Vermont Agency of Transportation (VTrans) Zero-Emission Transition Plan

Summary Report

January 31, 2022

Delivering a better world

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1. Introduction

The Vermont Agency of Transportation (AOT, or VTrans) has made a policy decision to transition the state's fleet of approximately 400 transit vehicles to zero-emission propulsion over the next few decades. Specifically, VTrans' plans call for 100 percent of the fleet to be powered by renewable energy by 2050.

This decision has service and operations implications across the seven transit agencies in the state: new infrastructure must be procured and installed, maintenance and training needs will change, and additional funding sources must be explored to meet the capital needs of the program.

Purpose and Components of the Project

From March to December 2021, VTrans researched and prepared the VTrans Zero-Emission Transition Plan. The purpose of the project was to examine ways the State and its transit agencies can scale up the electrification program to meet its zero-emission targets.

To facilitate Vermont's goal of transit fleet electrification, VTrans and consulting firm AECOM conducted outreach and stakeholder engagement, held regular meeting to discuss the progress of the study, and conducted analyses and modeling, and drafted a series of technical memoranda. The results of this work are contained in this summary report.

The transition plan has four main components, all of which are addressed in the summary:

- Stakeholder Engagement
- Energy / Utilities
- Transportation / Continuation of Service Delivery
- Economics / Timeframe

Please note that, at the outset of the project, the study was called the VTrans Battery-Electric Bus Transition Plan. The initial assumption was that Vermont's transit fleet would gradually be replaced by battery-electric buses. However, this designation ignores the potential for hydrogen fuel cells, which is another type of zero-emission vehicle. Therefore, the name of the project was renamed to be more precise about the State's possible adoption of hydrogen-powered buses in the future. Hydrogen is *not* part of the recommendations for near-term zero-emission bus implementation, due to the significant logistical challenges of operating a fuel cell fleet today. But it should be part of Vermont's long-range plans as the technology evolves and proliferates.[1]

Organization of the Summary Report

The summary report is organized as follows:

- Section 2 discusses the state of the zero-emission transit industry, including available vehicle and charging technologies and scenarios.
- Section 3 covers the outreach that was done with stakeholders in Vermont, particularly representatives of the seven transit agencies in the state.

[1] *"Zeroing in on ZEBs", CALSTART, 2020.*

- Section 4 looks at energy considerations. A zero-emission transition plan cannot focus solely on vehicles and operations; it must also examine electrical capacity at depots for the installation of chargers and emphasize coordination with utilities in the state.
- Section 5 summarizes the results of the route and block analysis, perhaps the most foundational aspect of a zero-emission transition plan. Because electric buses run on batteries with a limited capacity, their range is generally less than that of fossil fuel-powered buses. As a consequence, an analysis of each transit agency's schedule was done to determine whether an electric bus can do the work of a conventional bus on any route or block, given a set of assumptions.
- Section 6 offers insight into zero-emission bus subjects that did not neatly fit into the other technical memoranda in the study, including the integration of information technology (IT) with electric buses and chargers, and the training of the bus operators, maintenance crews, and first responders who will be handling zero-emission transit equipment in the future.
- Section 7 contains an analysis of capital costs, a transition timeline given several procurement scenarios, and potential funding sources for zero-emission vehicles and infrastructure.
- And, finally, Section 8 lists a set of recommendations for VTrans and Vermont's transit agencies as they continue to transition the state to zero-emission buses.

The appendices show current service data for each of the seven transit agencies in Vermont, and the results of the analysis that determined the probable extent to which existing scheduled service could be provided by battery-electric vehicles (full-size transit buses as well as vans and cutaways).

2. State of the Industry

In the first portion of the study, the project team sought to familiarize VTrans, transit providers, and stakeholders in Vermont with available zero-emission transit technology available today. Central to this effort was showing that transit operators in the state must adapt to a new way of thinking about providing zero-emission transit now and in the future. Electrification of a fleet demands new infrastructure, training and maintenance needs, additional capital costs, and other considerations.

Several providers in Vermont have already started the process – Advance Transit and Green Mountain Transit (GMT) have already tested electric vehicles for demonstration purposes, GMT is operating two vehicles in regular revenue service, and VTrans itself has received four grants from the Federal Transit Administration for 12 new electric buses. These vehicles will be distributed in the coming year to GMT, Advance Transit, Green Mountain Community Network, and Rural Community Transportation. Meanwhile, Marble Valley Rural Transit District has received Volkswagen Settlement funds for the acquisition of two electric buses.

Deployments in the U.S.[2]

As of December 2020, 2,790 zero-emission buses (ZEBs) were on the road in the U.S., with another 249 ZEBs operating in Canada. This represents an increase of 24 percent in ZEB deployments over 2019. Of those 2,790 ZEBs, only 87 were hydrogen fuel cell buses, with the remainder being battery-electric.

California leads the way, with 1,100 ZEBs in service, although the rest of the country is catching up fast: Washington State has 246, Florida has 164, Colorado has 100, and New York has 77. In Canada, Ontario has the most ZEBs by far of any province, with 170.

Vermont has two ZEBs in service, with more than a dozen more on order. Massachusetts leads New England with 28 ZEBs, while Maine and New Hampshire have none.

The trend toward ZEBs is, in spite of these recent strides, still in its infancy; most bus fleets in the U.S. have fewer than five ZEBs. Thirty-three agencies, however, have more than 20 ZEBs. These numbers reveal a willingness among transit operators to try electric buses; but scaling up remains a challenge.

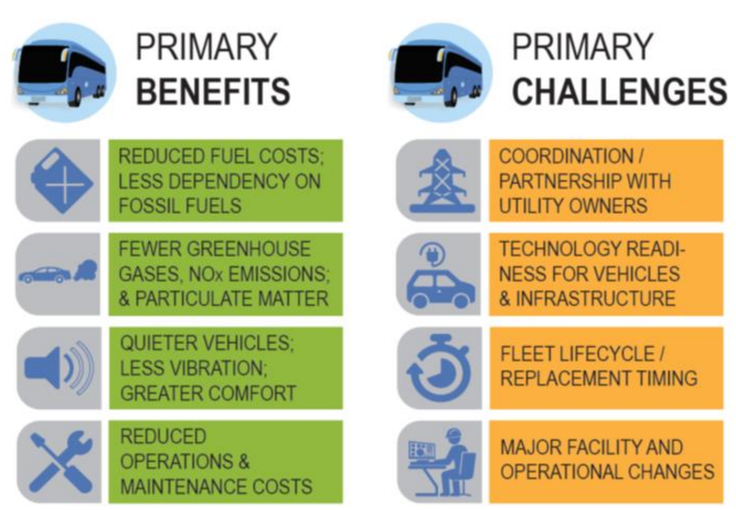
It's important to remember that approximately 80,000 transit buses are currently in service in the U.S., which means that only 3.5 percent of those vehicles are zero-emission as of 2020. While the surge in interest in ZEBs is encouraging, there is still a long way to go.

Prognosis for the Future

There is a growing awareness among transit providers in North America that ZEBs are a sustainable way forward. The recent popularity of electric buses, however, is tempered by the fact that it can take years to plan and implement a ZEB program, many questions remain about the charging infrastructure and working with utilities, and production lags behind demand – indeed, it can take many years for vehicle manufacturers to fill orders that would replace existing conventional buses at scale.

[2] *"Zeroing in on ZEBs", CALSTART, 2020.*

Within the transit industry, it's expected that – as lithium-ion battery technology continues to improve and offer more range, as chargers get faster, and as prices continue to fall – agencies will see electric buses as a realistic option for them. Further, as more transit agencies put ZEBs into service, a greater amount of literature and lessons-learned will become available on the technology and process of electric bus implementation. These factors should aid in the implementation of ZEBs in the coming years.[3]



Of all the carbon emitted in the U.S. every year, around 29 percent is a by-product of transportation, much of which comes from over-the-road trucks and private cars. However, transit comprises a substantial portion of carbon emissions today. If every diesel bus in the U.S. were replaced by a ZEB, the country would save more than 2 million tons of greenhouse gas emissions annually[4].

Technical Specifications

Electric buses commercially available in North America include 30-, 35-, 40-, and 60-foot articulated models. Virtually every transit bus manufacturer that produces diesel, natural gas, and hybrid-electric buses now offers a battery-electric version of their platform in one or more lengths. Several manufacturers also produce only electric buses, based on a bus chassis that is purpose-built for electric propulsion.

Most manufacturers offer both overhead high-power DC conductive charging and lower-power plug-in DC charging. All manufacturers have now settled on the use of the SAE J3105 standard for overhead conducting charging and the use of SAE J1772-CCS Type 1 connectors for plug-in charging.

The table on the following page summarizes manufacturers that currently offer electric buses in the North American market. Proterra, BYD, and Green Power Motor Company manufacture only battery-powered buses, while New Flyer, Gillig, Nova, and Alexander Dennis also manufacture diesel, CNG, and hybrid-electric buses. Battery-powered buses from these manufacturers use the same bus platform as bus types that use fossil fuels, with only minor modifications to accommodate the electric propulsion system.

BYD, Green Power, Alexander Dennis, and Complete Coach Works have focused on buses that use plug-in charging, typically overnight at the depot. Nova Bus offers only overhead conductive charging, which is typically used for in-route charging, but could also be used in a depot setting. Proterra, New Flyer, and Gillig offer both plug-in and overhead conductive charging on their buses. However, this is a very fluid market; in the future, additional new entrants are possible, along with additional charging options from existing market participants.

[3] *Transit agencies are not the only entities interested in exploring ZEBs; airports, universities, and school districts are also looking into electric buses and shuttles.*

[4] *"Electric Buses: Clean Transportation for Healthier Neighborhoods and Cleaner Air", Frontier, U.S. PIRG, and Environment America, 2019.*

Electric Bus Vehicle Types and Manufacturers in 2021[5]

Manufacturer	Manufacturing Facility	Vehicle Sizes	Model Names	Char-ging	Prices	Notes
BYD	Lancaster, CA	30-foot, 35-foot, 40-foot, 60-foot	K9, K11	Depot	$550,000 to $770,000	Chinese-owned company with a facility in California; 10 years. 280+ BEBs now operating in U.S.
PROTERRA	Burlingame, CA; Greenville, SC	35-foot, 40-foot, Low-floor cutaway	Catalyst: FC, FC+, XR, XR+, E2, E2+, E2 max; S1LF Shuttle	Depot, In-route	$750K-$800K for Catalyst. Shuttle bus cost unknown.	Manufactures only electric buses; 16 years. 550+ BEBs now operating in U.S.
GILLIG	Livermore, CA	40-foot	ePlus	Depot, In-route	$1,230,000	Electric trolleys (5 years) and electric buses (1 year).
NEW FLYER	St. Cloud Crookston, MN; Anniston, AL; Winnipeg, Manitoba	35-foot, 40-foot, 60-foot buses; soon to offer cutaways	Xcelsior Charge 40, Xcelsior Charge XE60	Depot, In-route	$785,000 to $1,000,000	6 years making electric buses. 110+ BEBs now operating in U.S.
NOVABUS	Saint-Eustache, Quebec; Plattsburgh, NY	40-foot	LFSe	In-route	unknown	Subsidiary of Volvo.
GreenPower MOTOR COMPANY	Porterville, CA	30-foot, 35-foot, 40-foot, 45-foot, 45-foot double decker	EV250, EV300, EV350, EV400, EV550	Depot	unknown	Canadian-owned company with a facility in California; 13 years; motor by Siemens.
ALEXANDER DENNIS	Larbert, Scotland, UK	45-foot double decker	Enviro400EV	Depot	unknown	Purchased by New Flyer, May 2019.
VANHOOL	Morristown, TN	45-foot intercity coach	CX45; Proterra E2 battery (2019)	In-route	unknown	Belgian company with facility in Tennessee.
CCW COMPLETE COACH WORKS	Riverside, CA	40-foot remanufactur ed	ZEPS (Zero Emissions Prop-ulsion Systems)	Depot	unknown	Converts diesel buses to electric.
Lightning Systems	Loveland, CO	Electric passenger vans, cargo vans, cutaways, trucks	Lightning eMotors provides drive trains for Ford & Chevy vehicles	Depot	unknown	Started in 2008; announced expansion in 2020.

[5] *APTA Database, Navigant Research, AECOM, and M.J. Bradley & Associates. Data is from 2020. Note: BYD, Proterra, Gillig, and New Flyer are the four primary manufacturers of battery-electric buses in the U.S., with the remainder combining to represent a smaller share of the market.*

Physical Dimensions

Electric buses have similar dimensions (height, length, and wheelbase) as CNG and diesel-electric hybrid buses on the market. For buses that use overhead high-power conductive charging, all manufacturers install the on-bus charge port on the roof, centered over the front axle. Therefore, the front overhang length (center of front axle to front bumper) may be important when siting in-route chargers. The front overhang of 40-foot electric buses ranges from 87 inches to 120 inches.

Note that the Proterra and Gillig buses are closer to 42 feet in length rather than the standard 40. When accepting buses from these manufacturers, transit agencies in Vermont should use a program such as AutoTURN to verify that 42-foot buses can negotiate intersections with a tight turning radius.

Vehicles: Application to Vermont

Since electric transit vehicles entered the market over 10 years ago, the emphasis among makers has been on 40- and 60-foot buses. However, an increasing number of manufacturers have been addressing the need for smaller, lighter-duty vehicles such as cutaways and vans.

Proterra has just introduced its S1LF Shuttle; New Flyer now makes smaller, low-floor electric shuttle buses through ARBOC; and companies such as GM, Ford, Chevrolet, Green Power, Endera, and Rivian have begun to offer electric cutaways and vans that can be used for transit.

Manufacturers are now turning their attention to smaller electric transit vehicles, such as cutaways and vans.

Because a substantial portion of transit vehicles in Vermont are not 40- or 60-foot buses, the state's agencies will benefit from the increase in options for smaller transit vehicles.

Conversion Kits

Because a new electric bus can be expensive to procure (up to $1 million vs $600,000 for a 40-foot diesel bus), an alternative approach for agencies is to *convert* an existing diesel bus to a fully electric bus, especially in the near term as manufacturers are still ramping up production of ZEBs.

Many parts of a bus – chassis, tires, cabins, and others – are the same regardless of propulsion type; so, with a conversion kit, a transit agency can replace the following systems to accelerate electrification without the high capital cost of procuring new: traction system, vehicle control system, battery, power distribution unit, charging connections, and driver console.

An increasing number of companies offer conversion kits, including E-Fill, Linkker, e-trofit, UES, Rawsuns, Elexicon, and others.

The current literature on converting conventional buses to electric buses suggests that the process of reorganizing a vehicle's systems is technically challenging. However, VTrans and Vermont's transit providers are encouraged to explore the potential for vehicle conversions in place of, or in addition to, the procurement of new electric vehicles as a cost-saving measure and/or a method of filling a gap in vehicles available to procure.

Batteries and Range

A key consideration in transitioning to an electric fleet is battery capacity, expressed in kilowatt hours (kWh), which determines how far the bus can go on a single charge (range). Most manufacturers offer a selection of battery sizes, from approximately 150 kWh to approximately 660 kWh. Proterra offers the largest battery currently available in the market – 660 kWh. The larger the battery, the longer the range (miles per charge). Also: the larger the battery, the heavier the bus; so, the practical limitation on maximum battery size is primarily weight, not volume. Proterra can offer a larger battery than other manufacturers due to the lower weight of their composite structure and lighter weight of their batteries.

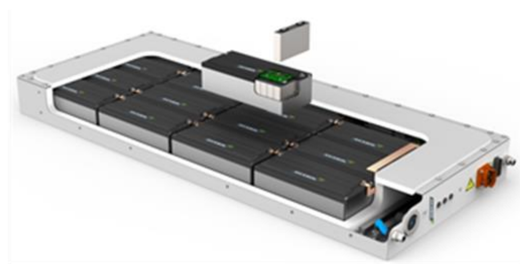
Smaller battery offerings (less than 250 kWh) are intended for buses that primarily use in-route opportunity charging. Larger batteries are intended for buses that primarily charge overnight at the depot. Since batteries are the single largest cost element for electric buses, larger batteries also typically increase the procurement cost of the bus.

Issues Affecting Range

The range (in miles) of electric buses before they need to be recharged is a function of how much energy they use (kWh/mile) and the amount of usable energy that they can carry in on-board batteries. One of the most important things for a transit agency to know as it begins to consider a potential transition to a battery-electric bus fleet is that energy use varies significantly by route and season. The more route miles a vehicle travels in a service day, and the colder the weather, the more energy will be depleted from the battery. Other factors influence range as well, such as steep roadway grades (the hillier the route, the more energy is needed) and bus driver behavior with regard to correct operation of regenerative braking.

Battery capacities actually have two numbers: nominal capacity and usable capacity. Nominal is how much energy can be stored in a new fully charged battery – for example, 450 kWh. Useable capacity is how much energy a battery can store accounting for degradation over time.

Battery manufacturers recommend that batteries *not* be discharged to zero state of charge every day. If they are, they will likely degrade and lose capacity faster than if a reserve margin of 5 to 20 percent charge is maintained in the battery. However, even with this reserve margin, all batteries will degrade as they are charged and discharged, losing effective capacity – potentially up to 2.4 percent per year, or up to 17 percent after seven years (bus mid-life), and up to 34 percent after 14 years (bus end-of-life).



Above: an AKASOL lithium-ion battery for electric buses. Image: greencarcongress.com. Below: cross-section of a battery mounted on the roof of an electric bus. Image: 100percentelectricbuses.wordpress.com.

Batteries and Range: Application to Vermont

With these issues in mind, transit agencies in Vermont should not plan for electric bus service using the manufacturer's nominal capacity, but rather a lower number that accounts for battery degradation, weather, topography, and others.

A technological advance that may potentially mitigate the cold weather burden on electric bus batteries in the future is renewable fuels in on-board heaters. One of the reasons that cold weather negatively impacts the range of electric buses to the extent that it does is that the cabins of buses must be heated in the winter. In a conventional bus, waste heat from the engine is filtered and distributed throughout the cabin. However, electric buses produce considerably less waste heat. Many agencies use diesel-fired heaters to get around this problem, but strictly speaking, these devices are not "zero-emission".

Manufacturers are working on a solution whereby an on-board heater is fueled by a renewable source, such as ethanol. This technology is still in development, however, and may be years away from being available. In the meantime, Vermont's transit agencies will want to consider diesel-fueled heaters, in the interest of preserving the range of their electric bus batteries during colder months.

Type 1 J1772 CCS plug and socket. Image: thedriven.io

Charging Types and Manufacturers

When people think of charging electric vehicles, typically they think of a plug with a cord attached to a charging unit, much like a gas pump and nozzle. That's only one way to charge vehicles, however; buses can also be charged via overhead conductive and wireless inductive chargers.

Wireless inductive chargers are embedded in the ground and charge buses via an electromagnetic field. They may be limited to charge rates below 300 kW due to space limitations for on-bus equipment. Also, wireless chargers are the least efficient and least proven of the charging technologies; they are still several years away from being widely commercially available.

Corded plug-ins are direct current (DC), have a charge rate of less than 150 kW, and are almost always used in depots; in-route locations are less desirable due to labor requirements (collective bargaining agreements often preclude bus operators from performing fueling tasks).

All manufacturers except Nova offer plug-in DC charging, using a charge port compatible with an SAE J1772 CCS-Type 1 connector, also referred to as a CCS connector. Thus, a single J1772-compliant DC charger can be used to charge any electric bus. All manufacturers provide a charge port on the curb-side rear of the bus and offer the option of a second charge port, on the street-side rear or street-side front of the bus.

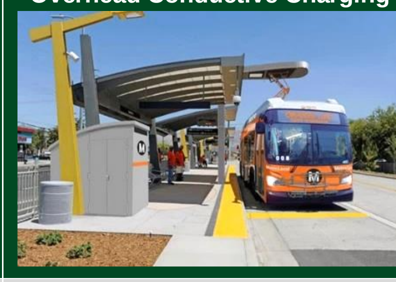
A New Flyer electric bus gets an in-route charge from a pantograph-down overhead conductive charger. This type of charger allows for charging of a bus at a layover or other location away from the depot at speeds faster than most plug-in chargers and do not require a maintenance crew member to perform the operation.

Plug-in charging of electric buses at a depot is generally analogous to home charging of personal electric vehicles; a charger is provided at every bus parking spot in the depot and buses are plugged in and charged during the time that they are parked – usually overnight between 9 pm and 5 am, or when a peak-service vehicle returns to the depot during midday.

The following is a list of charger manufacturers with a description of their products. While all have U.S.-based facilities, Buy America compliance might vary among the manufacturers and products available based on component sourcing. Pantographs are sold separately but can be procured through a U.S.-based manufacturer, such as Schunk or Valmont.

