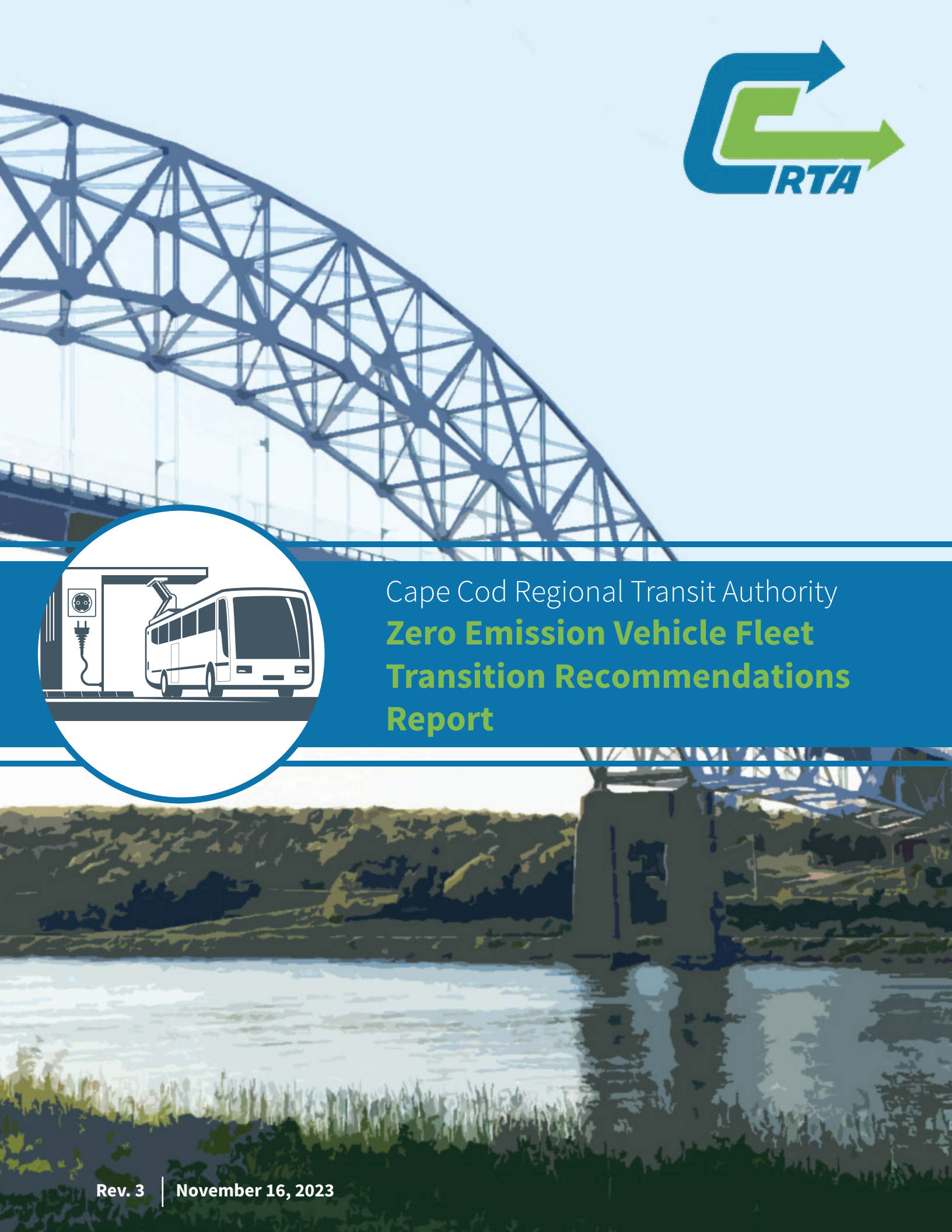

Cape Cod Regional Transit Authority

Zero Emission Vehicle Fleet Transition Recommendations Report

Rev. 3 | November 16, 2023

ZEV Fleet Transition Recommendations

11/16/2023	3		Emily Marble			
Date	**Rev.**	**Status**	**Prepared By**	**Checked By**	**Approved By**	**Approved By**
HATCH						**Client**

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1. Introduction

Cape Cod Regional Transit Authority (CCRTA) is a mid-sized regional transit authority providing fare-based transit service and paratransit service to 15 towns over 400 square miles on Cape Cod, Massachusetts, a low-lying peninsula. CCRTA, in consultation with the Cape Cod Commission, has committed to reduce its emissions and its fossil fuel dependence while continuing to offer its riders sustainable and reliable transportation. CCRTA commissioned this study to evaluate the feasibility of battery electric vehicles for both its fixed route and demand-response services which will support the development of an authority-wide zero emission vehicle (ZEV) transition plan and regional support study.

