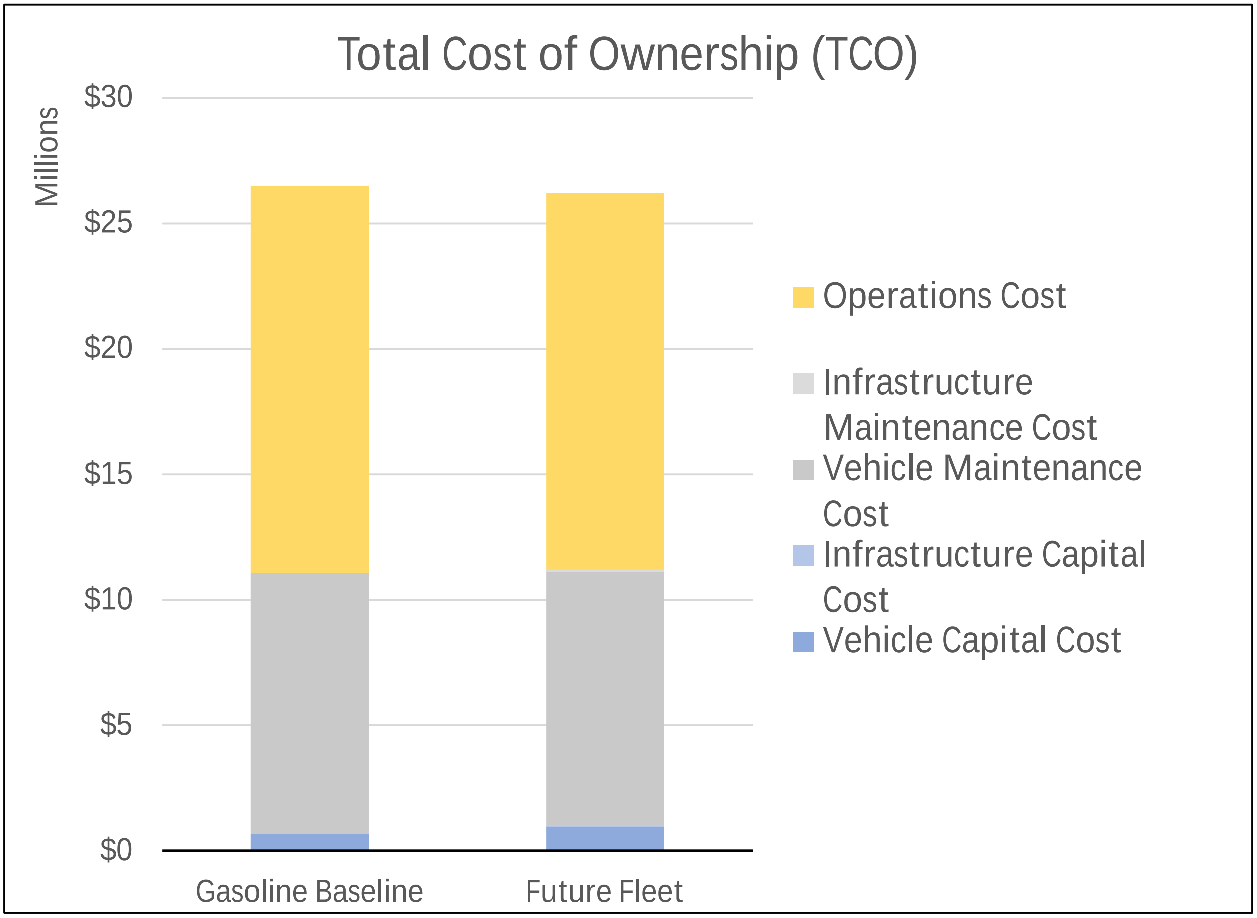

Figure 11 Lifecycle Cost Comparison

As shown above, vehicle electrification reduces total system cost at the expense of increasing initial capital cost. Although there is some expense related to the charging equipment, the bulk of the extra capital spending is on the vehicles themselves. While electric vehicles are much simpler mechanically, they command a cost premium due to their large battery systems.

Although only a quarter of the fleet is proposed for electrification, these factors yield a 49% increase in fleet-wide capital costs over the fossil fuel 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 diesel, the maintenance and operating costs of the proposed fleet are 2% lower than of the all-fossil fuel 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 1%.

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

The electric vehicle market is a fairly new and developing space, with rapid advancements in technology. Although Hatch has used the best information available to date to analyze the alternatives and recommend a path forward, it will be important in the coming years for WMTS 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 WMTS to change the speed of its electrification transition or change the desired end-state altogether.

15. Emissions Impacts

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

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

Section Summary

- Vehicle electrification will be critical to helping meet State emission goals.
- Forecasted grid conversion to clean energy will maximize the benefit of vehicle electrification.
- The transition is expected to reduce emissions by 8-9%.

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

The tank-to-wheel emissions impact considers the emissions reduction in the communities where the vehicles are operated. As a tank-to-wheel baseline, the 'tailpipe' emissions associated with WMTS's existing fossil fuel fleet were calculated. These calculations used industry emissions averages for fossil fuel vehicles and WMTS's fuel economy data. Electric vehicles do not have tailpipe emissions, as the light-duty vehicles planned for procurement do not have diesel heaters.