- **ABB**: HVC 450P chargers provide 450 kW DC output power to recharge a battery in 3 to 6 minutes. Uses the OppCharge standard (overhead pantograph connection to conductive rails on top of the bus). ABB charging powers are 150 kW, 300 kW, and 450 kW.
- **Siemens**: Three charging options: depot fast charging (150 kW - 600 kW); in-route charging (60 kW - 120 kW); and plug-in depot charging (30 kW - 150 kW).
- **ChargePoint**: DC fast-chargers (up to 500 kW) are compatible with any fast-charging connectors.
- **Heliox**: A range of depot chargers: (25 to 150kW); fast opportunity charging (up to 450kW).
- **BYD**: AC-DC quick charge inverters; offers range of depot chargers (40 to 80 kW).
- **Proterra**: A range of depot chargers (60 to 500kW); fast opportunity charging (up to 500kW).
- **New Flyer**: Uses the OppCharge standard; offers a range of depot chargers (150 to 450kW).

The graphic below shows a comparison of plug-in, overhead, and wireless charging types.

Corded Plug-In	Overhead Conductive Charging	Wireless Inductive Charging
		
• Charge Type: AC or DC • Charge Power: 40 to 120 kW • Charge Time: 1 to 8 hours depending on bus state of charge	• Charge Type: DC • Charge Power: 175 to 500 kW • Charge Time: 5 to 20 minutes for the fastest settings	• Charge Type: AC or DC • Charge Power: 5 to 300 kW • Charge Time: 5 minutes to 8 hours
PROS (+) • Lowest infrastructure cost	PROS (+) • Potential for in-route operations • Smaller capacity batteries possible with in-route charging • No need to plug / unplug buses	PROS (+) • Smallest infrastructure footprint • Simpler charging mechanism • Consistent power supply • No need to plug / unplug buses
CONS (--) • Buses charge at depot only • Larger battery capacity required • Larger batteries may reduce passenger capacity on the bus • Must plug in and unplug bus daily • Cords can be damaged and need replacing	CONS (--) • Higher infrastructure costs • Potential peak demand utility costs if in-route charging is used • Reliability: More moving parts can fail; snow and ice can be an issue in colder climates • Faster chargers can shorten battery life • Largest visual impact	CONS (--) • Higher infrastructure costs • Less efficient energy transfer than conductive charging • Charger receiver on bus requires active cooling during charging • Infant technology • Not offered as standard option by any North American bus manufacturers

Charging Strategies: Depot, In-Route, or Both

There are three scenarios for charging electric buses: at the depot, in-route, or a mix of the two. In addition, there are different times of day for charging buses:

- Overnight at the depot when buses are not in service
- Overnight *and* midday, when buses return to the depot between AM peak and PM peak runs
- Opportunity charging, where a bus stops in-route (i.e. at a layover location) to restore some or all of the energy used in service

As is the case with charging infrastructure, the charging scenario each transit agency chooses depends on its needs and schedules.

Depot charging is the easiest scenario for agencies to envision. Buses are charged overnight, pull out for a morning run, return to the depot midday (possibly for more charging, if necessary), go back into service for afternoon / evening runs, and then pull in for the night. Each bus would have its own charging unit, and a crew that is responsible for engaging and disengaging the charging dispenser.

While this system is simple in principle, the space requirements of so many charging units can make their placement in a cramped garage untenable. Additionally, some operating blocks may be too long to conform to the midday and overnight windows for slower plug-in charging. To overcome this challenge, fast chargers can be installed at the depot to improve vehicle turnaround times when the slower plug-in charge is not feasible. From a cost perspective, however, this solution may be infeasible for some agencies; an overhead conductive charger and mast can approach $1 million, whereas a slower plug-in charging unit costs only around $50,000. Further considerations must also be made to ensure the vehicle is compatible with overhead charging.

Another option is to acquire higher-powered charging units with multiple plug-in dispensers. Some companies (such as ABB, pictured at right) sell charging systems that divide the power inverters and controller/cord connections into separate units. In this scenario, a 100 to 150 kW power module will feed up to three charging heads and the power module (inverter) can be housed separately from the charge heads. The charge heads are typically smaller and lighter than in the all-in-one units, so less space between bus lanes may be required if the charge heads are ground-mounted, or less structure may be needed to support the charge heads if mounted overhead. In addition, these systems allow any individual bus to charge at up to 150 kW if only one of the three charge heads is actively charging.

An agency that runs intercity routes or has many blocks that are more than, say, 10 hours long, may be better served by an in-route charging system. In this scenario, buses are seldom at the depot long enough to do a full charge, so they must replenish their batteries at strategic locations along routes.

In-route chargers are typically installed at one or both termini on a route, at or near existing bus transfer points or layover locations, and buses are charged for 5 to 15 minutes each time they come to the end of the route where the charger is located. Depending on route length, and whether charging is done at one or both termini, buses may charge once every 1 to 2 hours in service. With a 450 kW in-route charger, total in-route charge time will typically be 30 to 60 minutes per day per bus, depending on daily mileage.

In-route charging requires higher charge rates than depot charging — typically 300 to 600 kW. In-route chargers are faster than plug-in chargers, but the energy consumed may be more expensive because most charging takes place during the day when electricity demand charges are often higher, as opposed to overnight depot charging which takes advantage of off-peak energy pricing. The increased power demand can also result in higher utility bills. At the same time, because in-route chargers can recharge a bus more quickly, fewer of them are required than plug-in chargers.

There are also schedule implications with in-route charging, in that charging at terminals would be done during recovery time at a layover location. If a bus arrives late, there may not be enough recovery time to re-charge before the next trip begins. To provide sufficient time for charging, recovery times may need to be increased to accommodate terminal charging. This increase in cycle time would also increase the number of buses required to meet service, if service frequencies are to remain the same.

In summary, depot charging is typically performed by corded plug-in charging of buses overnight and can be supplemented with midday charging to improve range in cases where buses return to the depot between runs. Turnaround time for these midday charges could be improved with faster charging solutions such as overhead chargers at an increased cost. While space-saving solutions do exist for plug-in chargers, this can still become a concern at larger depots. In-route charging, on the other hand, reduces space concerns at the depot and improves vehicle range by supplying energy to vehicles in service during layovers. These solutions come at increased costs of the units and installation, as well as for the energy, and can also introduce further complexities in scheduling.

Charging Types: Application to Vermont

Wireless conductive charging should be explored in future years as the technology improves.

Overhead conductive chargers only work with transit buses at this time, and so would only be practical for a transit agency whose fleet is composed of buses rather than light- or medium-duty vehicles. Overhead chargers are most valuable for buses assigned to long blocks that cannot complete their scheduled service without opportunity charging, although a few transit agencies use them for depot charging as well.

Most transit agencies with a mix of buses and smaller electric vehicles opt for plug-in charging at depots.

The time of day in which electric vehicles are charged depends on the schedule of the transit provider. Across North America, most EVs and buses are charged at the depot overnight. But if peak-period vehicles return to the depot at midday, there is another opportunity to charge. The agency will need to be mindful of the cost of electricity during peak demand periods, however.

Hydrogen Fuel Cell Buses

Fuel cells have actually existed since the 1980s; but, in 2021, it is still considered a less-mature zero-emission transit technology than battery-electric bus. This is primarily because the commercial availability of liquid hydrogen in the U.S. remains limited, and logistical difficulties exist in acquiring a steady supply of fuel needed for zero-emission buses.

Hydrogen is appealing to transit agencies for several reasons. One is that, operationally, hydrogen is similar to diesel or compressed natural gas, in that crews fuel the vehicles overnight and they can run for an entire service day without needing to return to the depot for refueling. There is no need for expensive batteries, electrical upgrades, or charging infrastructure, and there is less range anxiety than with battery-electric buses. However, hydrogen is made through reforming, a chemical process that requires natural gas. So, while hydrogen and battery buses both have no *tailpipe* emissions, hydrogen has a larger carbon footprint due to the way most of it is created.

The main barrier to a more widespread use of fuel cells is the lack of sites where liquid hydrogen is created; in most cases, the fuel must be trucked to depots over many hundreds of miles. Because the trucks operate on fossil fuels, this defeats the purpose of having a zero-emission transit fleet.

Storage is a challenge as well. Hydrogen is as flammable as fossil fuels, so the material must be kept in solid form (cryogenic) during transport, or as gas in more dangerous high-pressure tanks. When hydrogen is liquefied, it loses about 40 percent of its energy, which is far less efficient than energy stored in lithium-ion batteries.

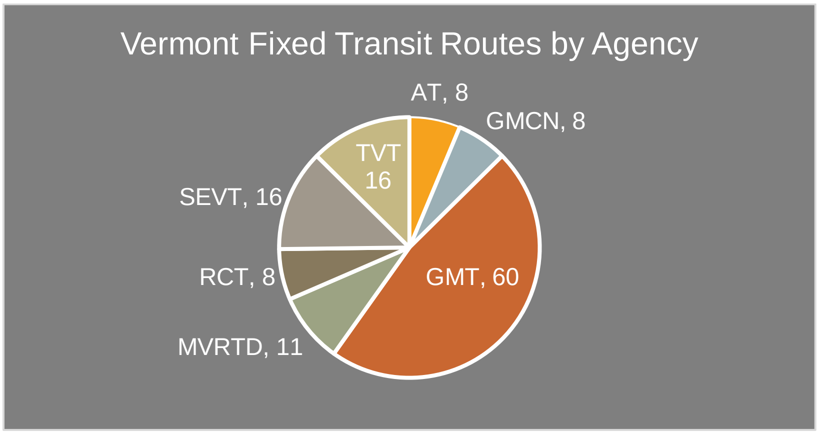
Hydrogen is, in some ways, more attractive than battery buses because of lower capital costs, ease of operation, and less disruption to schedules and facilities. But challenges still remain in the acquisition, transport, and storage of hydrogen fuel. Because the zero-emission bus industry is advancing so rapidly, it may be the case that hydrogen finds its place alongside battery-electric buses in zero-emission fleets in the next 10 years.

However, owing to logistical hurdles, hydrogen still lags behind. Only a handful of U.S. agencies – mostly in Hawaii, California, and Ohio – have successfully rolled out hydrogen-powered vehicles. Only one is operating in all of New England (at the MBTA in Boston). Of the 2,790 zero-emission buses in service in the U.S. in December 2020, only 87 were hydrogen.[6]

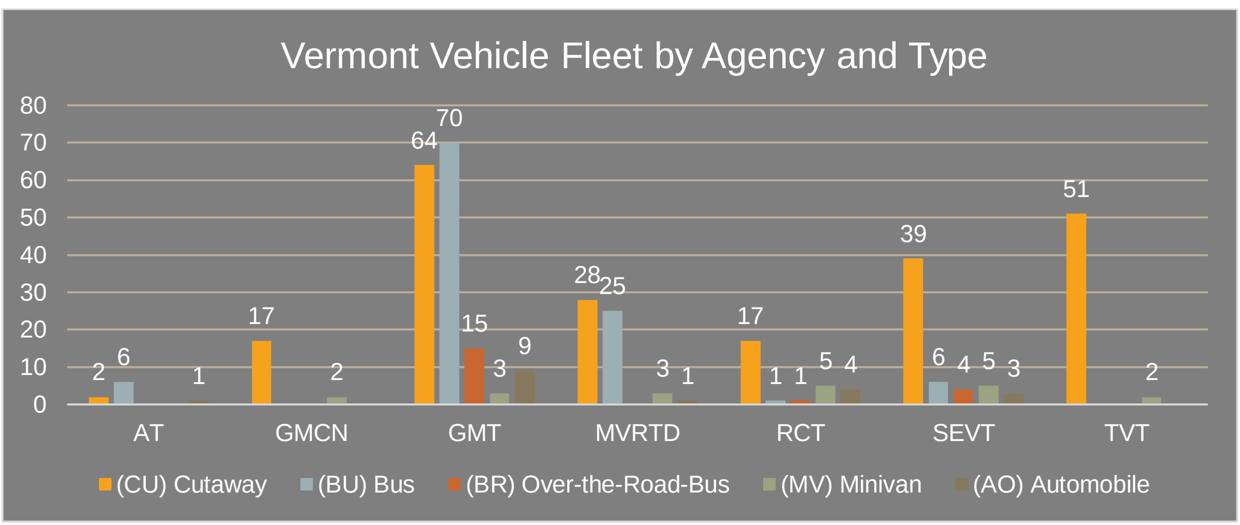
[6] *"Zeroing in on ZEBs", CALSTART, 2020.*

3. Existing Conditions

Seven transit providers in Vermont operate 123 routes, with Green Mountain Transit operating nearly half. The pie chart below shows the distribution of fixed transit routes in Vermont by agency, according to information available via General Transit Feed Specification (GTFS).



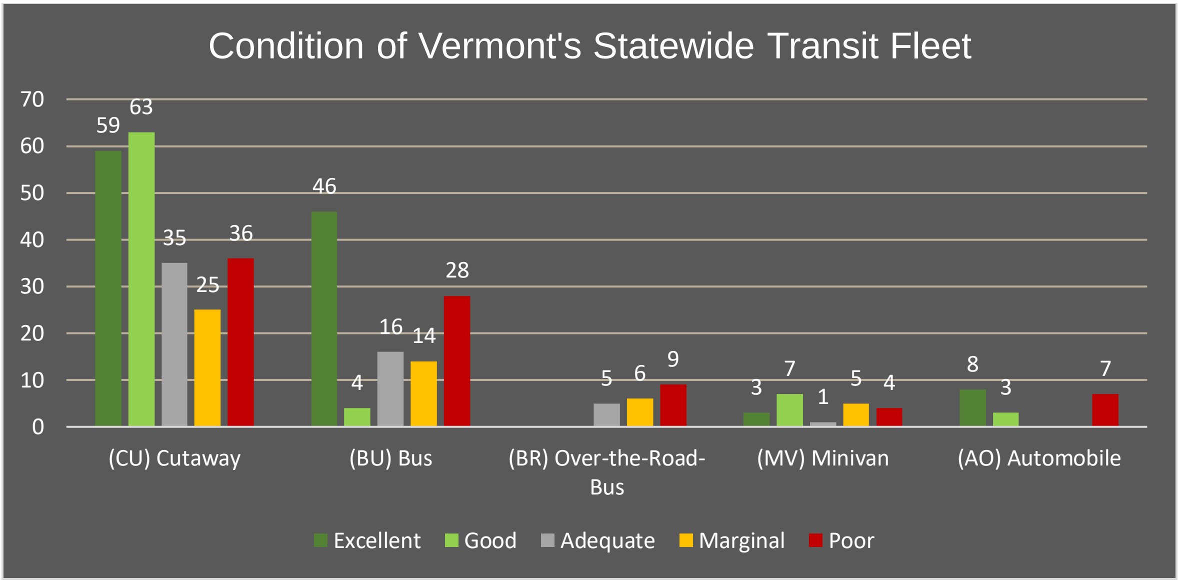
Statewide, the fleet of approximately 400 transit vehicles is shown by agency and vehicle type below.



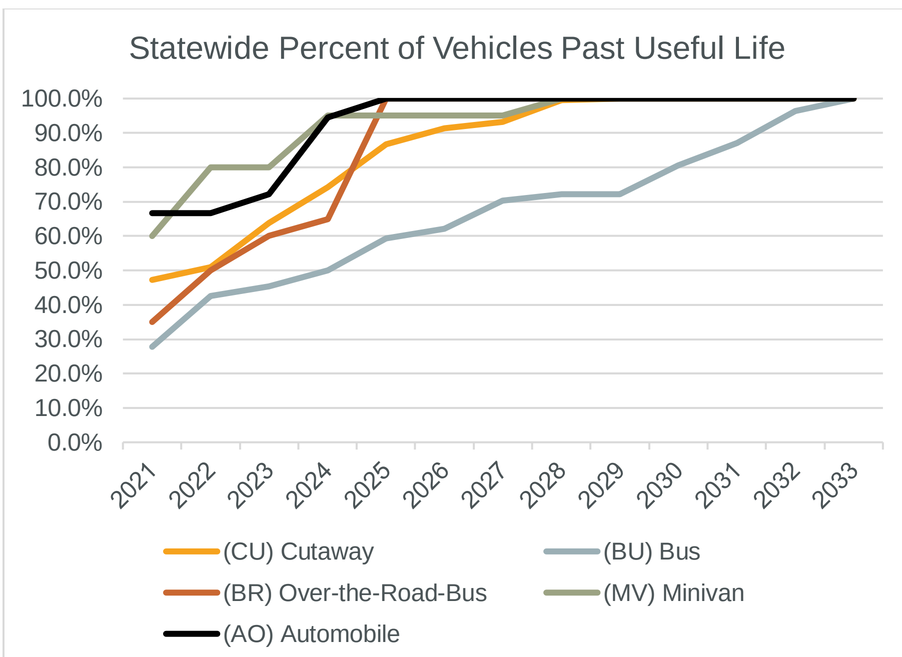
As part of this study, the project team provided a detailed profile of each agency's routes, vehicles, and facilities that was used for later analysis and projection. Vehicles were determined to be beyond their useful lives based on the vehicle type and age. In general, smaller vehicles have a shorter useful life, as short as 4 years for sedan-style vehicles to up to 12 years for full-sized buses.

Operators also list a combined total of 18 facilities, most of which have outdoor vehicle storage.

As shown in the graph below, the condition of vehicles overall was good, with half rated as "excellent" or "good" condition as compared to just under 35 percent being rated "marginal" or "poor".

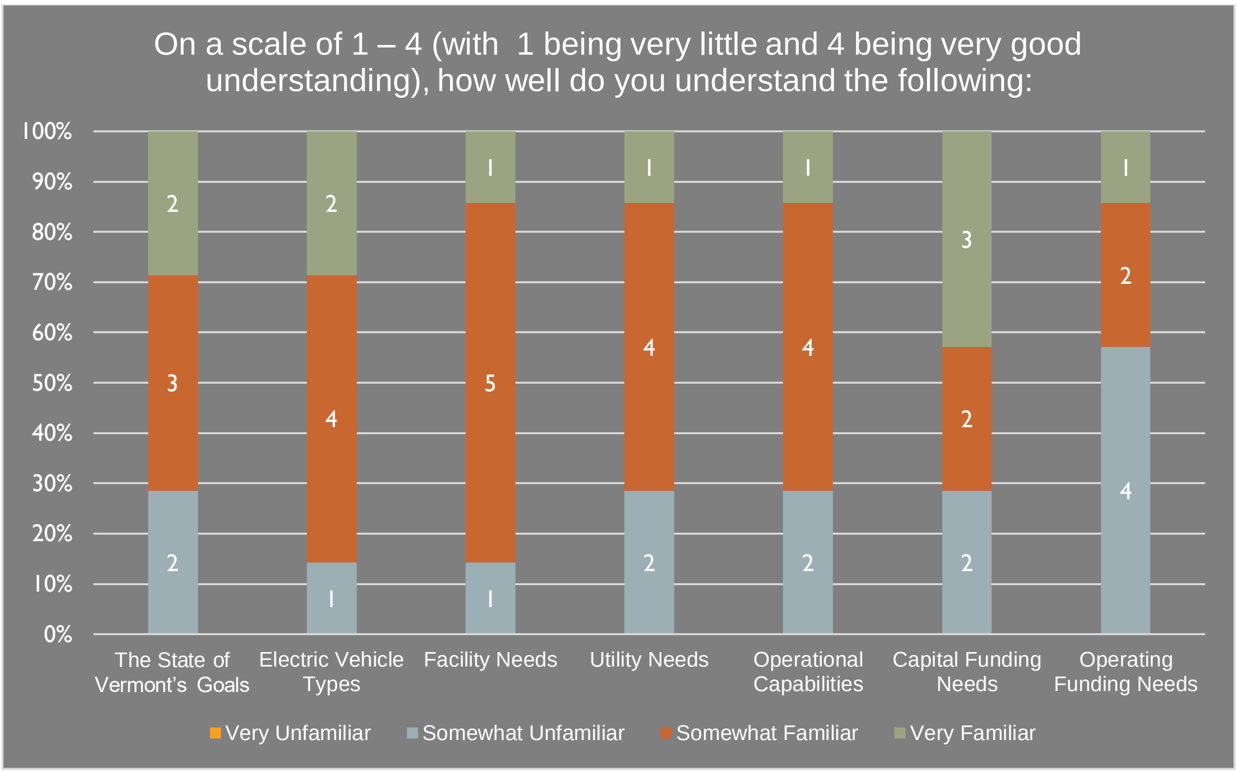


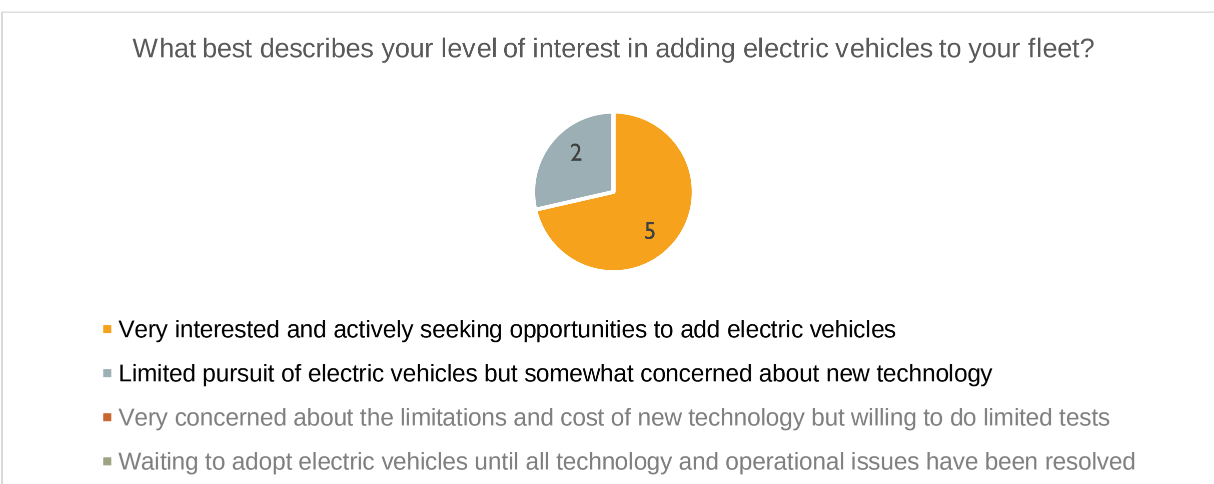
Some of the transit vehicles currently operating in Vermont are beyond their useful life – the point at which the vehicle should be decommissioned and replaced with a new one. As of 2021, fewer than 30 percent of Vermont's buses are beyond their useful life, while minivans and automobiles are both over 60 percent. By 2033, all vehicles in Vermont's transit fleet will have gone beyond their useful life, as shown in the graph below.

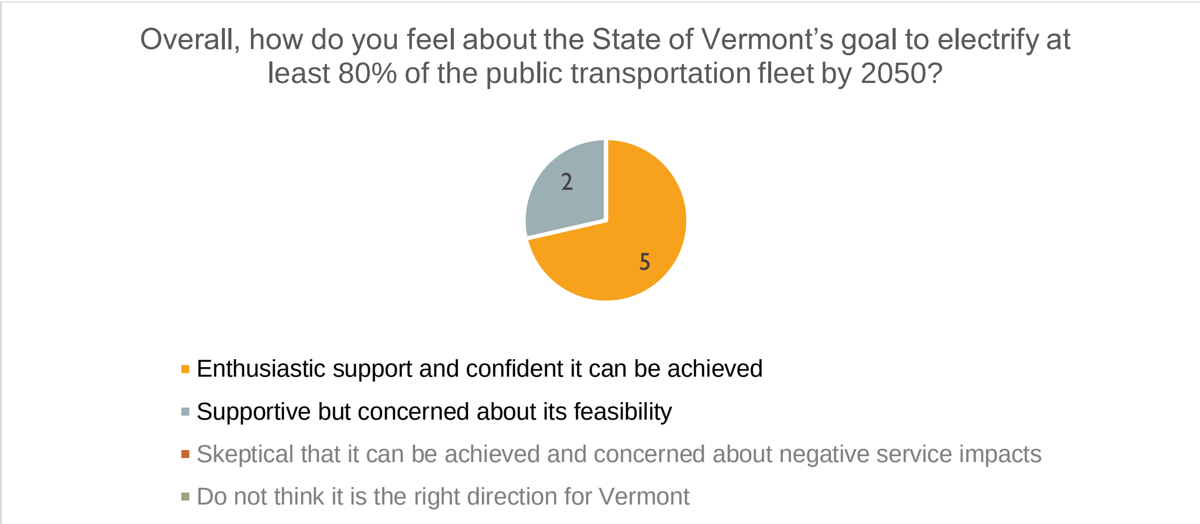


4. Outreach

Because transit providers in Vermont are at different stages of knowledge and implementation of electric buses and vehicles, the project team reached out to agency representatives to collect technical information and ask questions about their electrification readiness and needs. The results of this effort are summarized in the graphs below. In general, Vermont's transit service providers expressed strong interest in converting to zero-emission vehicles with some hesitation due to unfamiliar technology and questions about large-scale implementation.







In addition to surveying transit providers, VTrans collaborated with the Federal Transit Administration, the Vermont State Legislature, and VEIC. Members of these groups were active in the project's Technical Advisory Committee, which met monthly for the duration of the project.

Through these efforts, VTrans built an understanding of where and how the zero-emission transition of Vermont's transit fleet fits into other statewide initiatives, and helped set the stage for future implementation steps.

5. Energy and Facilities Assessment

Another consideration when planning for the addition of electric buses to a transit fleet is the readiness of the existing electrical infrastructure to accommodate chargers. Extensive upgrades to the local distribution infrastructure are costly, and potential construction could impact the schedule of the conversion to a zero-emission fleet. As such, VTrans should understand the existing electrical infrastructure of the bus storage locations in Vermont and their capacity to accommodate electric bus chargers.

The utility is responsible for the infrastructure necessary to deliver power to its clients, but only to a certain point. As the figure below shows, power is transmitted via high-voltage transmission lines, and then stepped down to a lower voltage for customer use at a local substation. From there, an on-site transformer typically steps down the voltage further to comply with a standard of service outlined in the rate structure of the account. The standard of service specifies a voltage, frequency, and number of phases to be delivered by the utility. In some cases, this on-site transformer is owned and operated by the utility. In other cases, it is owned by the customer but operated by the utility. The client is responsible for all distribution infrastructure downstream of this transformer.

The power requirements of electric bus chargers, shown below, may exceed the capacity of the current infrastructure at some of the bus garages in Vermont. In this case, a load analysis would need to be performed to determine the required capacity. VTrans, or the transit agency, would then coordinate with the utility to upsize the transformer and utility feeder. Downstream infrastructure, such as switchgears, will also need to be upgraded.

Power requirements of electric bus chargers by type are as follows:

	Slower Depot Chargers	Fast Chargers (Overhead and In-Route)
AC Voltage	480V	480V
AC Current	200A	400A
Phases	3-Phase	3-Phase
Watts	Between 125 and 250 kW per charger, depending on model	Between 250 and 500 kW per charger, depending on model
Quantity of Loads to be Fed	Battery capacity varies by bus; approximately 250 to 300 kWh per bus	Battery capacity varies by bus; approximately 250 to 300 kWh per bus

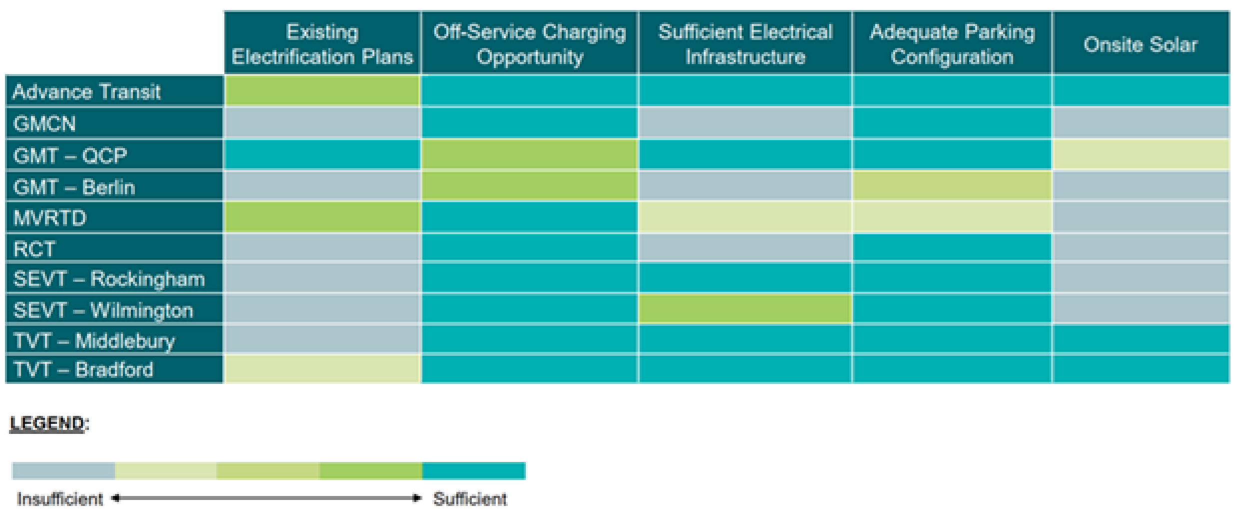
Electrifying the bus fleets in Vermont will require coordination and collaboration across multiple transit agencies and electric utilities. Operating electric buses requires a significant capital investment in infrastructure, both utility-owned and agency-owned, and increases in electricity consumption and demand will affect operational costs.

As part of the study, the project team collected data on transit facilities in Vermont and performed a high-level assessment of their readiness for electrification based on the following criteria:

- State of existing electrification plans, with findings ranging from no existing electrification plans to the agency already having chargers onsite.

- Availability of off-service charging opportunities; while GMT – QCP and GMT – Berlin each have some routes with only 6 hours off-service, most agencies and routes exhibit sufficient availability.
- Readiness of electrical infrastructure on-site for charging, the primary qualifier being the availability of 480V service; some sites are presently undergoing electrical upgrades as identified in the figure.
- Adequacy of parking configurations to support 1:1 charger installation for fleet conversion, with “sufficient” representing sites where there would be limited impact on parking configuration from what is presently available.
- Availability of onsite solar power, with “sufficient” representing existing solar installation to support existing building loads (additional solar would be required if intending to support battery-electric bus charging)

See the results in the following figure. The findings of this analysis were that upgrades to electrical infrastructure will be needed at up to five facilities; physical space and parking appears to be sufficient at facilities; and all seven agencies are capable of EV charging during non-service hours. Two areas where agencies should improve include the development of existing plans for transit electrification and looking ahead toward the installation of solar infrastructure.



The energy and facility analysis also concluded that:

- Charging station installations will require space in the parking garage or parking lot for curbs, bollards, and charging units.
- New parking configurations may be needed to ensure there is adequate space for transit vehicles.
- Many facilities currently have low-electricity usage, resulting in inexpensive monthly bills. Fleet electrification is expected to incur an increase in electricity costs:
    - Approximately $1,000 per vehicle per month
    - Could be offset by savings on fuel costs
- Charging during off-peak times will be critical for reducing monthly bills
    - Each kW during peak times costs roughly $11 more than off-peak times

- VTrans and Vermont's agencies should continue pursuing partnerships with electric utilities. Potential options include:
    - Incentive programs
    - Make-ready programs
    - Charging electricity rates
    - Technical assistance programs
    - Funding and financing assistance

As each transit agency in Vermont moves forward in its transit electrification plans, the study team recommends a more in-depth analysis of each facility's electrical and space capacity. Not only will each agency's transit needs change from year to year, but electric vehicle technology is rapidly evolving as well. Things that may be unknown or constrained in 2021 may not be issues in five or ten years, when some transit providers will be further along in implementing their electrification plans.

Understanding the available space and electrical infrastructure at each depot also provides guidance on where to place the charging infrastructure. Further, knowing the energy needs of the existing transit fleet will allow transit agencies to develop a charging strategy: whether the vehicles should be charged at the garages, at in-route locations around the state, or a combination of the two. These will be important considerations as each transit provider in Vermont moves from the conceptual planning stage to the implementation phase.

6. Route and Block Analysis

The crucial question facing VTrans is: How can Vermont's transit agencies move toward zero-emission fleets over the coming decades without interrupting their scheduled services? To answer this question, the project team collected data from state transit agencies on:

- Fleet composition
- Transit service types, and
- Available physical space at depots for electric bus parking and charging infrastructure

The project team also collected GTFS[7] data on existing transit schedules. This information is critically important, as it allows a thorough assessment of the energy needs of each route and operating block[8] that is currently scheduled in the state of Vermont, and helps determine which could be operated by an electric vehicle and which would need to be modified to continue the service as scheduled.

The collected data served as inputs to a model that assesses whether a currently scheduled bus block can be served by an electric vehicle of the same size operating on a single overnight charge. The reason a "single overnight charge" is important is that most electric vehicles are charged at the depot at night when transit is mostly inactive and when electricity is less expensive. Charging vehicles during the day is possible, but it opens the door to potentially higher operating costs (i.e. more expensive electricity).

Therefore, the goal of transit electrification – and the foundation of a route and block analysis – is to have a vehicle replacement ratio of 1:1, where an electric vehicle can take the place of an existing vehicle while not sacrificing any scheduled service.

To do the route and block analysis, the study team put data for each transit provider and block into a model (see Appendices) that included the following key points:

- **Vehicle Types**. This is important because the amount of energy required to run a 40-foot transit bus is different than the energy needs of a van or cutaway (shuttle bus).
- **Total Block Length in Miles**, including deadhead miles. This is the most important data point in the analysis, because the greater the number of daily miles a vehicle is in operation, the greater its energy needs will be.
- **Assumptions** (see the following page). The study team made assumptions about a number of factors that influence the calculations. Among the most important are 1) the nominal capacity in kilowatt hours (kWh) of the battery, since the size of the battery is the primary determinant of vehicle range; 2) useable capacity, accounting for battery degradation over time, and 3) other factors, such as kWh used per mile, the use of diesel heaters, and so on.
- After the input of the data for each transit provider and block was complete, the project team then assessed whether that existing vehicle would be able to operate with an electric vehicle of the same size, assuming a single overnight charge at the depot.

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[7] *General Transit Feed Specification and other transit data is typically available to the public through online sources.*
[8] *A "block" is a transit scheduling term; it is defined as the period of time between a vehicle's departure from the depot and its return to the depot, including "deadhead" (i.e. non-revenue) time for getting to and from the route. In some cases, a block ends not when a vehicle returns to the depot, but rather when it "interlines" (i.e. when a bus is assigned to one route but then switches to another route during the service day). If interlining is done with an electric bus, the two segments should be broken into two separate blocks, to allow for the correct calculation of energy use.*

The assumptions that went into the route and block analysis are listed below. Calculations are shown by block for each transit agency in the Appendices.

1. All vehicles are assumed to use auxiliary diesel heaters rather than on-board electric heaters. This makes a significant difference in energy consumption and range, as electric heaters draw far more energy from an EV battery than a diesel heater.[9]
2. The charging scenario is assumed to be overnight depot charging. This does not preclude transit providers from using in-route opportunity charging or daytime depot charging in the future if buses equipped with overhead charging equipment are procured. These are useful (but expensive) alternatives for getting more range out of EV batteries. But overnight depot charging is an appropriate starting point for the route and block analysis.
3. Correct vehicle operator behavior is assumed. A skilled driver can get more range out of an EV by accelerating correctly and applying regenerative braking successfully. By contrast, a poorly trained or inattentive driver can significantly reduce the range of an EV.
4. Energy use of 2.1 kWh per mile is assumed for electric buses, and 1.2 kWh per mile for vans, and cutaways/shuttle buses. This is an industry standard. Note that kWh/mile can be higher for routes with especially steep grades. Further analysis should take topography into consideration for rural routes that operate in a very hilly environment.
5. Transit buses (30-, 35-, and 40-foot) are assumed to have new batteries with nominal capacity of 450 kWh. In the coming years, battery capacities – and therefore vehicle ranges – will increase. But 450 kWh is the 2021 standard for a typical transit bus battery.
6. Cutaways and vans are assumed to have new batteries with nominal capacity of 130 kWh. These are also expected to increase in the coming years.
7. To calculate useable battery capacity, the study team subtracted from nominal capacity based on:
    a. Degradation of the battery at an annual rate of 2.4%,
    b. 15% of battery capacity is reserved for operational flexibility,
    c. The half-life of a battery being 7 years (at which time it should be replaced).
8. The approximate range of a 35- or 40-foot bus, using the assumptions listed above, is 152 miles in a service day.
9. The approximate range of a van or cutaway/shuttle bus, using these assumptions, is 91 miles in in a service day.
10. Ranges used in the model are expected to account for a range of conditions including cold temperatures, as diesel heaters help to mitigate the impact of cold weather on vehicle range; however, additional consideration should be given by each agency in circumstances where EVs will be operating in extreme cold.

Transit providers may want to look closely at average speeds and topography to get more precise predictions of range on rural routes. For this route and block analysis, the assumptions will work for most routes and in a wide range of weather events. The following are the preliminary findings of the VTrans Route and Block Analysis.

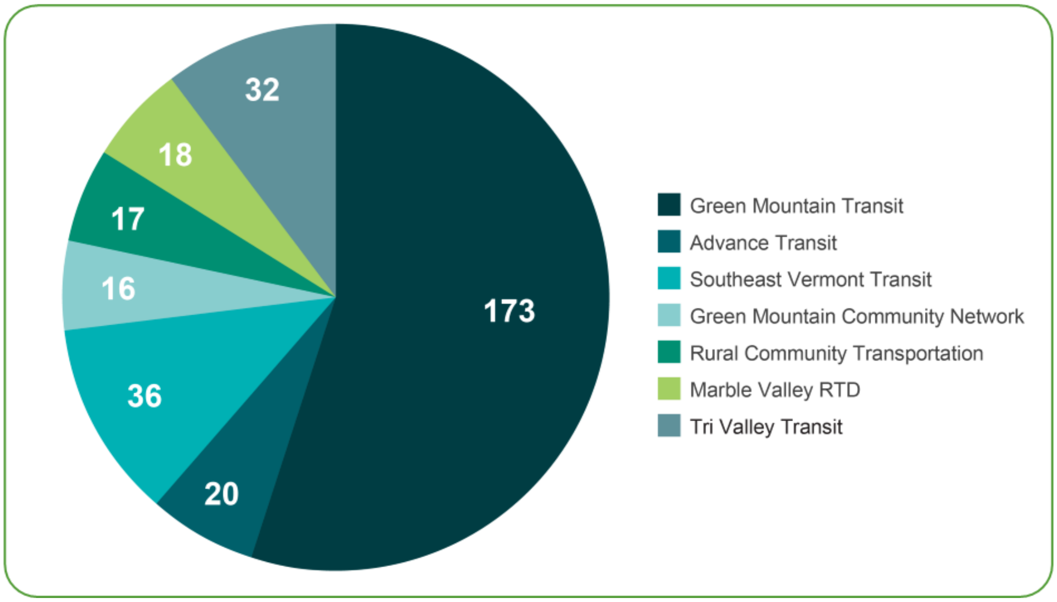
1. Of the 312 blocks currently scheduled in Vermont, 86 percent can be operated using a standard (35’ or 40’) electric bus. The remaining 16 percent are too long for the range of an EV available

[9] *While the use of auxiliary diesel heaters, by definition, means that a battery-electric vehicle is no longer “zero emission”, many transit agencies across North America are learning that their use is a necessary evil to extend the range of electric buses and allow for a greater realization of the agency’s transit electrification and climate policy goals. In a cold-winter state such as Vermont, the use of diesel-powered cabin heaters is recommended until a better, cleaner technology is available.*

on the market today. This number is encouraging, as it will allow for a smoother transition to EVs in the more urban, denser areas of the state where electric buses would be deployed.

2. Fifty-four percent of the state's currently scheduled blocks can be operated using an electric shuttle bus. This number poses more of a challenge, as several transit providers in Vermont currently deploy *only* cutaway vehicles/shuttles buses or vans. Therefore, the transition to EV will likely need to wait until the battery capacity of lighter-duty electric-powered vehicles can catch up to the range requirement of rural transit systems or other work-arounds are considered.[10]

Note that most of the transit service blocks in Vermont (see the pie chart below) are in the Green Mountain Transit system, provided by the Chittenden Country Transportation Authority. Again, the majority of the GMT blocks are in denser, semi-urban areas around Burlington where the transition to electric buses would be more feasible (and, in fact, is already underway).



As mentioned, the full results of the analysis are shown by transit provider and scheduled block in the Appendices. To understand how to read the tables shown in the Appendices, the most important column to look at in the screen-shot sample below is the one called Total Length in Miles (Route + Deadhead). If the total length for the scheduled block is over 152, then the block is likely too long to be served by an electric bus (in this case, 35-foot) with a standard 450 kWh battery. If the total length is over 91, then the block most likely cannot be served by an electric cutaway. On the next page is actual data for Advance Transit.

As shown in the table below, 11 of Advance's 20 blocks could be operated as scheduled by an electric 35-foot bus on a single overnight depot charge. Conversely, only five of the 20 could be operated by an electric cutaway. In this example, Advance Transit and VTrans will have some decisions to make regarding transit electrification for this provider. Should they increase the size of their vehicles to 35-

[10] *The study team's understanding is that Vermont's rural transit providers would be less willing to consider increasing the size of the vehicles in their fleet, largely due to capital cost and potential operational constraints.*

footers, to accommodate the process of electrification? Or should Advance wait until the batteries for cutaways have more capacity, thereby allowing for greater vehicle range?