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

Battery electric vehicles have a third emissions source: grid electricity generation. The local utility, Central Maine Power, was not able to provide specific details on the emissions associated with its electricity production as part of this project. Therefore, the emissions calculations assumed an EPA and EIA average grid mix for Maine. Similar to the state's overall goals to reduce emissions, the state has also set the goal of reducing grid emissions by roughly 67% by 2030 by transitioning to more renewable energy production. To account for these future grid emissions reduction goals, calculations were completed based on the most recent actual data available (2020), as well as projections that assume that the 2030 targets are met. Table 10 and Figure 12 summarize the results of the emissions calculations. These results demonstrate that the transition plan will achieve 8% emissions reduction assuming the grid mix that existed in 2020, or 9% 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, WMTS's transition plan will help reduce emissions but will not meet the 45% goal established by the State of Maine. The small magnitude of this reduction is largely due to the small size of the pilot fleet – only 25% of the fleet. More significant emissions reductions will be possible when a greater portion of the fleet is transitioned.

Table 10 CO_2 Emissions Estimate Results

Scenario	Well-to-Tank (kg)	Tank-to-Wheel (kg)	Grid (kg)	Total (kg)	Reduction over Baseline
Fossil Fuel Baseline	1,243,249	2,102,225	-----	3,345,474	----------
Future Fleet (2020 grid mix)	1,121,671	1,896,647	45,745	3,064,064	8%
Future Fleet (2030 grid mix)	1,121,671	1,896,647	15,096	3,033,414	9%

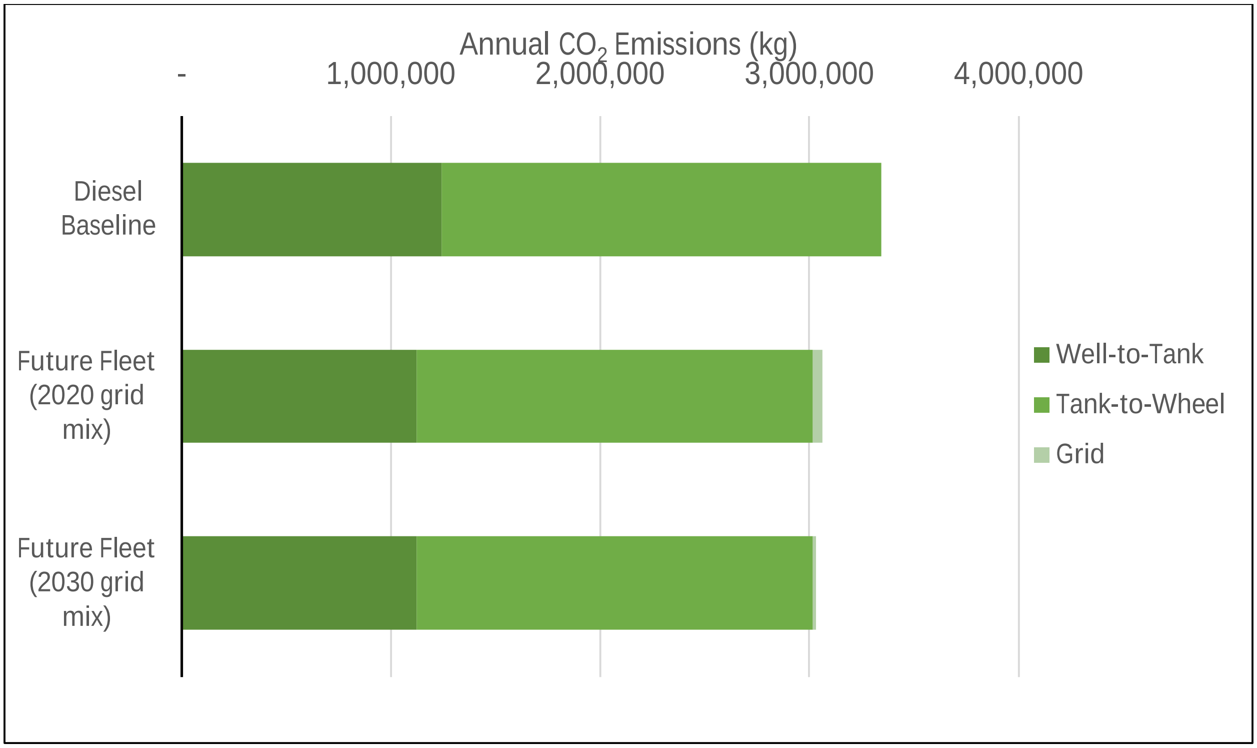

Figure 12 Graph of CO_2 Emissions Estimate Results

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

- Purchase green energy agreements through energy retailers to reduce or eliminate the emissions associated with grid production
- Assuming the initial pilot is successful, purchase additional electric vehicles
- Explore schedule changes to allow increased charging time at layovers, allowing electrification of lengthy routes without large increases in fleet size

16. Workforce Assessment

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

Section Summary

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

Table 11 Workforce Skill Gaps and Required Training

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

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

+ Add requirements to vehicle and infrastructure specifications to require contractors to deliver training programs to meet identified skill gaps as part of capital projects.
+ Coordinate with other peer transit agencies, especially within the state of Maine, to transfer 'lessons learned'. Send staff to transit agency properties that have already deployed battery electric vehicles to learn about the technology.
+ Coordinate with local vocational and community colleges to learn about education programs applicable to battery electric technologies, similar to the one Southern Maine Community College recently introduced.

17. Alternative Transition Scenarios

As part of this study, WMTS was presented with alternative fleet and infrastructure transition scenarios that would also satisfy the agency's operational requirements. These alternatives considered different scales of electrification, vehicle choices, and charging locations. Through discussions, however, the agency currently favors the transition plan presented in this report. Should WMTS's plans or circumstances change in the future, it is possible that one of the alternative transition plans discussed in earlier stakeholder meetings may become more advantageous. Hatch recommends that the agency review this transition plan on an annual basis to reevaluate the assumptions and decisions made at the time this report was authored.

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

18. Recommendations and Next Steps

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

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

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