Operator	Block ID	Route	Vehicle Type	Length (miles)	Deadhead (miles)	Total Length in Miles (Route + Deadhead)	Can This Block Be Served by One Electric Bus?	Can This Block Be Served by One Electric Cutaway or Van?
Advance Transit	1	Blue	35' Gillig	294.78	21.40	316.18	no	no
Advance Transit	2	Blue	35' Gillig	316.55	21.40	337.95	no	no
Advance Transit	3	Blue	35' Gillig	165.53	42.80	208.33	no	no
Advance Transit	6	Brown	30' Gillig	142.23	7.00	149.23	no	no
Advance Transit	7	Orange	30' Gillig	179.06	7.00	186.06	no	no
Advance Transit	15	Blue	30' Gillig	131.07	21.40	152.47	no	no
Advance Transit	41	Green	30' Gillig	211.67	3.00	214.67	no	no
Advance Transit	42	Green	30' Gillig	214.13	3.00	217.13	no	no
Advance Transit	51	Red	35' Gillig	165.61	13.00	178.61	no	no
Advance Transit	52	Red	35' Gillig	130.80	13.00	143.80	yes	no
Advance Transit	DHMC20	DHMC Lot 20	35' Gillig	132.45	7.50	139.95	yes	no
Advance Transit	DHShuttle1	Dartmouth/Hanover Shuttle	Cutaway - 18 passenger	97.79	3.80	101.59	yes	no
Advance Transit	DHShuttle1	Dartmouth/Hanover Shuttle	Cutaway - 18 passenger	102.08	3.80	105.88	yes	no
Advance Transit	DHShuttle2	Dartmouth/Hanover Shuttle	Cutaway - 18 passenger	97.94	7.60	105.54	yes	no
Advance Transit	DHShuttle2	Dartmouth/Hanover Shuttle	Cutaway - 18 passenger	54.03	7.60	61.63	yes	yes
Advance Transit	DHShuttle3	Dartmouth/Hanover Shuttle	Cutaway - 18 passenger	66.25	5.40	71.65	yes	yes
Advance Transit	DHShuttle3	Dartmouth/Hanover Shuttle	Cutaway - 18 passenger	54.03	5.40	59.43	yes	yes
Advance Transit	DHShuttle4	Dartmouth/Hanover Shuttle	Cutaway - 18 passenger	31.55	1.90	33.45	yes	yes
Advance Transit	DHShuttle4	Dartmouth/Hanover Shuttle	Cutaway - 18 passenger	31.55	1.90	33.45	yes	yes
Advance Transit	YO	Yellow, Orange	30' Gillig	92.97	11.00	103.97	yes	no

In the chart below, a summary is shown of all seven transit agencies in Vermont and the number of blocks that can be served by either an 1) an electric 35- or 40-foot bus, or 2) an electric van or shuttle.

GMT has the best outlook for fleet electrification, while some of the rural transit agencies (which deploy only vans or cutaways at this time) will most likely have to wait to transition their fleets to EV or find another work-around.

Potential Block Replacement with Electric Vehicles

TRANSIT AGENCY	NUMBER OF BLOCKS	CAN IT BE SERVED BY ONE ELECTRIC BUS?		CAN IT BE SERVED BY ONE ELECTRIC VAN OR CUTAWAY?	
		Yes	No	Yes	No
Green Mountain Transit	173	161	12	106	67
Advance Transit	20	11	9	5	15
Southeast Vermont Transit	36	29	7	17	19
Green Mountain Community Network	16	15	1	5	11
Rural Community Transportation	17	12	5	11	6
Marble Valley RTD	18	15	3	5	13
Tri Valley Transit	32	27	5	25	7

Although some of Vermont's transit providers are – in light of today's available technology – at a disadvantage when it comes to fleet electrification, there are some work-arounds available to facilitate the process. Some potential solutions to overcome the limitations of EV technology include:

1. In cases where many blocks cannot be served by a single replacement EV an agency could expand the size of its fleet. Having two EVs to do the work of one conventional vehicle may solve

the problem, but the obvious drawback is the additional capital cost of vehicles and higher operational costs due to more drivers and maintenance crews needed to operate the larger fleet.

2. If blocks are scheduled primarily for peak-period service, then EVs can return to the depot for midday charging. While this will allow for significantly more range, electricity could be more expensive during daytime (peak demand) hours depending on local utility rate schedules. For vehicles that operate all day, however, a midday break for charging could translate to reduced service available for transit customers.

3. Transit providers could experiment with changing around their fixed-route schedules to better accommodate the challenges associated with the replacement of existing vehicles with EVs. However, this could result in reduced service for transit customers, as well as riders who are confused by the sudden wholesale changing of schedules. For transit-dependent customers in the state, sweeping changes to schedules could negatively affect the goodwill local governments acquire by transitioning their fleets to environmentally friendly vehicles.

4. For intercity routes or blocks that operate from early morning to late at night, installing in-route overhead conductive chargers at strategic locations around the state. Unlike plug-in chargers at a depot, overhead conductive chargers can top up an EV battery in much less time (as little as 10 or 15 minutes with a charging rate of 500 kW). Another advantage is that, because overhead in-route chargers have pantographs that operate automatically, maintenance crews are not required to plug and unplug the EVs. In-route chargers are a good option for urban systems with buses that cover many daily route miles.

   However, opportunity charging sometimes means that additional layover time must be added to schedules to allow for bus charging. The overhead charging units are also expensive, sometimes $1 million per unit. Property or right-of-way would need to be acquired for the installation of in-route chargers, and utilities must ensure an adequate electrical feed to the site. Being outside, in-route chargers are more susceptible to failure due to vandalism or extreme weather conditions. And, at this time, the in-route chargers on the market only work with transit buses, which doesn’t help the approximately three-quarters of vehicles in Vermont’s transit fleet comprised of vans and cutaways.

7. IT, Training, Maintenance, Safety

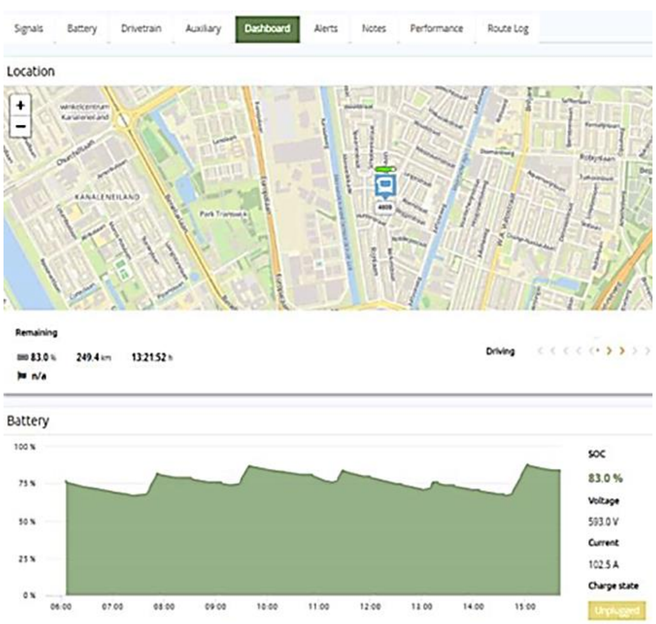
In this portion of the study, the project team examined IT considerations such as telematics and performance monitoring, charge management (or smart charging), and the potential for charging as a service. The training of bus operators, maintenance crews, and first responders was also researched for this study.

Telematics and Performance Monitoring

An often overlooked question for the implementation of electric bus systems is how to monitor the performance of vehicles and chargers and obtain reports that can guide a transit agencies on decisions affecting their service. Telematics helps to answer that question. It's a combination of hardware (placed on buses) and software (on a computer at the depot) that gives real-time information on the following, among other data points:

- Current vehicle state of charge
- State of charge over time
- Remaining range of the vehicle
- Energy charged and used on a given day
- kWh per mile used
- Operator behavior
- Battery health

The system can text or email "push" notifications to operations staff when there is an incident or a problem, while bus operators and supervisors can use easy-to-read dashboards to get a quick snapshot of how the electric buses in the fleet are performing at any time (see images below).



In many cases, electric bus manufacturers provide telematics packages as part of a procurement. However, these systems tend to be limited in scope and reporting capabilities. Third-party companies, such as ViriCiti, offer more comprehensive monitoring (e.g. chargers, in addition to vehicles) and reporting that can be customized according to each agency's needs. Further, their system is a dashboard that can be accessed from any computer in any location, not just at the garage where the vehicles are stored and maintained.

VTrans and the transit agencies in Vermont are advised to determine what their key performance indicators are before launching an electric bus program, and then investing in a telematics system to closely monitor whether those goals are being achieved.

Charge Management

A "smart charging" system is an automated, rule-based vehicle charging network in which electric buses and chargers are monitored and managed via a Wi-Fi-connected smart charging system to determine the priority of charge based on service need and cost to charge. In other words, it's a system that helps agencies take the guesswork out of when to charge electric vehicles, in what order, and for how long.

Smart charging optimizes operations by ensuring that buses are ready for pull-out with the correct state of charge, which increases fleet utilization and decreases anxiety about vehicle range. Additionally, a charge management system can monitor energy use and perform "load balancing", i.e., spreading out the electrical load at a garage over a wider period of time. This helps to decrease the megawatts used overnight while vehicles charge up, saving money.

Smart charging systems should be compatible with Open Charge Point Protocol 1.6 (OCPP 1.6) to enable smart grid integration and automation. Successful deployment of these systems and strategies can optimize electric bus charging times to minimize the maximum electric demand, thereby avoiding costly demand charges and minimizing the total cost of ownership to the agency.

Note that, for smaller transit providers with fewer vehicles, charge management is less critical than for a depot with dozens of buses. For larger fleets, smart charging can be a valuable tool to manage costs and ensure the performance of electric vehicles.

Charging as a Service

Charging as a Service (CaaS) is a subscription-based service provided by a vendor to facilitate the implementation and charging of electric vehicles. An increasing number of companies offer "turnkey solutions" with no up-front costs for equipment and installation, including ChargePoint, Amply, Greenlots, Virta, Lightning, Blink, and others.

In short, the provider bundles all capital and operating expenses, including energy costs, into a fixed rate, which offers a measure of predictability to transit providers and decreases the likelihood of surprisingly expensive utility bills.

Of particular value to transit providers is that CaaS companies manages the permitting and construction process and IT integration at the depot where charging is to take place. Because the vendor manages the charging infrastructure, agencies often see greater up-times for equipment.

Training[11]

The operation of an electric vehicle is different enough from that of a conventional vehicle that it requires specific training. First off, it is important to understand the safety issues that can arise with the incorrect operation of an EV, and that the range of the EV can be adversely affected as well.

Electric bus manufacturers all have training programs that are unique to EVs, and several offer on-site technical support for an additional fee. The training modules come with manuals that explain the safe and efficient operation of the EV in addition to the relationship between the EV, battery capacity, and range.

The literature on electric bus training indicates that operators must, in particular, be aware of:

- Avoiding sudden starts and stops
- The proper use of regenerative braking
- The exact alignment of routes and correct turns (to promote better range)

Similarly, garage crews must also be trained in the preventive maintenance and repair of electric buses. Around 75 percent of a conventional bus and electric bus is the same; however, crews must know how to:

- Safely handle high-voltage systems
- Troubleshoot and service electric propulsion components
- Work with electric bus diagnostic systems

The repair of chargers is highly specialized and generally handled by manufacturers. Also, some electric buses, such as those made by Proterra, have composite bodies rather than metal – making them more difficult to fix if the chassis cracks. Batteries, too, would need servicing by their manufacturers.

To decrease the amount of maintenance needing to be done by local crews, VTrans can explore extended warranties that cover difficult-to-repair items on an electric bus. Further, many agencies around the U.S. have found that leasing buses and/or batteries is preferable to buying them outright, especially when testing and evaluating the performance of electric buses in small numbers.

In either case, transit agencies should be prepared for occasional delays in spare parts – owing to the small number of manufacturers and supply chain issues that are not uncommon with electric buses. Agencies are advised to stockpile spare parts to the extent practicable, to minimize vehicle downtime because of slow supply chains.

The operation and maintenance of electric buses requires not just additional training, but a complete change in mindset among transit agency staff – from planners to schedulers to garage crews. The best way to train operators and crews on electric buses is to:

- Train in small groups
- Have an electric bus or vehicle present during training and allow hands-on familiarity with the equipment; don't rely solely on manuals and videos
- Have a representative of the manufacturer on-site during training as much as possible

[11] *TRB's "Guidebook for Deploying Zero-Emission Transit Buses" TCRP #219, 2021, is a good resource for informing transit agencies about how to train their staffs in the technology changes associated with electric bus.*

- Make sure that staff understands the relationship between correct vehicle operation, maintenance, and battery capacities to vehicle range
- Have electric bus operators consistently operate electric buses; avoid letting them switch frequently between electric and conventional buses, as they may forget how to correctly operate electric vehicles
- Recurrent training
- Partner with regional community colleges and vocational schools to offer courses in BEB technologies

And, finally, electric vehicles have unique safety challenges for first responders[12]. Training courses should cover:

- The basics of electric vehicles and charging infrastructure
- Electrical concepts and electric shock hazards
- Identification methods and initial response procedures
- Emergency operations such as disabling electric vehicles
- Unanticipated vehicle movements and immobilizing vehicles
- High-voltage battery damage and re-ignition
- Vehicle and battery fires, extrication, and submersion
- Incidents involving charging stations and equipment
- Special towing and vehicle recovery considerations

Application to Vermont

Operating an electric vehicle fleet is more complicated than merely buying buses and installing chargers. VTrans and Vermont's transit agencies should consider telematics and performance monitoring systems, smart charging software, and potentially entering into an agreement with a company that offers charging as a service. These tools will remove much of the risk and unexpected costs for Vermont's transit agencies as they move forward into electrifying their fleets.

Further, transit providers should avail themselves of training programs provided by vehicle and charger manufacturers, as the correct and safe operation of electric vehicles and proper maintenance will contribute to the overall success of an agency's deployment.

[12] *"U.S. Emergency Responder Safety Training for Advanced Electric Drive Vehicles" from the National Fire Protection Association (NFPA) is a good resource on this topic.*

8. Financial Analysis and Funding Sources

The goal of the financial analysis was to estimate the cost of Vermont's transition to an electric transit vehicle fleet by 2050. Three scenarios were assessed:

- Existing fleet
- Scenario 1: Buy battery-electric vehicles when existing vehicles reach the end of their useful life
- Scenario 2: Buy battery-electric vehicles to meet the state's mandate:
  - 10 percent of the statewide fleet by 2025
  - 50 percent of Green Mountain Transit's fleet by 2026
  - 100 percent of the statewide fleet by 2050

Assumptions included a constant fleet size, vehicle useful lives, costs, how costs decrease over time, costs of equipment, mid-life overhauls, installation, and vehicles. The project team also understood that:

- 30 buses would be purchased in the first 5 years based on existing contracts
- All costs are assessed in 2021 dollars; no discounting or escalation was applied
- The analysis covers 2022 to 2050 for all agencies in total; except that Green Mountain Transit is called out specifically for Scenario 2
- The analysis considers capital costs only; operating costs are excluded
- Assumes depot chargers are installed when a bus is purchased until enough chargers are available to support the fleet (1-to-1 ratio)
- Current fleet technology can be replaced 1:1 with battery-electric vehicles
- Buses have an assumed useful life of 12 years
- Cutaways have an assumed useful life of 7 years
- Battery-electric bus batteries have an assumed useful life of 7 years, and so their replacement is incorporated in the mid-life overhaul cost

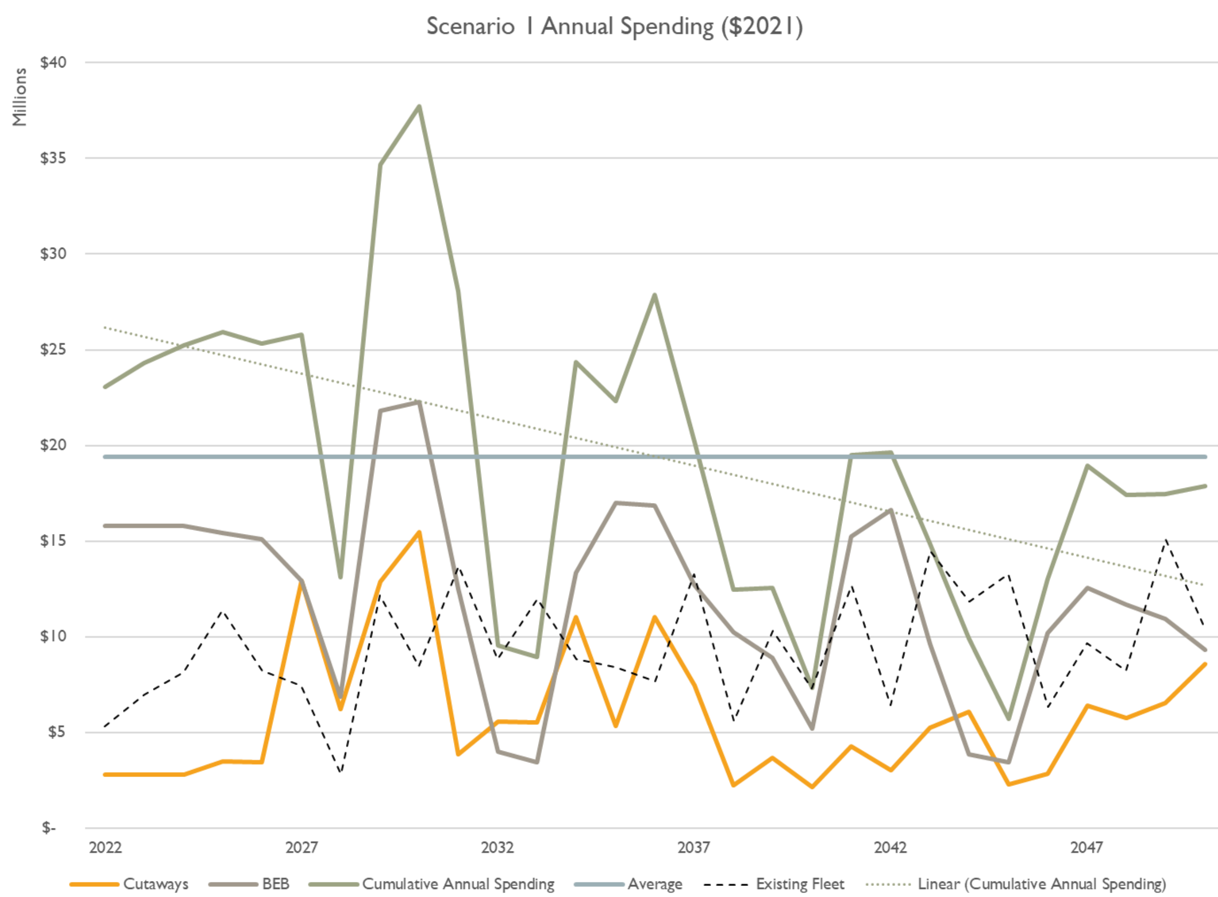
Incorporating the findings of the Route and Block Analysis performed in an earlier section of this document requires an additional level of analysis not performed in this project. The financial analysis performed here is demonstrative of the funds necessary to purchase battery electric vehicles to replace the current fleet.

Capital cost assumptions can be found in the following table.

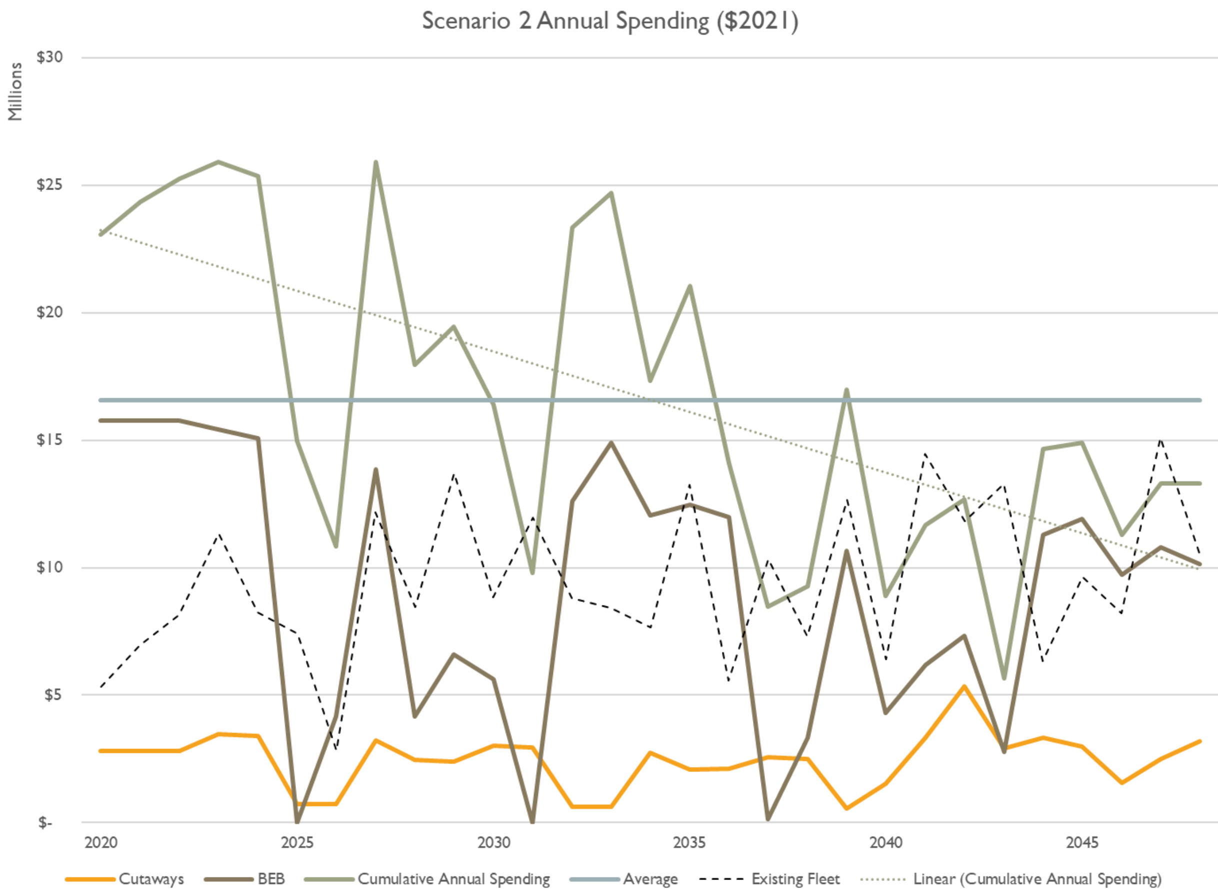
Analysis Assumption	Value	Source/Notes
Cost of Chargers		
Depot Equipment Only, per bus bay, slow charger (2021$)	$60,000	*Included in BEB purchase until there are enough chargers for the fleet
Installation Only, depot, per bus bay, slow charger (2021$)	$50,000	*Included in BEB purchase until there are enough chargers for the fleet
Charging Equipment Replacement Cost at end of useful life (slow charger) (2021$)	$60,000	WMATA BEB Study
Charging Equipment Replacement Cost Installation at end of useful life (slow charger) (2021$)	$10,500	WMATA BEB Study

Cost of Buses		
BEB bus + battery + charger + install + warranty (2019$)	$957,079	From Active Inventory, actual purchase price of BEB
Cutaway BEB + battery + charger + install (2021$)	$200,000	Assumption
ICE (2021$)	$180,000	Assumption
Assumed cost based on fuel type not length, YOE$		
Gas	$72,997	VTrans fleet data
Diesel	$327,397	VTrans fleet data
Hybrid	$21,486	VTrans fleet data
Midlife Overhaul as % of Initial Capital Cost (Diesel, Hybrid, CNG, BEB)	26%	WMATA BEB Study

On the next few pages, the first set of graph and table shows annual spending, in 2021 dollars, under Scenario 1, while the second set of graph and table shows annual spending under Scenario 2.



Year	EV Cutaways	EV Buses	ICE Vehicles	*Total Vehicles to Procure*	*Total Cost*
2022	14	16	25	55	$23,068,132
2023	14	16	32	62	$24,328,132
2024	14	16	37	67	$25,228,132
2025	14	16	39	69	$25,918,155
2026	14	16	38	68	$25,336,665
2027	65	14	0	79	$25,799,152
2028	30	3	0	33	$13,085,084
2029	68	20	0	88	$34,665,605
2030	70	21	0	91	$37,725,712
2031	14	10	65	89	$28,051,185
2032	14	0	0	14	$9,546,277
2033	14	0	0	14	$8,940,206
2034	65	16	0	81	$24,352,478
2035	30	16	0	46	$22,302,876
2036	68	16	0	84	$27,849,133
2037	70	16	0	86	$20,164,092
2038	14	16	0	30	$12,475,890
2039	14	14	0	28	$12,557,128
2040	14	3	0	17	$7,298,637
2041	65	20	0	85	$19,478,251
2042	30	21	0	51	$19,641,686
2043	68	10	0	78	$14,845,074
2044	70	0	0	70	$9,910,645
2045	14	0	0	14	$5,698,568
2046	14	16	0	30	$12,995,024
2047	14	16	0	30	$18,931,230
2048	65	16	0	81	$17,397,926
2049	30	16	0	46	$17,475,445
2050	68	16	0	84	$17,869,285


Scenario 2 Annual Spending ($2021)
Millions
$30
$25
$20
$15
$10
$5
$-
2020
2025
2030
2035
2040
2045
Cutaways
BEB
Cumulative Annual Spending
Average
Existing Fleet
Linear (Cumulative Annual Spending)

Year	EV Cutaways	EV Buses	ICE Vehicles	*Total Vehicles to Procure*	*Total Cost*
2022	14	16	25	55	$23,068,132
2023	14	16	32	62	$24,328,132
2024	14	16	37	67	$25,228,132
2025	14	16	39	69	$25,918,155
2026	14	16	38	68	$25,336,665
2027	0	0	79	79	$14,960,591
2028	0	0	33	33	$10,834,838
2029	14	11	49	74	$25,896,581
2030	14	0	63	77	$17,959,088
2031	14	3	58	75	$19,440,905
2032	14	2	43	59	$16,380,046
2033	14	0	38	52	$9,777,226
2034	0	16	56	72	$23,322,093
2035	0	16	51	67	$24,693,305
2036	14	16	14	44	$17,324,031
2037	14	16	36	66	$21,033,181
2038	14	16	0	30	$14,083,919
2039	14	0	32	46	$8,469,464
2040	14	0	19	33	$9,266,660
2041	0	11	32	43	$16,975,410
2042	0	0	17	17	$8,893,701
2043	14	3	12	29	$11,675,549
2044	34	5	0	39	$12,663,502
2045	34	3	0	37	$5,670,686
2046	34	19	0	53	$14,641,690
2047	34	19	0	53	$14,886,823
2048	20	19	0	39	$11,285,107
2049	20	19	0	39	$13,309,405
2050	34	19	0	53	$13,316,455

Under Scenario 1, internal combustion engines (ICE) will still need to be purchased to maintain fleet size initially. By 2032, the fleet has been fully electrified. Bus purchases will need to either decrease due to change in useful life, the fleet total will change, or ICE buses will need to be purchased again. (This assumes ICE buses are purchased in 2031 because they are less expensive than battery-electric buses and Vermont has reached full fleet.)

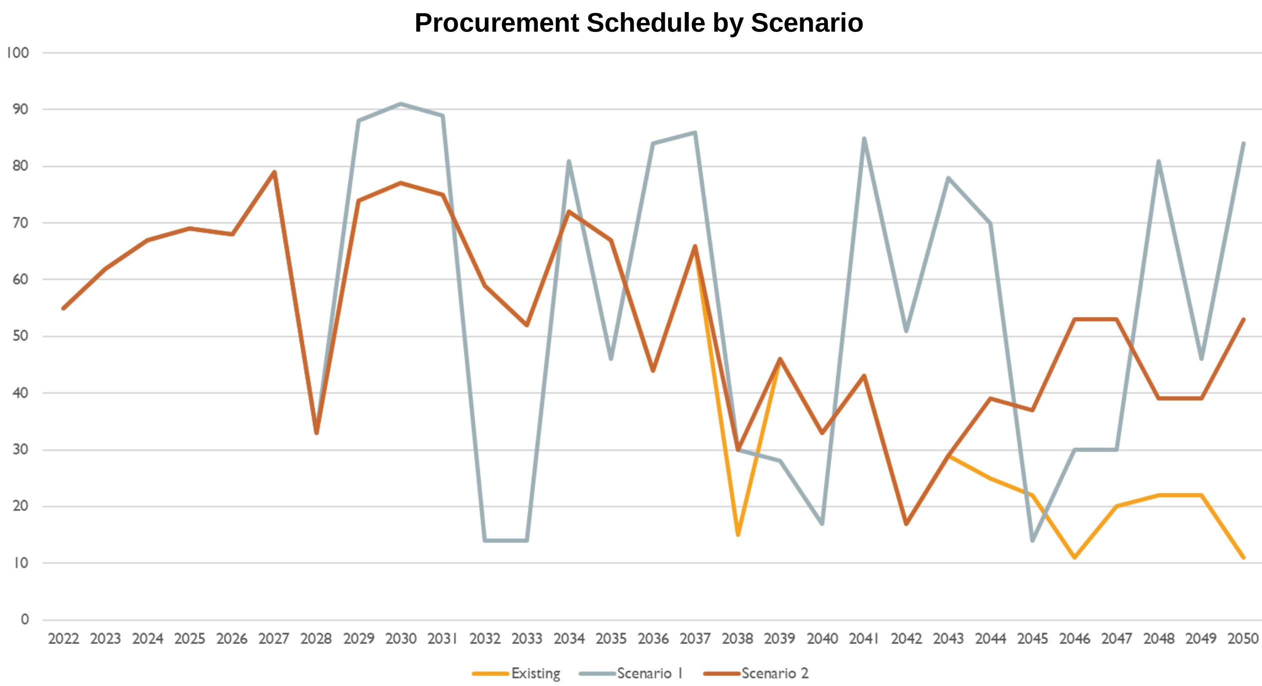
Under Scenario 2, ICE will need to be purchased through much of the analysis period to maintain fleet size. This results in saving costs but is more costly in emissions and not fully switching to electric or using the infrastructure to its fullest.

Extra buses would be purchased in 2022-2026 based on the 30 buses per year assumption; these could go to agencies other than Green Mountain Transit (which reaches 77 percent electrified fleet by 2026).

Because there is a long stretch of time with no mandate, there is no incentive to continue electrifying between 2027 and 2043. Therefore, Vermont must begin purchasing electric vehicles again in 2044 to transition the entire fleet by 2050 in Scenario 2.

	Fleet Size	Total Cost (2022-2050) $2021M	Delta from Existing Fleet $2021M
Existing Fleet	423	$275.0	-
Scenario 1		$562.9	$287.9
Scenario 2		$480.6	$205.6

The graph below shows the procurement schedule of electric buses by scenario.



While the transition of the state's transit fleet to electric vehicles would require a substantial capital investment, a number of federal funding options are available via the Infrastructure Investment and Jobs Act (IIJA). The IIJA modifies existing funding and creates new funding programs to support electrification of transit fleets that would defray the cost of Vermont's electrification program:

- $5.6 billion in existing FTA **Low or No Emission Vehicle Competitive Grants** to support the transition of transit vehicles to low or zero-emission technologies
- $5.1 billion in existing **Buses and Bus Facilities formula and competitive grants** (Sec. 30018 Grants for Buses and Bus Facilities) for which low or zero-emission vehicles are eligible
- Bill that makes electric vehicle charging equipment eligible for funding through existing **Surface Transportation Block Grant Program** (STBGP) and allows for the purchase of zero-emission vehicles in the **Congestion Mitigation and Air Quality Improvement Program**
- Provides $6.4 billion over five years to states by formula through a new **Carbon Reduction Program** for projects supporting a reduction in transportation emissions

    - Eligible projects include transportation electrification, EV charging, public transportation, bicycle and walking corridors, infrastructure to support congestions pricing, port electrification, and diesel engine retrofits (Sec. 11403)
- EV projects remain eligible elements of the existing **RAISE grant program**, funded at $1.5B/year
- FTA's **Public Transportation Innovation Program** (Section 5312) provides funding to develop innovative products and services assisting transit agencies in better meeting the needs of their customers. (No Notice of Funding Opportunity (NOFO) is currently active).
- EPA's **Diesel Emissions Reduction Act** (DERA) program funds grants and rebates that protect human health and improve air quality by reducing harmful emissions from diesel engines. Vermont was allotted $337,000 in FY2021.

9. Conclusions and Recommendations

Upon completion of the analyses described in the previous sections, the following are conclusions and recommendations for VTrans to use in zero-emission decision-making moving forward:

1. There is an increasing awareness of and demand for electric transit vehicles among agencies, but presently there is also limited production capacity among makers of electric buses in particular. The situation is made more complicated by the exclusion of BYD, a Chinese-owned company, from procurements using federal funds. Therefore, VTrans should prioritize ordering electric buses as quickly as is possible before more transit providers in the U.S. develop their own electrification plans and procurements thus reducing availability of supply.

2. VTrans should continue to collaborate with utilities in Vermont on electrical upgrades to bus facilities and on special rates for electric vehicles. This will save the state time and money in the future. Operating cost parity with conventionally fueled transit vehicles depends heavily on utility rates for battery electric bus deployments. Transit agencies are also advised to conduct a more in-depth analysis of infrastructure and space needs at their facilities, including resilience measures such as solar panels and energy storage systems.

3. VTrans should explore the potential for conversion kits in addition to, or as an alternative to, new electric vehicle purchases. Similarly, VTrans should look into the benefits of leasing electric vehicles and batteries as opposed to purchasing them outright.

4. As an alternative to battery leasing, the costs and terms of paying for additional battery warranties over the standard offering should also be weighed as an option as a safeguard against deterioration of the useful life of the vehicles.

5. Because battery technology is rapidly improving, vehicle range and service that would be difficult to fulfill today with electric vehicles may *not* be out of the question in another five or ten years. Therefore, the results of the route and block analysis are merely an indication of what is possible in 2021, but not in the future. VTrans should consider building out the electric bus fleet of Green Mountain Transit – the only urban agency in the state – as it waits for vehicle ranges to improve enough to serve longer routes of rural agencies.

6. Related to the above: more manufacturers are developing light- and medium-duty electric vehicles such as vans and cutaways. Even a few years ago, it was difficult to deploy smaller electric transit vehicles; however, Vermont's rural transit providers may not have to wait much longer if current trends hold.

7. While not strictly "zero-emission", VTrans is advised to use auxiliary diesel heaters on its electric vehicles, as doing so will greatly assist in improving electric vehicle range during colder months.

8. VTrans should consider hydrogen fuel cell vehicles and wireless inductive chargers as options to improve zero emission vehicle performance on presently infeasible routes. These are two technologies that exist, but are uncommon today due to logistical concerns that may be solved in the coming years.

9. Around 86 percent of currently scheduled blocks can be served by an equivalent electric bus, and 54 percent can be served by an electric van or cutaway – both on a single overnight charge. In those cases where existing transit service in the state *cannot* be fulfilled by a 1-to-1 replacement of an existing conventional vehicle with an electric vehicle, VTrans and the state's agencies may consider:

    a. Expanding fleet sizes so that two electric buses can, in some cases, do the work of one conventional bus;
    b. Installing in-route overhead conductive chargers in strategic locations around the state, to allow electric buses to continue operation during the service day via opportunity charging; or
    c. Permitting vehicles assigned to long blocks to return to the depot for midday charging.

    Note that these options are expensive, but may be a preferable alternative to changing schedules and reducing service until battery technology improves to the extent that these measures are not required.

10. VTrans is also advised to:

    a. Use telematics systems for performance monitoring of its electric vehicles and chargers, and to develop key performance indicators in advance of deployments;
    b. Explore whether a charge management system would be beneficial for transit providers;
    c. Investigate working with "charging as a service" companies to facilitate the implementation and charging of electric vehicles; and
    d. Work with manufacturers to provide as much training as possible for operators, maintenance crews, and first responders, as electric vehicle fleets have different requirements than those of conventional fleets.

11. VTrans has already had success in leveraging federal funds for electric bus procurements, and is encouraged to continue applying for as much funding as possible to defray the capital cost of transit electrification. Although the current administration has committed to green transportation and is providing more funding than ever, federal grants remain competitive. Vermont is ahead of the curve by establishing a long-range zero-emission transition plan in accordance with FTA requirements.

Appendix A: Advance Transit (AT)

Operator	Block ID	Route	Calendar Days	Calendar Type	Start Time	End Time	Length (hrs:mins)	Avg Speed (mph)	Vehicle Type	Length (miles)	Deadhead (miles)	Total Length in Miles (Route + Deadhead)	Can This Block Be Served by One Electric Bus?	Can This Block Be Served by One Electric Cutaway or Van?
Advance Transit	1	Blue	Mon-Fri	Year-round	5:15 AM	6:15 PM	13:00	16.19	35' Gillig	294.78	21.40	316.18	no	no
Advance Transit	2	Blue	Mon-Fri	Year-round	5:45 AM	7:10 PM	13:25	16.19	35' Gillig	316.55	21.40	337.95	no	no
Advance Transit	3	Blue	Mon-Fri	Year-round	6:15 AM	6:40 PM	12:25	16.19	35' Gillig	165.53	42.80	208.33	no	no
Advance Transit	6	Brown	Mon-Fri	Year-round	6:25 AM	5:55 PM	11:30	16.19	30' Gillig	142.23	7.00	149.23	no	no
Advance Transit	7	Orange	Mon-Fri	Year-round	6:20 AM	6:25 PM	12:05	16.19	30' Gillig	179.06	7.00	186.06	no	no
Advance Transit	15	Blue	Mon-Fri	Year-round	9:15 AM	6:10 PM	8:55	16.19	30' Gillig	131.07	21.40	152.47	no	no
Advance Transit	41	Green	Mon-Fri	Year-round	5:50 AM	6:08 PM	12:18	16.19	30' Gillig	211.67	3.00	214.67	no	no
Advance Transit	42	Green	Mon-Fri	Year-round	6:10 AM	6:33 PM	12:23	16.19	30' Gillig	214.13	3.00	217.13	no	no
Advance Transit	51	Red	Mon-Fri	Year-round	6:00 AM	6:25 PM	12:25	16.19	35' Gillig	165.61	13.00	178.61	no	no
Advance Transit	52	Red	Mon-Fri	Year-round	8:45 AM	6:35 PM	9:50	16.19	35' Gillig	130.80	13.00	143.80	yes	no
Advance Transit	DHMC20	DHMC Lot 20	Mon-Fri	Year-round	6:00 AM	6:00 PM	12:00	16.19	35' Gillig	132.45	7.50	139.95	yes	no
Advance Transit	DHShuttle1	Dartmouth/Hanover Shuttle	Mon-Fri	School in session only	6:40 AM	7:23 PM	12:43	16.19	Cutaway - 18 passenger	97.79	3.80	101.59	yes	no
Advance Transit	DHShuttle1	Dartmouth/Hanover Shuttle	Mon-Fri	School _ winter Break	6:40 AM	7:23 PM	12:43	16.19	Cutaway - 18 passenger	102.08	3.80	105.88	yes	no
Advance Transit	DHShuttle2	Dartmouth/Hanover Shuttle	Mon-Fri	School in session only	7:10 AM	7:03 PM	11:53	16.19	Cutaway - 18 passenger	97.94	7.60	105.54	yes	no
Advance Transit	DHShuttle2	Dartmouth/Hanover Shuttle	Mon-Fri	School _ winter Break	7:10 AM	7:03 PM	11:53	16.19	Cutaway - 18 passenger	54.03	7.60	61.63	yes	yes
Advance Transit	DHShuttle3	Dartmouth/Hanover Shuttle	Mon-Fri	School in session only	7:20 AM	7:13 PM	11:53	16.19	Cutaway - 18 passenger	66.25	5.40	71.65	yes	yes
Advance Transit	DHShuttle3	Dartmouth/Hanover Shuttle	Mon-Fri	School _ winter Break	7:20 AM	7:13 PM	11:53	16.19	Cutaway - 18 passenger	54.03	5.40	59.43	yes	yes
Advance Transit	DHShuttle4	Dartmouth/Hanover Shuttle	Mon-Fri	School in session only	7:00 PM	9:06 PM	2:06	16.19	Cutaway - 18 passenger	31.55	1.90	33.45	yes	yes
Advance Transit	DHShuttle4	Dartmouth/Hanover Shuttle	Mon-Fri	School _ winter Break	7:00 PM	9:06 PM	2:06	16.19	Cutaway - 18 passenger	31.55	1.90	33.45	yes	yes
Advance Transit	YO	Yellow, Orange	Mon-Fri	Year-round	6:30 AM	5:53 PM	11:23	16.19	30' Gillig	92.97	11.00	103.97	yes	no

Appendix B: Green Mountain Transit / Chittenden County Transportation Authority (GMT / CCTA)

Operator	Block ID	Route	Calendar Days	Calendar Type	Start Time	End Time	Length (hrs:mins)	Avg Speed (mph)	Vehicle Type	Length (miles)	Deadhead (miles)	Total Length in Miles (Route + Deadhead)	Can This Block Be Served by One Electric Bus?	Can This Block Be Served by One Electric Cutaway or Van?
GMT (CCTA)	14	116	Mon-Fri	Year-round	5:25 AM	6:22 AM	0:57	26.60	35'/40'/ vans/cutaways	33.65	3.36	37.01	yes	yes
GMT (CCTA)	15	116	Mon-Fri	Year-round	4:15 PM	5:16 PM	1:01	26.60	35'/40'/ vans/cutaways	31.02	3.10	34.13	yes	yes
GMT (CCTA)	16	115	Mon-Fri	Year-round	5:25 AM	7:10 AM	1:45	14.70	35'/40'/ vans/cutaways	50.65	5.06	55.71	yes	yes
GMT (CCTA)	17	115	Mon-Fri	Year-round	3:15 PM	5:15 PM	2:00	14.70	35'/40'/ vans/cutaways	52.75	5.27	58.02	yes	yes
GMT (CCTA)	26	Neighborhood Specials	MTuThF	School in session only	7:15 AM	8:05 AM	0:50	14.70	35'/40'/ vans/cutaways	9.28	0.93	10.20	yes	yes
GMT (CCTA)	34	Neighborhood Specials	MTuThF	School in session only	7:03 AM	7:55 AM	0:52	14.70	35'/40'/ vans/cutaways	7.17	0.72	7.88	yes	yes
GMT (CCTA)	36	Neighborhood Specials	MTuThF	School in session only	6:50 AM	7:55 AM	1:05	14.70	35'/40'/ vans/cutaways	12.02	1.20	13.23	yes	yes
GMT (CCTA)	37	Neighborhood Specials	MTuThF	School in session only	7:00 AM	7:45 AM	0:45	14.70	35'/40'/ vans/cutaways	6.38	0.64	7.02	yes	yes
GMT (CCTA)	39	Neighborhood Specials	MTuThF	School in session only	7:20 AM	8:00 AM	0:40	14.70	35'/40'/ vans/cutaways	8.08	0.81	8.88	yes	yes
GMT (CCTA)	41	Neighborhood Specials	MTuThF	School in session only	2:45 PM	3:25 PM	0:40	14.70	35'/40'/ vans/cutaways	6.21	0.62	6.83	yes	yes
GMT (CCTA)	42	Neighborhood Specials	MTuThF	School in session only	2:45 PM	3:30 PM	0:45	14.70	35'/40'/ vans/cutaways	7.23	0.72	7.95	yes	yes
GMT (CCTA)	44	Neighborhood Specials	MTuThF	School in session only	2:50 PM	3:30 PM	0:40	14.70	35'/40'/ vans/cutaways	4.73	0.47	5.21	yes	yes
GMT (CCTA)	45	Neighborhood Specials	MTuThF	School in session only	3:00 PM	3:45 PM	0:45	14.70	35'/40'/ vans/cutaways	3.80	0.38	4.18	yes	yes
GMT (CCTA)	47	Neighborhood Specials	MTuThF	School in session only	2:50 PM	3:35 PM	0:45	14.70	35'/40'/ vans/cutaways	3.95	0.39	4.34	yes	yes
GMT (CCTA)	48	Neighborhood Specials	MTuThF	School in session only	2:50 PM	3:50 PM	1:00	14.70	35'/40'/ vans/cutaways	9.77	0.98	10.74	yes	yes
GMT (CCTA)	49	Neighborhood Specials	MTuThF	School in session only	3:10 PM	3:30 PM	0:20	14.70	35'/40'/ vans/cutaways	4.43	0.44	4.87	yes	yes
GMT (CCTA)	101	Red Line, Purple Line	Mon-Fri	Year-round	6:00 AM	2:31 PM	8:31	14.70	35'/40'/ vans/cutaways	82.24	8.22	90.47	yes	yes
GMT (CCTA)	102	Red Line, Blue Line, Gold Loo	Mon-Fri	Year-round	6:00 AM	6:47 PM	12:47	14.70	35'/40'/ vans/cutaways	119.85	11.99	131.84	yes	no
GMT (CCTA)	103	Red Line	Mon-Fri	Year-round	6:00 AM	5:58 PM	11:58	14.70	35'/40'/ vans/cutaways	129.08	12.91	141.99	yes	no
GMT (CCTA)	104	Red Line	Mon-Fri	Year-round	6:20 AM	6:00 PM	11:40	14.70	35'/40'/ vans/cutaways	120.89	12.09	132.98	yes	no
GMT (CCTA)	105	Red Line	Mon-Fri	Year-round	7:10 AM	10:35 AM	3:25	14.70	35'/40'/ vans/cutaways	42.33	4.23	46.56	yes	yes
GMT (CCTA)	106	Red Line, Blue Line	Mon-Fri	Year-round	7:30 AM	8:20 PM	12:50	14.70	35'/40'/ vans/cutaways	145.83	14.58	160.41	no	no
GMT (CCTA)	108	Red Line	Mon-Fri	Year-round	3:20 PM	6:38 PM	3:18	14.70	35'/40'/ vans/cutaways	34.77	3.48	38.25	yes	yes
GMT (CCTA)	201	Blue Line	Mon-Fri	Year-round	6:00 AM	2:30 PM	8:30	14.70	35'/40'/ vans/cutaways	87.93	8.79	96.73	yes	no
GMT (CCTA)	202	Blue Line	Mon-Fri	Year-round	6:00 AM	5:58 PM	11:58	14.70	35'/40'/ vans/cutaways	146.51	14.65	161.16	no	no
GMT (CCTA)	203	Blue Line, Green Line	Mon-Fri	Year-round	6:00 AM	9:15 PM	15:15	14.70	35'/40'/ vans/cutaways	166.93	16.69	183.62	no	no
GMT (CCTA)	204	Blue Line	Mon-Fri	Year-round	6:20 AM	8:00 AM	1:40	14.70	35'/40'/ vans/cutaways	24.69	2.47	27.16	yes	yes
GMT (CCTA)	205	Blue Line	Mon-Fri	Year-round	6:20 AM	10:13 AM	3:53	14.70	35'/40'/ vans/cutaways	49.53	4.95	54.49	yes	yes
GMT (CCTA)	206	Blue Line	Mon-Fri	Year-round	6:20 AM	10:00 AM	3:40	14.70	35'/40'/ vans/cutaways	49.20	4.92	54.12	yes	yes
GMT (CCTA)	207	Green Line, 3	Mon-Fri	Year-round	6:20 AM	8:28 AM	2:08	14.70	35'/40'/ vans/cutaways	23.99	2.40	26.39	yes	yes
GMT (CCTA)	208	Blue Line	Mon-Fri	Year-round	7:00 AM	9:20 AM	2:20	14.70	35'/40'/ vans/cutaways	34.94	3.49	38.44	yes	yes
GMT (CCTA)	209	Blue Line	Mon-Fri	Year-round	4:00 PM	6:35 PM	2:35	14.70	35'/40'/ vans/cutaways	32.33	3.23	35.56	yes	yes
GMT (CCTA)	628	Red Line, Blue Line	Sun	Year-round	8:00 AM	7:00 PM	11:00	14.70	35'/40'/ vans/cutaways	117.06	11.71	128.76	yes	no
GMT (CCTA)	629	Red Line, Green Line, Gold L	Sun	Year-round	8:00 AM	6:53 PM	10:53	14.70	35'/40'/ vans/cutaways	100.71	10.07	110.78	yes	no
GMT (CCTA)	630	Red Line, Purple Line	Sun	Year-round	8:45 AM	6:56 PM	10:11	14.70	35'/40'/ vans/cutaways	105.93	10.59	116.52	yes	no
GMT (CCTA)	632	Blue Line	Sun	Year-round	8:00 AM	6:55 PM	10:55	14.70	35'/40'/ vans/cutaways	108.19	10.82	119.01	yes	no
GMT (CCTA)	634	Blue Line	Sun	Year-round	8:45 AM	7:40 PM	10:55	14.70	35'/40'/ vans/cutaways	108.19	10.82	119.01	yes	no
GMT (CCTA)	637	Red Line, Purple Line, Green	Sun	Year-round	8:00 AM	5:25 PM	9:25	14.70	35'/40'/ vans/cutaways	95.83	9.58	105.41	yes	no
GMT (CCTA)	638	Green Line, Gold Loop	Sun	Year-round	7:40 AM	1:25 PM	5:45	14.70	35'/40'/ vans/cutaways	56.51	5.65	62.16	yes	yes
GMT (CCTA)	701	Red Line, Green Line	Mon-Fri	Year-round	5:30 AM	6:58 PM	13:28	14.70	35'/40'/ vans/cutaways	133.05	13.30	146.35	yes	no
GMT (CCTA)	702	Red Line, 3	MoFr	Year-round	6:05 AM	7:45 PM	13:40	14.70	35'/40'/ vans/cutaways	105.11	10.51	115.62	yes	no
GMT (CCTA)	702	Red Line, 3, 16	Tues	Year-round	6:05 AM	7:45 PM	13:40	14.70	35'/40'/ vans/cutaways	118.87	11.89	130.76	yes	no
GMT (CCTA)	702	Red Line, 3, 19	Th	Year-round	6:05 AM	7:45 PM	13:40	14.70	35'/40'/ vans/cutaways	132.39	13.24	145.63	yes	no

Appendix B: Green Mountain Transit (GMT / CCTA), continued

Operator	Block ID	Route	Calendar Days	Calendar Type	Start Time	End Time	Length (hrs:mins)	Avg Speed (mph)	Vehicle Type	Length (miles)	Deadhead (miles)	Total Length in Miles (Route + Deadhead)	Can This Block Be Served by One Electric Bus?	Can This Block Be Served by One Electric Cutaway or Van?
GMT (CCTA)	702	Red Line, 3, 20	Wed	Year-round	6:05 AM	7:45 PM	13:40	14.70	35'/40'/ vans/cutaways	117.74	11.77	129.51	yes	no
GMT (CCTA)	703	Red Line, 3	Mon-Fri	Year-round	3:23 PM	3:52 PM	0:29	14.70	35'/40'/ vans/cutaways	6.93	0.69	7.62	yes	yes
GMT (CCTA)	704	Red Line	Mon-Fri	Year-round	3:15 PM	3:27 PM	0:12	14.70	35'/40'/ vans/cutaways	2.02	0.20	2.23	yes	yes
GMT (CCTA)	705	Red Line	Mon-Fri	Year-round	3:20 PM	3:32 PM	0:12	14.70	35'/40'/ vans/cutaways	2.02	0.20	2.23	yes	yes
GMT (CCTA)	801	Red Line, Blue Line, Green Li	Mon-Fri	Year-round	6:30 AM	8:25 PM	13:55	14.70	35'/40'/ vans/cutaways	110.54	11.05	121.59	yes	no
GMT (CCTA)	901	Green Line	Mon-Fri	Year-round	6:00 AM	6:41 PM	12:41	14.70	35'/40'/ vans/cutaways	123.58	12.36	135.94	yes	no
GMT (CCTA)	902	Blue Line, Green Line	Mon-Fri	Year-round	6:10 AM	4:00 PM	9:50	14.70	35'/40'/ vans/cutaways	105.16	10.52	115.68	yes	no
GMT (CCTA)	1001	Orange-Silver Line	Mon-Fri	Year-round	6:00 AM	10:45 AM	4:45	14.70	35'/40'/ vans/cutaways	72.87	7.29	80.15	yes	yes
GMT (CCTA)	1002	Orange-Silver Line	Mon-Fri	Year-round	6:45 AM	7:45 AM	1:00	14.70	35'/40'/ vans/cutaways	18.22	1.82	20.04	yes	yes
GMT (CCTA)	1101	Purple Line	Mon-Fri	Year-round	6:00 AM	3:16 PM	9:16	14.70	35'/40'/ vans/cutaways	78.77	7.88	86.65	yes	yes
GMT (CCTA)	1102	Purple Line	Mon-Fri	Year-round	6:45 AM	10:46 AM	4:01	14.70	35'/40'/ vans/cutaways	39.39	3.94	43.32	yes	yes
GMT (CCTA)	1132	Red Line, Green Line, Gold Lo	Sat	Year-round	6:30 AM	11:50 PM	17:20	14.70	35'/40'/ vans/cutaways	150.94	15.09	166.04	no	no
GMT (CCTA)	1165	Green Line	Sat	Year-round	6:00 AM	10:55 PM	16:55	14.70	35'/40'/ vans/cutaways	123.11	12.31	135.42	yes	no
GMT (CCTA)	1166	Green Line	Sat	Year-round	6:10 AM	3:41 PM	9:31	14.70	35'/40'/ vans/cutaways	96.75	9.68	106.43	yes	no
GMT (CCTA)	1167	Orange-Silver Line, Gold Loop	Sat	Year-round	7:15 AM	7:30 PM	12:15	14.70	35'/40'/ vans/cutaways	135.97	13.60	149.57	yes	no
GMT (CCTA)	1168	Red Line, Purple Line	Sat	Year-round	6:00 AM	11:06 PM	17:06	14.70	35'/40'/ vans/cutaways	134.48	13.45	147.93	yes	no
GMT (CCTA)	1170	Purple Line	Sat	Year-round	6:45 AM	10:42 AM	3:57	14.70	35'/40'/ vans/cutaways	38.90	3.89	42.79	yes	yes
GMT (CCTA)	1171	Blue Line, Purple Line	Sat	Year-round	6:30 AM	11:42 PM	17:12	14.70	35'/40'/ vans/cutaways	170.47	17.05	187.51	no	no
GMT (CCTA)	1172	Blue Line	Sat	Year-round	6:30 AM	11:10 AM	4:40	14.70	35'/40'/ vans/cutaways	64.65	6.47	71.12	yes	yes
GMT (CCTA)	1173	Blue Line	Sat	Year-round	7:00 AM	4:10 PM	9:10	14.70	35'/40'/ vans/cutaways	112.44	11.24	123.68	yes	no
GMT (CCTA)	1174	Blue Line	Sat	Year-round	7:00 AM	2:40 PM	7:40	14.70	35'/40'/ vans/cutaways	89.46	8.95	98.40	yes	yes
GMT (CCTA)	1175	Blue Line	Sat	Year-round	3:30 PM	11:35 PM	8:05	14.70	35'/40'/ vans/cutaways	99.59	9.96	109.55	yes	no
GMT (CCTA)	1176	Red Line, Green Line	Sat	Year-round	6:10 AM	7:36 PM	13:26	14.70	35'/40'/ vans/cutaways	129.25	12.92	142.17	yes	no
GMT (CCTA)	1177	Red Line, Blue Line	Sat	Year-round	6:30 AM	7:40 PM	13:10	14.70	35'/40'/ vans/cutaways	149.61	14.96	164.57	no	no
GMT (CCTA)	1178	Red Line	Sat	Year-round	6:30 AM	7:15 PM	12:45	14.70	35'/40'/ vans/cutaways	129.37	12.94	142.31	yes	no
GMT (CCTA)	1179	Red Line	Sat	Year-round	7:00 AM	3:38 PM	8:38	14.70	35'/40'/ vans/cutaways	86.75	8.68	95.43	yes	no
GMT (CCTA)	1180	Red Line, Blue Line, Green Li	Sat	Year-round	7:30 AM	9:15 PM	13:45	14.70	35'/40'/ vans/cutaways	150.44	15.04	165.49	no	no
GMT (CCTA)	2102	Gold Loop	Mon-Fri	Year-round	8:00 AM	9:53 AM	1:53	14.70	35'/40'/ vans/cutaways	16.91	1.69	18.60	yes	yes
GMT (CCTA)	2104	Blue Line	Mon-Fri	Year-round	8:40 AM	11:00 AM	2:20	14.70	35'/40'/ vans/cutaways	32.33	3.23	35.56	yes	yes
GMT (CCTA)	2105	Blue Line	Mon-Fri	Year-round	8:20 AM	12:00 PM	3:40	14.70	35'/40'/ vans/cutaways	47.78	4.78	52.56	yes	yes
GMT (CCTA)	2108	Red Line	Mon-Fri	Year-round	4:00 PM	11:00 PM	7:00	14.70	35'/40'/ vans/cutaways	69.83	6.98	76.82	yes	yes
GMT (CCTA)	2109	Blue Line, Gold Loop	Mon-Fri	Year-round	4:00 PM	11:20 PM	7:20	14.70	35'/40'/ vans/cutaways	74.56	7.46	82.01	yes	yes
GMT (CCTA)	2110	Purple Line	Mon-Fri	Year-round	3:45 PM	11:45 PM	8:00	14.70	35'/40'/ vans/cutaways	78.07	7.81	85.87	yes	yes
GMT (CCTA)	2111	Green Line, 56	Mon-Fri	Year-round	4:05 PM	11:25 PM	7:20	14.70	35'/40'/ vans/cutaways	79.65	7.96	87.61	yes	yes
GMT (CCTA)	2112	Blue Line	Mon-Fri	Year-round	3:40 PM	11:35 PM	7:55	14.70	35'/40'/ vans/cutaways	82.72	8.27	91.00	yes	yes
GMT (CCTA)	3601	36	Mon-Fri	Year-round	5:45 AM	8:05 AM	2:20	26.60	35'/40'/ vans/cutaways	63.50	6.35	69.85	yes	yes
GMT (CCTA)	3602	36	Mon-Fri	Year-round	4:05 PM	6:37 PM	2:32	26.60	35'/40'/ vans/cutaways	65.97	6.60	72.56	yes	yes
GMT (CCTA)	5601	Red Line, 56	Mon-Fri	Year-round	5:50 AM	3:20 PM	9:30	26.60	35'/40'/ vans/cutaways	97.88	9.79	107.67	yes	no
GMT (CCTA)	5602	56, Purple Line	Mon-Fri	Year-round	6:48 AM	8:40 AM	1:52	26.60	35'/40'/ vans/cutaways	38.95	3.89	42.84	yes	yes
GMT (CCTA)	5603	56, Purple Line	Mon-Fri	Year-round	12:15 PM	8:30 PM	8:15	26.60	35'/40'/ vans/cutaways	90.09	9.01	99.10	yes	no
GMT (CCTA)	5604	56	Mon-Fri	Year-round	5:00 PM	6:45 PM	1:45	26.60	35'/40'/ vans/cutaways	38.59	3.86	42.45	yes	yes
GMT (CCTA)	7601	76	Mon-Fri	Year-round	5:05 AM	7:50 AM	2:45	14.70	35'/40'/ vans/cutaways	78.48	7.85	86.32	yes	yes
GMT (CCTA)	7602	76	Mon-Fri	Year-round	4:40 PM	7:15 PM	2:35	14.70	35'/40'/ vans/cutaways	75.57	7.56	83.12	yes	yes

Appendix B: Green Mountain Transit (GMT / CCTA), continued

Operator	Block ID	Route	Calendar Days	Calendar Type	Start Time	End Time	Length (hrs:mins)	Avg Speed (mph)	Vehicle Type	Length (miles)	Deadhead (miles)	Total Length in Miles (Route + Deadhead)	Can This Block Be Served by One Electric Bus?	Can This Block Be Served by One Electric Cutaway or Van?
GMT (CCTA)	8001	80/89, 93	Mon-Fri	Year-round	6:20 AM	1:10 PM	6:50	14.70	35'/40'/ vans/cutaways	95.76	9.58	105.34	yes	no
GMT (CCTA)	8001	80/89	Sat	Year-round	9:30 AM	10:40 AM	1:10	14.70	35'/40'/ vans/cutaways	16.30	1.63	17.93	yes	yes
GMT (CCTA)	8002	80/89, 93	Mon-Fri	Year-round	12:10 PM	3:40 PM	3:30	14.70	35'/40'/ vans/cutaways	56.99	5.70	62.68	yes	yes
GMT (CCTA)	8002	80/89	Sat	Year-round	10:45 AM	3:40 PM	4:55	14.70	35'/40'/ vans/cutaways	65.21	6.52	71.73	yes	yes
GMT (CCTA)	8101	81	Mon-Fri	Year-round	6:55 AM	6:15 PM	11:20	14.70	35'/40'/ vans/cutaways	176.88	17.69	194.57	no	no
GMT (CCTA)	8101	81	Sat	Year-round	7:55 AM	6:02 PM	10:07	14.70	35'/40'/ vans/cutaways	161.89	16.19	178.08	no	no
GMT (CCTA)	8201	82	Mon-Fri	Year-round	7:14 AM	5:48 PM	10:34	14.70	35'/40'/ vans/cutaways	117.82	11.78	129.60	yes	no
GMT (CCTA)	8201	82	Sat	Year-round	8:16 AM	5:48 PM	9:32	14.70	35'/40'/ vans/cutaways	104.13	10.41	114.55	yes	no
GMT (CCTA)	8301	83	Mon-Fri	Year-round	6:40 AM	9:47 AM	3:07	14.70	35'/40'/ vans/cutaways	84.23	8.42	92.65	yes	no
GMT (CCTA)	8302	83	Mon-Fri	Year-round	3:05 PM	6:05 PM	3:00	14.70	35'/40'/ vans/cutaways	81.67	8.17	89.83	yes	yes
GMT (CCTA)	8501	85	Tues	Year-round	9:45 AM	1:15 PM	3:30	14.70	35'/40'/ vans/cutaways	26.73	2.67	29.40	yes	yes
GMT (CCTA)	8701	87	Wed	Year-round	8:45 AM	11:25 AM	2:40	14.70	35'/40'/ vans/cutaways	34.80	3.48	38.28	yes	yes
GMT (CCTA)	8901	80/89, 92	Mon-Fri	Year-round	6:30 AM	5:50 PM	11:20	14.70	35'/40'/ vans/cutaways	96.65	9.66	106.31	yes	no
GMT (CCTA)	8901	80/89	Sat	Year-round	8:00 AM	9:55 AM	1:55	14.70	35'/40'/ vans/cutaways	32.60	3.26	35.86	yes	yes
GMT (CCTA)	8902	80/89	Mon-Fri	Year-round	6:00 AM	10:00 AM	4:00	14.70	35'/40'/ vans/cutaways	63.44	6.34	69.79	yes	yes
GMT (CCTA)	8902	80/89	Sat	Year-round	8:30 AM	7:25 PM	10:55	14.70	35'/40'/ vans/cutaways	81.51	8.15	89.66	yes	yes
GMT (CCTA)	8903	80/89	Mon-Fri	Year-round	3:30 PM	7:30 PM	4:00	14.70	35'/40'/ vans/cutaways	63.88	6.39	70.27	yes	yes
GMT (CCTA)	8903	80/89	Sat	Year-round	4:00 PM	6:55 PM	2:55	14.70	35'/40'/ vans/cutaways	48.91	4.89	53.80	yes	yes
GMT (CCTA)	8904	80/89	Mon-Fri	Year-round	4:00 PM	7:00 PM	3:00	14.70	35'/40'/ vans/cutaways	48.02	4.80	52.82	yes	yes
GMT (CCTA)	9201	92	Mon-Fri	Year-round	6:50 AM	9:30 AM	2:40	14.70	35'/40'/ vans/cutaways	29.72	2.97	32.69	yes	yes
GMT (CCTA)	9202	92	Mon-Fri	Year-round	10:50 AM	1:30 PM	2:40	14.70	35'/40'/ vans/cutaways	29.72	2.97	32.69	yes	yes
GMT (CCTA)	9301	93	Mon-Fri	Year-round	4:30 PM	6:35 PM	2:05	14.70	35'/40'/ vans/cutaways	48.39	4.84	53.23	yes	yes
GMT (CCTA)	9304	84	Mon-Fri	Year-round	12:05 PM	1:30 PM	1:25	14.70	35'/40'/ vans/cutaways	36.75	3.68	40.43	yes	yes
GMT (CCTA)	9601	96	Mon-Fri	Year-round	5:40 AM	7:40 AM	2:00	26.60	35'/40'/ vans/cutaways	65.66	6.57	72.23	yes	yes
GMT (CCTA)	9602	96	Mon-Fri	Year-round	4:33 PM	6:40 PM	2:07	26.60	35'/40'/ vans/cutaways	66.91	6.69	73.60	yes	yes
GMT (CCTA)	102B	Red Line	Mon-Fri	Year-round	12:00 PM	6:35 PM	6:35	14.70	35'/40'/ vans/cutaways	68.32	6.83	75.15	yes	yes
GMT (CCTA)	102C	Green Line	Mon-Fri	Year-round	3:00 PM	7:25 PM	4:25	14.70	35'/40'/ vans/cutaways	48.02	4.80	52.82	yes	yes
GMT (CCTA)	109C	109	Tues	Year-round	10:00 AM	1:35 PM	3:35	14.70	35'/40'/ vans/cutaways	27.73	2.77	30.50	yes	yes
GMT (CCTA)	110-1	110	Mon-Fri	Year-round	6:45 AM	9:26 AM	2:41	14.70	35'/40'/ vans/cutaways	33.83	3.38	37.21	yes	yes
GMT (CCTA)	110-2	110	Mon-Fri	Year-round	9:45 AM	1:26 PM	3:41	14.70	35'/40'/ vans/cutaways	45.11	4.51	49.62	yes	yes
GMT (CCTA)	110-3	110	Mon-Fri	Year-round	1:45 PM	5:40 PM	3:55	14.70	35'/40'/ vans/cutaways	45.11	4.51	49.62	yes	yes
GMT (CCTA)	110-S	110	Sat	Year-round	9:45 AM	3:26 PM	5:41	14.70	35'/40'/ vans/cutaways	61.61	6.16	67.77	yes	yes
GMT (CCTA)	1132B	Red Line, Gold Loop	Sat	Year-round	9:00 AM	7:06 PM	10:06	14.70	35'/40'/ vans/cutaways	90.78	9.08	99.86	yes	no
GMT (CCTA)	1132C	Gold Loop	Sat	Year-round	2:30 PM	3:53 PM	1:23	14.70	35'/40'/ vans/cutaways	12.54	1.25	13.79	yes	yes
GMT (CCTA)	1165B	Red Line	Sat	Year-round	11:30 AM	4:06 PM	4:36	14.70	35'/40'/ vans/cutaways	51.69	5.17	56.86	yes	yes
GMT (CCTA)	1165C	Blue Line	Sat	Year-round	7:30 AM	3:10 PM	7:40	14.70	35'/40'/ vans/cutaways	96.98	9.70	106.68	yes	no
GMT (CCTA)	1167B	Blue Line, Orange-Silver Line	Sat	Year-round	11:00 AM	11:22 PM	12:22	14.70	35'/40'/ vans/cutaways	168.50	16.85	185.35	no	no
GMT (CCTA)	1167C	Red Line	Sat	Year-round	4:00 PM	8:36 PM	4:36	14.70	35'/40'/ vans/cutaways	51.40	5.14	56.54	yes	yes
GMT (CCTA)	1168B	Purple Line	Sat	Year-round	10:30 AM	8:27 PM	9:57	14.70	35'/40'/ vans/cutaways	90.64	9.06	99.71	yes	no
GMT (CCTA)	1174B	Blue Line	Sat	Year-round	9:30 AM	12:52 PM	3:22	14.70	35'/40'/ vans/cutaways	39.85	3.99	43.84	yes	yes
GMT (CCTA)	1178B	Green Line	Sat	Year-round	11:00 AM	8:25 PM	9:25	14.70	35'/40'/ vans/cutaways	91.48	9.15	100.63	yes	no
GMT (CCTA)	1178C	Red Line, Gold Loop	Sat	Year-round	4:00 PM	8:15 PM	4:15	14.70	35'/40'/ vans/cutaways	41.99	4.20	46.19	yes	yes
GMT (CCTA)	202B	Blue Line	Mon-Fri	Year-round	10:30 AM	7:26 PM	8:56	14.70	35'/40'/ vans/cutaways	113.85	11.39	125.24	yes	no

Appendix B: Green Mountain Transit (GMT / CCTA), continued

Operator	Block ID	Route	Calendar Days	Calendar Type	Start Time	End Time	Length (hrs:mins)	Avg Speed (mph)	Vehicle Type	Length (miles)	Deadhead (miles)	Total Length in Miles (Route + Deadhead)	Can This Block Be Served by One Electric Bus?	Can This Block Be Served by One Electric Cutaway or Van?
GMT (CCTA)	203B	Blue Line	Mon-Fri	Year-round	11:20 AM	3:30 PM	4:10	14.70	35'/40'/ vans/cutaways	47.78	4.78	52.56	yes	yes
GMT (CCTA)	203C	Red Line	Mon-Fri	Year-round	3:00 PM	7:15 PM	4:15	14.70	35'/40'/ vans/cutaways	42.33	4.23	46.56	yes	yes
GMT (CCTA)	203D	Red Line	Mon-Fri	Year-round	12:40 PM	11:40 PM	11:00	14.70	35'/40'/ vans/cutaways	119.72	11.97	131.69	yes	no
GMT (CCTA)	207B	Blue Line	Mon-Fri	Year-round	6:40 AM	9:00 AM	2:20	14.70	35'/40'/ vans/cutaways	32.33	3.23	35.56	yes	yes
GMT (CCTA)	2104B	Green Line	Mon-Fri	Year-round	8:30 AM	9:41 AM	1:11	14.70	35'/40'/ vans/cutaways	15.31	1.53	16.84	yes	yes
GMT (CCTA)	5601B	Red Line, Orange-Silver Line	Mon-Fri	Year-round	10:30 AM	7:30 PM	9:00	14.70	35'/40'/ vans/cutaways	98.57	9.86	108.42	yes	no
GMT (CCTA)	632B	Red Line, Blue Line	Sun	Year-round	12:30 PM	7:15 PM	6:45	14.70	35'/40'/ vans/cutaways	69.00	6.90	75.89	yes	yes
GMT (CCTA)	638B	Red Line, Green Line, Purple	Sun	Year-round	11:00 AM	7:45 PM	8:45	14.70	35'/40'/ vans/cutaways	88.05	8.80	96.85	yes	yes
GMT (CCTA)	702B	Red Line	Mon-Fri	Year-round	9:30 AM	1:00 PM	3:30	14.70	35'/40'/ vans/cutaways	42.33	4.23	46.56	yes	yes
GMT (CCTA)	801B	Blue Line, Orange-Silver Line	Mon-Fri	Year-round	11:00 AM	7:20 PM	8:20	14.70	35'/40'/ vans/cutaways	103.63	10.36	114.00	yes	no
GMT (CCTA)	801C	Blue Line	Mon-Fri	Year-round	12:20 PM	6:07 PM	5:47	14.70	35'/40'/ vans/cutaways	66.40	6.64	73.04	yes	yes
GMT (CCTA)	8601CCTA	86	Mon-Fri	Year-round	6:15 AM	8:50 AM	2:35	26.60	35'/40'/ vans/cutaways	86.78	8.68	95.46	yes	yes
GMT (CCTA)	8601GMT	86	Mon-Fri	Year-round	5:42 AM	8:10 AM	2:28	26.60	35'/40'/ vans/cutaways	84.31	8.43	92.74	yes	yes
GMT (CCTA)	8602CCTA	86	Mon-Fri	Year-round	3:43 PM	5:40 PM	1:57	26.60	35'/40'/ vans/cutaways	63.91	6.39	70.30	yes	yes
GMT (CCTA)	8602GMT	86	Mon-Fri	Year-round	6:40 AM	8:55 AM	2:15	26.60	35'/40'/ vans/cutaways	84.31	8.43	92.74	yes	yes
GMT (CCTA)	8603CCTA	86	Mon-Fri	Year-round	3:53 PM	6:20 PM	2:27	26.60	35'/40'/ vans/cutaways	84.52	8.45	92.98	yes	yes
GMT (CCTA)	8603GMT	86	Mon-Fri	Year-round	12:02 PM	2:25 PM	2:23	26.60	35'/40'/ vans/cutaways	84.70	8.47	93.17	yes	yes
GMT (CCTA)	8604CCTA	86	Mon-Fri	Year-round	4:38 PM	7:15 PM	2:37	26.60	35'/40'/ vans/cutaways	86.28	8.63	94.91	yes	yes
GMT (CCTA)	8604GMT	86	Mon-Fri	Year-round	4:07 PM	6:40 PM	2:33	26.60	35'/40'/ vans/cutaways	84.70	8.47	93.17	yes	yes
GMT (CCTA)	MTN1	108	Mon-Fri	Seasonal - Winter	6:30 AM	12:30 PM	6:00	14.70	35'/40'/ vans/cutaways	110.05	11.01	121.06	yes	no
GMT (CCTA)	MTN1	108	Sat	Seasonal - Winter	6:30 AM	12:30 PM	6:00	14.70	35'/40'/ vans/cutaways	110.05	11.01	121.06	yes	no
GMT (CCTA)	MTN1	108	Sun	Seasonal - Winter	6:30 AM	12:30 PM	6:00	14.70	35'/40'/ vans/cutaways	110.05	11.01	121.06	yes	no
GMT (CCTA)	MTN2	108	Mon-Fri	Seasonal - Winter	12:00 PM	9:00 PM	9:00	14.70	35'/40'/ vans/cutaways	146.73	14.67	161.41	no	no
GMT (CCTA)	MTN2	108	Sat	Seasonal - Winter	7:00 AM	12:00 PM	5:00	14.70	35'/40'/ vans/cutaways	91.71	9.17	100.88	yes	no
GMT (CCTA)	MTN2	108	Sun	Seasonal - Winter	12:00 PM	9:00 PM	9:00	14.70	35'/40'/ vans/cutaways	146.73	14.67	161.41	no	no
GMT (CCTA)	MTN3	108	Mon-Fri	Seasonal - Winter	12:30 PM	7:00 PM	6:30	14.70	35'/40'/ vans/cutaways	110.05	11.01	121.06	yes	no
GMT (CCTA)	MTN3	108	Sat	Seasonal - Winter	12:00 PM	5:00 PM	5:00	14.70	35'/40'/ vans/cutaways	73.37	7.34	80.70	yes	yes
GMT (CCTA)	MTN3	108	Sun	Seasonal - Winter	12:30 PM	7:00 PM	6:30	14.70	35'/40'/ vans/cutaways	110.05	11.01	121.06	yes	no
GMT (CCTA)	MTN4	108	Sat	Seasonal - Winter	12:30 PM	6:30 PM	6:00	14.70	35'/40'/ vans/cutaways	91.71	9.17	100.88	yes	no
GMT (CCTA)	MTN5	108	Sat	Seasonal - Winter	2:00 PM	9:00 PM	7:00	14.70	35'/40'/ vans/cutaways	110.05	11.01	121.06	yes	no
GMT (CCTA)	MTN6	108	Sat	Seasonal - Winter	4:00 PM	10:00 PM	6:00	14.70	35'/40'/ vans/cutaways	110.05	11.01	121.06	yes	no
GMT (CCTA)	SB5	122	Mon-Sun	Seasonal - Winter	8:00 AM	5:00 PM	9:00	14.70	35'/40'/ vans/cutaways	134.86	13.49	148.34	yes	no
GMT (CCTA)	SB6	125, 124	Mon-Fri	Seasonal - Winter	8:00 AM	5:40 PM	9:40	14.70	35'/40'/ vans/cutaways	60.43	6.04	66.47	yes	yes
GMT (CCTA)	SB7	125	Sat-Sun	Seasonal - Winter	8:00 AM	5:38 PM	9:38	14.70	35'/40'/ vans/cutaways	116.20	11.62	127.82	yes	no
GMT (CCTA)	SB8	124	Sat-Sun	Seasonal - Winter	8:00 AM	5:35 PM	9:35	14.70	35'/40'/ vans/cutaways	61.78	6.18	67.96	yes	yes
GMT (CCTA)	T-46	88	Mon-Fri	Year-round	7:20 AM	11:00 AM	3:40	14.70	35'/40'/ vans/cutaways	41.84	4.18	46.03	yes	yes
GMT (CCTA)	T-47	88	Mon-Fri	Year-round	11:00 AM	3:00 PM	4:00	14.70	35'/40'/ vans/cutaways	45.65	4.56	50.21	yes	yes
GMT (CCTA)	T-48	88	Mon-Fri	Year-round	3:00 PM	5:25 PM	2:25	14.70	35'/40'/ vans/cutaways	28.22	2.82	31.04	yes	yes
GMT (CCTA)	Tilley	Tilley Drive Shuttle	Mon-Fri	Year-round	7:30 AM	4:55 PM	9:25	14.70	35'/40'/ vans/cutaways	46.97	4.70	51.67	yes	yes
GMT (CCTA)	VFA	124, 125	Mon-Fri	Seasonal - Winter	8:00 AM	1:40 PM	5:40	14.70	35'/40'/ vans/cutaways	83.05	8.30	91.35	yes	no
GMT (CCTA)	VFA	124, 125	Sat-Sun	Seasonal - Winter	8:00 AM	2:15 PM	6:15	14.70	35'/40'/ vans/cutaways	89.94	8.99	98.94	yes	no
GMT (CCTA)	VFB	120	Mon-Fri	Seasonal - Winter	2:00 PM	4:40 PM	2:40	14.70	35'/40'/ vans/cutaways	58.56	5.86	64.42	yes	yes
GMT (CCTA)	VFB	120	Sat-Sun	Seasonal - Winter	2:00 PM	4:40 PM	2:40	14.70	35'/40'/ vans/cutaways	58.56	5.86	64.42	yes	yes
GMT (CCTA)	VFA	122	Mon-Sun	Seasonal - Winter	12:00 PM	1:00 PM	1:00	14.70	35'/40'/ vans/cutaways	16.86	1.69	18.54	yes	yes

Appendix B: Green Mountain Transit (GMT / CCTA), continued

Operator	Block ID	Route	Calendar Days	Calendar Type	Start Time	End Time	Length (hrs:mins)	Avg Speed (mph)	Vehicle Type	Length (miles)	Deadhead (miles)	Total Length in Miles (Route + Deadhead)	Can This Block Be Served by One Electric Bus?	Can This Block Be Served by One Electric Cutaway or Van?
GMT (CCTA)	203B	Blue Line	Mon-Fri	Year-round	11:20 AM	3:30 PM	4:10	14.70	35'/40'/ vans/cutaways	47.78	4.78	52.56	yes	yes
GMT (CCTA)	203C	Red Line	Mon-Fri	Year-round	3:00 PM	7:15 PM	4:15	14.70	35'/40'/ vans/cutaways	42.33	4.23	46.56	yes	yes
GMT (CCTA)	203D	Red Line	Mon-Fri	Year-round	12:40 PM	11:40 PM	11:00	14.70	35'/40'/ vans/cutaways	119.72	11.97	131.69	yes	no
GMT (CCTA)	207B	Blue Line	Mon-Fri	Year-round	6:40 AM	9:00 AM	2:20	14.70	35'/40'/ vans/cutaways	32.33	3.23	35.56	yes	yes

Appendix C: Southeast Vermont Transit (SEVT)

Operator	Block ID	Route	Calendar Days	Calendar Type	Start Time	End Time	Length (hrs:mins)	Avg Speed (mph)	Vehicle Type	Length (miles)	Deadhead (miles)	Total Length in Miles (Route + Deadhead)	Can This Block Be Served by One Electric Bus?	Can This Block Be Served by One Electric Cutaway or Van?
SEVT	2149	Current - 1	Mon-Fri	Year-round	9:00 AM	1:59 PM	4:59	17.75	35' / 40' / cutaways	82.76	8.28	91.04	yes	no
SEVT	2150	Current - 2	Mon-Fri	Year-round	9:00 AM	12:00 PM	3:00	17.75	35' / 40' / cutaways	61.39	6.14	67.53	yes	yes
SEVT	2152	Current - 1	Mon-Fri	Year-round	2:30 PM	3:44 PM	1:14	17.75	35' / 40' / cutaways	20.69	2.07	22.76	yes	yes
SEVT	2154	Current - 53	Mon-Fri	Year-round	2:10 PM	6:05 PM	3:55	36.00	35' / 40' / cutaways	97.08	9.71	106.79	yes	no
SEVT	2155	Current - 53	Mon-Fri	Year-round	5:50 AM	9:57 AM	4:07	36.00	35' / 40' / cutaways	96.91	9.69	106.60	yes	no
SEVT	2156	Current - 57	Mon-Fri	Year-round	6:35 AM	11:30 AM	4:55	36.00	35' / 40' / cutaways	131.84	13.18	145.02	yes	no
SEVT	2157	Current - 57	Mon-Fri	Year-round	3:36 PM	6:01 PM	2:25	36.00	35' / 40' / cutaways	66.56	6.66	73.22	yes	yes
SEVT	110829	Current - 71	Mon-Fri	Year-round	5:30 AM	5:05 PM	11:35	17.75	35' / 40' / cutaways	92.90	9.29	102.19	yes	no
SEVT	110830	Current - 72	Mon-Fri	Year-round	6:30 AM	6:05 PM	11:35	17.75	35' / 40' / cutaways	92.91	9.29	102.20	yes	no
SEVT	110831	Current - 73	Mon-Fri	Year-round	5:15 AM	5:20 PM	12:05	17.75	35' / 40' / cutaways	101.76	10.18	111.93	yes	no
SEVT	111025	Current - 4,7	Mon-Sat	Year-round	8:15 AM	4:48 PM	8:33	17.75	35' / 40' / cutaways	121.21	12.12	133.33	yes	no
SEVT	111026	Current - 4,7	Mon-Sat	Year-round	8:46 AM	5:20 PM	8:34	17.75	35' / 40' / cutaways	114.93	11.49	126.43	yes	no
SEVT	Okemo 61A	Current - 61A	Mon-Fri	Seasonal - Winter	6:47 AM	6:23 PM	11:36	17.75	35' / 40' / cutaways	139.91	13.99	153.90	no	no
SEVT	Okemo 61A	Current - 61A	Sat-Sun	Seasonal - Winter	5:45 AM	6:15 PM	12:30	17.75	35' / 40' / cutaways	203.49	20.35	223.84	no	no
SEVT	3784	Moover - Mount Snow	Mon-Fri	Seasonal - Winter	8:00 AM	5:20 PM	9:20	17.75	35' / 40' / cutaways	67.07	6.71	73.78	yes	yes
SEVT	3785	Moover - Mount Snow	Sat-sun	Seasonal - Winter	7:00 AM	5:05 PM	10:05	17.75	35' / 40' / cutaways	61.51	6.15	67.66	yes	yes
SEVT	3786	Moover - Mount Snow	Sat-sun	Seasonal - Winter	8:15 AM	5:05 PM	8:50	17.75	35' / 40' / cutaways	54.43	5.44	59.87	yes	yes
SEVT	3792	Moover - Readsboro-W. Wilm	Mon-Sun	Year-round	6:55 AM	8:00 AM	1:05	17.75	35' / 40' / cutaways	31.68	3.17	34.84	yes	yes
SEVT	3793	Moover - Readsboro-W. Wilm	Mon-Fri	School in session only	4:30 PM	5:00 PM	0:30	17.75	35' / 40' / cutaways	14.97	1.50	16.47	yes	yes
SEVT	3794	Moover - West Dover	Mon-Fri	School in session only	7:00 AM	9:15 AM	2:15	17.75	35' / 40' / cutaways	105.35	10.53	115.88	yes	no
SEVT	3795	Moover - Wilmington-Brattlebo	Mon-Fri	School in session only	3:00 PM	4:30 PM	1:30	17.75	35' / 40' / cutaways	94.40	9.44	103.84	yes	no
SEVT	3796	Moover - Wilmington-Brattlebo	Mon-Fri	Year-round	7:00 AM	9:45 AM	2:45	17.75	35' / 40' / cutaways	78.30	7.83	86.13	yes	yes
SEVT	3797	Moover - Wilmington-Brattlebo	Mon-Fri	Year-round	1:30 PM	5:55 PM	4:25	17.75	35' / 40' / cutaways	114.72	11.47	126.20	yes	no
SEVT	3798	Moover - Wilmington-Brattlebo	Sat-sun	Year-round	9:00 AM	10:30 AM	1:30	17.75	35' / 40' / cutaways	40.07	4.01	44.08	yes	yes
SEVT	3799	Moover - Readsboro-W. Wilm	Mon-Sun	Year-round	5:00 PM	6:10 PM	1:10	17.75	35' / 40' / cutaways	33.21	3.32	36.53	yes	yes
SEVT	3799	Moover - Wilmington-Brattlebo	Sat-sun	Year-round	3:00 PM	4:30 PM	1:30	17.75	35' / 40' / cutaways	40.07	4.01	44.08	yes	yes
SEVT	3800	Moover - Wilmington-Benning	Mon-Fri	Summer only	7:00 AM	9:40 AM	2:40	17.75	35' / 40' / cutaways	84.50	8.45	92.95	yes	yes
SEVT	3801	Moover - Wilmington-Benning	Mon-Fri	Summer only	3:20 PM	5:15 PM	1:55	17.75	35' / 40' / cutaways	42.32	4.23	46.55	yes	yes
SEVT	3842	Moover - Wilmington-West Do	Mon-Fri	Seasonal - Winter	6:45 AM	2:55 PM	8:10	17.75	35' / 40' / cutaways	167.31	16.73	184.05	no	no
SEVT	3843	Moover - Wilmington-West Do	Mon-Fri	Seasonal - Winter	3:00 PM	10:55 PM	7:55	17.75	35' / 40' / cutaways	167.31	16.73	184.05	no	no
SEVT	3844	Moover - Wilmington-West Do	Sat-sun	Seasonal - Winter	5:45 AM	2:55 PM	9:10	17.75	35' / 40' / cutaways	188.23	18.82	207.05	no	no
SEVT	3845	Moover - Wilmington-West Do	Sat-sun	Seasonal - Winter	3:00 PM	10:55 PM	7:55	17.75	35' / 40' / cutaways	167.31	16.73	184.05	no	no
SEVT	3848	Moover - Wilmington-West Do	Sat-sun	Seasonal - Winter	8:30 AM	4:25 PM	7:55	17.75	35' / 40' / cutaways	167.31	16.73	184.05	no	no
SEVT	3851	Moover - SMV-Upper SnowTre	Sat-sun	Seasonal - Winter	7:00 AM	5:15 PM	10:15	17.75	35' / 40' / cutaways	53.62	5.36	58.98	yes	yes
SEVT	118074	Moover - Mount Snow	Mon-Fri	Seasonal - Winter	8:00 AM	5:15 PM	9:15	17.75	35' / 40' / cutaways	32.86	3.29	36.15	yes	yes
SEVT	134078	Moover - Wilmington-West Do	Mon-Sun	Seasonal - Winter	5:00 PM	5:25 PM	0:25	17.75	35' / 40' / cutaways	10.03	1.00	11.03	yes	yes

Appendix D: Green Mountain Community Network (GMCN)

Operator	Block ID	Route	Calendar Days	Calendar Type	Start Time	End Time	Length (hrs:mins)	Avg Speed (mph)	Vehicle Type	Length (miles)	Deadhead (miles)	Total Length in Miles (Route + Deadhead)	Can This Block Be Served by One Electric Bus?	Can This Block Be Served by One Electric Cutaway or Van?
GMCN	2147	Purple Line	Mon-Fri	School in session only	12:10 PM	4:20 PM	4:10	19.66	20-Passenger Gas E-450	87.75	0.00	87.75	yes	yes
GMCN	2147	Purple Line	Mon-Fri	No-School	12:10 PM	4:20 PM	4:10	19.66	20-Passenger Gas E-450	85.08	0.00	85.08	yes	yes
GMCN	2148	Purple Line	Mon-Fri	School in session only	7:00 AM	10:55 AM	3:55	19.66	20-Passenger Gas E-450	91.62	0.00	91.62	yes	no
GMCN	2148	Purple Line	Mon-Fri	No-School	7:00 AM	10:55 AM	3:55	19.66	20-Passenger Gas E-450	85.08	0.00	85.08	yes	yes
GMCN	109711	Blue Line	MTuTh	Year-round	2:17 PM	4:13 PM	1:56	19.66	20-Passenger Gas E-450	109.13	0.00	109.13	yes	no
GMCN	109711	Blue Line	WF	Year-round	2:17 PM	4:13 PM	1:56	19.66	20-Passenger Gas E-450	110.05	0.00	110.05	yes	no
GMCN	109712	Brown Line	Mon-Fri	Summer only	7:25 AM	5:15 PM	9:50	19.66	20-Passenger Gas E-450	134.19	0.00	134.19	yes	no
GMCN	109712	Brown Line	Mon-Fri	School in session only	7:25 AM	5:15 PM	9:50	19.66	20-Passenger Gas E-450	116.95	0.00	116.95	yes	no
GMCN	109713	Emerald Line	Mon-Fri	Summer only	6:55 AM	5:30 PM	10:35	19.66	20-Passenger Gas E-450	126.99	0.00	126.99	yes	no
GMCN	109713	Emerald Line	Mon-Fri	School in session only	6:55 AM	5:15 PM	10:20	19.66	20-Passenger Gas E-450	129.81	0.00	129.81	yes	no
GMCN	109713	Emerald Line	Mon-Fri	No-School	6:55 AM	5:15 PM	10:20	19.66	20-Passenger Gas E-450	126.99	0.00	126.99	yes	no
GMCN	109714	Green Line	Sat	Year-round	11:00 AM	5:33 PM	6:33	19.66	20-Passenger Gas E-450	69.77	0.00	69.77	yes	yes
GMCN	109715	Light Green Line	Sat	Year-round	11:17 AM	5:50 PM	6:33	19.66	20-Passenger Gas E-450	80.20	0.00	80.20	yes	yes
GMCN	109716	Orange Line	Mon-Fri	Year-round	6:15 AM	7:10 PM	12:55	19.66	20-Passenger Gas E-450	296.50	0.00	296.50	no	no
GMCN	109716	Orange Line	Sat	Year-round	6:15 AM	5:05 PM	10:50	19.66	20-Passenger Gas E-450	120.56	0.00	120.56	yes	no
GMCN	109717	Red Line	Mon-Fri	Year-round	8:00 AM	5:59 PM	9:59	19.66	20-Passenger Gas E-450	148.87	0.00	148.87	yes	no

Appendix E: Rural Community Transportation (RCT)

Operator	Block ID	Route	Calendar Days	Calendar Type	Start Time	End Time	Length (hrs:mins)	Avg Speed (mph)	Vehicle Type	Length (miles)	Deadhead (miles)	Total Length in Miles (Route + Deadhead)	Can This Block Be Served by One Electric Bus?	Can This Block Be Served by One Electric Cutaway or Van?
RCT	8576	Greenleaf	Tues	Year-round	12:00 PM	2:05 PM	2:05	14.90	cutaways	46.70	4.67	51.37	yes	yes
RCT	8577	Greenleaf	Tues	Year-round	3:30 PM	5:20 PM	1:50	14.90	cutaways	47.29	4.73	52.02	yes	yes
RCT	8578	Jay-Lyn	Mon-Fri	Year-round	5:15 AM	5:50 PM	12:35	14.90	cutaways	170.94	17.09	188.04	no	no
RCT	8579	Jay-Lyn	Mon-Fri	Year-round	8:10 AM	6:10 PM	10:00	14.90	cutaways	141.73	14.17	155.91	no	no
RCT	8582	Johnson Shopper	Thurs	Year-round	9:20 AM	10:40 AM	1:20	14.90	cutaways	20.87	2.09	22.95	yes	yes
RCT	8583	Johnson Shopper	Thurs	Year-round	12:00 PM	1:45 PM	1:45	14.90	cutaways	20.48	2.05	22.53	yes	yes
RCT	8588	The Highlander	Mon-Sat	Year-round	7:15 AM	11:28 AM	4:13	14.90	cutaways	62.98	6.30	69.27	yes	yes
RCT	8589	The Highlander	Mon-Sat	Year-round	12:30 PM	4:45 PM	4:15	14.90	cutaways	62.99	6.30	69.29	yes	yes
RCT	8590	Twin City	Mon-Fri	Year-round	5:50 AM	5:35 PM	11:45	27.00	cutaways	125.33	12.53	137.86	yes	no
RCT	8592	US 2 Commuter	Mon-Fri	Year-round	6:00 AM	6:40 AM	0:40	27.00	cutaways	20.90	2.09	22.99	yes	yes
RCT	8593	US 2 Commuter	Mon-Fri	Year-round	6:10 AM	6:30 PM	12:20	27.00	cutaways	163.81	16.38	180.19	no	no
RCT	118075	Morrisville to Barre Commuter	Mon-Fri	Year-round	6:00 AM	5:40 PM	11:40	27.00	cutaways	160.33	16.03	176.37	no	no
RCT	133444	US 2 Commuter	Mon-Fri	Year-round	6:15 AM	6:45 PM	12:30	27.00	cutaways	162.34	16.23	178.57	no	no
RCT	100A	Route 100	Mon-Fri	Year-round	6:15 AM	8:00 AM	1:45	27.00	cutaways	45.60	4.56	50.16	yes	yes
RCT	100B	Route 100	Mon-Fri	Year-round	7:08 AM	7:55 AM	0:47	27.00	cutaways	22.05	2.20	24.25	yes	yes
RCT	100C	Route 100	Mon-Fri	Year-round	3:41 PM	6:45 PM	3:04	27.00	cutaways	80.49	8.05	88.54	yes	yes
RCT	100D	Route 100	Mon-Fri	Year-round	5:00 PM	5:47 PM	0:47	27.00	cutaways	23.55	2.36	25.91	yes	yes

Appendix F: Marble Valley Regional Transit District (MVRTD)

Operator	Block ID	Route	Calendar Days	Calendar Type	Start Time	End Time	Length (hrs:mins)	Avg Speed (mph)	Vehicle Type	Length (miles)	Deadhead (miles)	Total Length in Miles (Route + Deadhead)	Can This Block Be Served by One Electric Bus?	Can This Block Be Served by One Electric Cutaway or Van?
MVRTD - The Bus	2327	Ludlow	Mon-Fri	Seasonal - Winter	7:00 AM	7:50 AM	0:50	19.25	30' buses / cutaways	29.68	2.97	32.65	yes	yes
MVRTD - The Bus	109718	Hospital	Mon-Sat	Year-round	8:00 AM	4:55 PM	8:55	11.80	30' buses / cutaways	104.00	10.40	114.40	yes	no
MVRTD - The Bus	109719	Fair Haven	Mon-Fri	Year-round	5:30 AM	9:13 AM	3:43	19.25	30' buses / cutaways	93.00	9.30	102.30	yes	no
MVRTD - The Bus	109719	Fair Haven	Sat-Sun	Year-round	5:30 AM	9:13 AM	3:43	19.25	30' buses / cutaways	93.00	9.30	102.30	yes	no
MVRTD - The Bus	109720	South	Mon-Sat	Year-round	8:00 AM	4:53 PM	8:53	11.80	30' buses / cutaways	98.98	9.90	108.88	yes	no
MVRTD - The Bus	109721	Rutland-Killington Commuter	Mon-Sun	Seasonal - Winter	7:15 AM	6:45 PM	11:30	19.25	30' buses / cutaways	203.43	20.34	223.77	no	no
MVRTD - The Bus	109722	West	Mon-Sat	Year-round	8:00 AM	4:55 PM	8:55	11.80	30' buses / cutaways	107.32	10.73	118.06	yes	no
MVRTD - The Bus	109724	South Extension	Mon-Sat	Year-round	8:00 AM	4:53 PM	8:53	11.80	30' buses / cutaways	90.87	9.09	99.96	yes	no
MVRTD - The Bus	109725	North	Mon-Sat	Year-round	8:00 AM	4:50 PM	8:50	11.80	30' buses / cutaways	80.88	8.09	88.97	yes	yes
MVRTD - The Bus	109726	Middlebury Connector	Mon-Fri	Year-round	5:30 AM	6:45 PM	13:15	19.25	30' buses / cutaways	209.03	20.90	229.94	no	no
MVRTD - The Bus	109727	Middlebury Connector	Saturday	Year-round	9:30 AM	7:15 PM	9:45	19.25	30' buses / cutaways	139.36	13.94	153.29	no	no
MVRTD - The Bus	109728	Manchester	Mon-Sat	Year-round	6:30 AM	10:40 AM	4:10	19.25	30' buses / cutaways	134.77	13.48	148.25	yes	no
MVRTD - The Bus	109729	Proctor	Mon-Fri	Year-round	8:00 AM	4:56 PM	8:56	19.25	30' buses / cutaways	14.57	1.46	16.03	yes	yes
MVRTD - The Bus	111064	Ludlow	Mon-Fri	Seasonal - Winter	4:00 PM	4:50 PM	0:50	19.25	30' buses / cutaways	29.68	2.97	32.65	yes	yes
MVRTD - The Bus	111065	Manchester	Mon-Sat	Year-round	3:00 PM	7:11 PM	4:11	19.25	30' buses / cutaways	129.67	12.97	142.64	yes	no
MVRTD - The Bus	111067	Fair Haven	Mon-Fri	Year-round	11:15 AM	1:13 PM	1:58	19.25	30' buses / cutaways	47.82	4.78	52.60	yes	yes
MVRTD - The Bus	111068	Fair Haven	Mon-Fri	Year-round	3:30 PM	7:26 PM	3:56	19.25	30' buses / cutaways	95.64	9.56	105.21	yes	no
MVRTD - The Bus	111068	Fair Haven	Sat-Sun	Year-round	3:30 PM	7:26 PM	3:56	19.25	30' buses / cutaways	95.64	9.56	105.21	yes	no

Appendix G: Tri Valley Transit (TVT)

Operator	Block ID	Route	Calendar Days	Calendar Type	Start Time	End Time	Length (hrs:mins)	Avg Speed (mph)	Vehicle Type	Length (miles)	Deadhead (miles)	Total Length in Miles (Route + Deadhead)	Can This Block Be Served by One Electric Bus?	Can This Block Be Served by One Electric Cutaway or Van?
TriValley Transit	3119	MSB - Hannaford	Mon-Fri	Year-round	7:00 AM	12:00 PM	5:00	15.96	Cutaway	60.00	4.00	64.00	yes	yes
TriValley Transit	3119	MSB - Hannaford	Mon-Fri	Year-round	12:00 PM	7:00 PM	7:00	15.96	Cutaway	65.00	4.00	69.00	yes	yes
TriValley Transit	3120	TriTown Vergennes	Mon-Fri	Year-round	6:15 AM	12:00 PM	5:45	15.96	Cutaway	150.00	4.00	154.00	no	no
TriValley Transit	3120	TriTown Vergennes	Mon-Fri	Year-round	12:25 PM	6:20 PM	5:55	15.96	Cutaway	153.00	4.00	157.00	no	no
TriValley Transit	3121	TriTown Bristol	Mon-Fri	Year-round	5:45 AM	12:40 PM	6:55	15.96	Cutaway	190.00	4.00	194.00	no	no
TriValley Transit	3121	TriTown Bristol	Mon-Fri	Year-round	12:55 PM	6:50 PM	5:55	15.96	Cutaway	152.00	4.00	156.00	no	no
TriValley Transit	3123	116 Commuter	Mon-Fri	Year-round	6:10 AM	9:15 PM	15:05	29.46	Cutaway	94.00	4.00	98.00	yes	no
TriValley Transit	3123	116 Commuter	Mon-Fri	Year-round	3:30 PM	6:45 PM	3:15	29.46	Cutaway	93.00	4.00	97.00	yes	no
TriValley Transit	3124	Burlington Link Express Sat	Sat	Year-round	9:45 AM	2:45 PM	5:00	29.46	Cutaway	152.00	4.00	156.00	no	no
TriValley Transit	3124	Burlington Link Express Sat	Sat	Year-round	4:45 AM	7:15 AM	2:30	29.46	Cutaway	78.00	4.00	82.00	yes	yes
TriValley Transit	3125	Rutland Connector	Mon-Fri	Year-round	5:30 AM	8:00 AM	2:30	15.96	Cutaway	72.00	4.00	76.00	yes	yes
TriValley Transit	3125	Rutland Connector	Mon-Fri	Year-round	11:15 AM	1:45 PM	2:30	15.96	Cutaway	72.00	4.00	76.00	yes	yes
TriValley Transit	3125	Rutland Connector	Mon-Fri	Year-round	4:14 AM	6:45 PM	14:31	15.96	Cutaway	72.00	4.00	76.00	yes	yes
TriValley Transit	3125	Rutland Connector	Sat	Year-round	9:30 AM	12:00 PM	2:30	15.96	Cutaway	72.00	4.00	76.00	yes	yes
TriValley Transit	3125	Rutland Connector	Sat	Year-round	4:45 AM	7:15 PM	14:30	15.96	Cutaway	72.00	4.00	76.00	yes	yes
TriValley Transit		MSB - Hospital, Marble Works	Mon-Fri A Bus	Year-round	7:30 AM	12:30 AM	17:00	15.96	Cutaway	65.00	4.00	69.00	yes	yes
TriValley Transit		MSB - Hospital, Marble Works	Mon-Fri A Bus	Year-round	12:30 AM	6:30 PM	18:00	15.96	Cutaway	65.00	4.00	69.00	yes	yes
TriValley Transit		MSB - Hospital, Marble Works	Mon - Fri B Bus	Year-round	6:40 AM	10:00 AM	3:20	15.96	Cutaway	40.00	4.00	44.00	yes	yes
TriValley Transit		MSB - Hospital, Marble Works	Mon - Fri B Bus	Year-round	3:25 PM	6:15 PM	2:50	15.96	Cutaway	40.00	4.00	44.00	yes	yes
TriValley Transit	103248	MSB - Hannaford, Hospital, M	Sat	Year-round	10:00 AM	4:00 PM	6:00	15.96	Cutaway	70.00	4.00	74.00	yes	yes
TriValley Transit		Link 1	Mon-Fri	Year-round	6:15 AM	9:00 AM	2:45	15.96	Cutaway	77.00	4.00	81.00	yes	yes
TriValley Transit		Link 3	Mon-Fri	Year-round	3:15 AM	6:05 PM	14:50	15.96	Cutaway	80.00	4.00	84.00	yes	yes