To provide information to CCRTA that will inform procurement decisions, capital planning efforts, and ultimate transition strategy Hatch performed operations analysis, financial modeling, emissions impact analysis, market research, and environmental justice review. Related findings and recommendations are included within this report.

1.1 Existing Conditions

The authority currently owns and operates both a revenue and non-revenue service fleet of approximately 149 diesel and gasoline powered vehicles. These vehicles service both fixed and demand-response routes. Vehicles include standard 29' and 35' low-floor transit buses, mixed-sized cutaway vans, caravans, trolleys for seasonal service, and staff vehicles consisting of SUV's and one electric sedan. The authority also owns and maintains Council on Aging (COA) vehicles consisting of cutaways and caravans as well as taxis however CCRTA does not operate these vehicles; these were not included in Hatch's analysis.

Table 1 Current Fixed Route and Demand Response Fleet Summary

Vehicle Type	Fixed Route	Demand Response	Total
29' Bus	29		29
35' Bus	7		7
32' Trolley	5		5
21' Cutaway		31	31
23' Cutaway		3	3
26' Cutaway	8	34	42
28' Cutaway	14		14
Van		8	8

CCRTA operates eight fixed service routes year-round and ten fixed service routes during the summertime with a mixed fleet of buses, cutaways, caravans and seasonal trolleys. See Table 1 for a summary of CCRTA's current fixed route and demand response fleet. During winter months, the authority operates six days per week (Monday through Saturday) on seven of its eight fixed service routes with The Shuttle operating on Friday, Saturday, and Sundays, only. During the summertime, from Memorial Day to Labor Day, CCRTA adds two fixed-route trolley services and expands all services to seven days per week. In May, CCRTA began a pilot program for the summer of 2023 to expand the Flex service to accommodate Provincetown restaurant and bar staff. This pilot program will also see the "shoulder season" expanded, with this service starting prior to Memorial Day, and running past Labor Day. Except as noted otherwise, the remainder of this study considers seven-day service for all fixed-routes, during peak tourist season (summertime).

CCRTA provides a daily, public demand-response service called Dial-A-Ride Transportation (DART). DART is CCRTA's ride by appointment transportation service. DART runs across all of the Cape's 15 towns six days per week (Monday through Saturday), with limited service on Sunday. Daily hours of operation vary by town. Under the DART umbrella, CCRTA also provides an application-based, on-demand service called SmartDART. This service is only currently available in Yarmouth and Barnstable, with immediate plans underway for expansion of service area into East Falmouth. Further expansion in the short term may include Dennis, along with potential for SmartDART in Provincetown. CCRTA vehicles currently servicing both DART and SmartDART are the cutaways and vans.

2. Operations Modeling

CCRTA's current operating model, for both fixed-route and demand-response services, is similar to that of many transit authorities across the country. Vehicles typically leave the depot at the beginning of the operator's shift, operate for as long as the operator is on duty, and then return to the depot at the conclusion of the shift. This has advantages in the context of electric vehicle operation, because it limits required vehicle range to the distance traveled over an eight to ten hour shift, but even this type of schedule does not allow 1:1 substitution of battery-electric vehicles. Batteries are low-density means of energy storage that do not provide the same vehicle range as gasoline or diesel fuel. In addition, seasonal factors affecting range become much more significant after a transition to electric vehicles. Even when diesel heaters are installed in battery electric buses, as was assumed in this study, icy road conditions and cold temperatures degrade the performance of the vehicles. In the case of cutaways and smaller vehicles typically used by CCRTA, auxiliary heaters are not an option. Although practices to extend range like pre-conditioning the vehicles before leaving the depot are recommended, winter conditions will present challenges to electric vehicle operation. CCRTA's operating model will need to account for these limitations as service must operate year-round.

A simulation was conducted to predict how electric vehicles would perform on CCRTA's fixed routes and demand-response services. Simulation was necessary because the available range estimates – typically provided by vehicle manufacturers – are maximum values that ignore the effects of gradients, road congestion, driver performance, severe weather, and other authority-specific factors. To ensure that operations would be reliable across all seasons throughout the lifespan of the vehicles, two margins were subtracted from the advertised vehicle battery capacities. First, the battery was assumed to be six years old (i.e., shortly before its expected replacement). As batteries degrade over time, their capacity decreases. To account for this, the battery capacity was reduced by 20%. Second, the vehicle was assumed to need to charge before its level of charge falls below 20%. This is both a manufacturer's recommendation – batteries have a longer life if they are not discharged to 0% – and an operational safety buffer to prevent dead vehicles from becoming stranded on the road. Combining these two reduction factors yields a usable battery capacity of 64% of the nominal value. The following Table 2 summarizes the advertised battery capacity and the corresponding usable battery capacity for the all the vehicle types that were analyzed.

Table 2 Vehicle Battery Capacity and Usable Capacity Assumptions

Vehicle Class	Advertised Battery Capacity (kWh)	Usable Battery Capacity (kWh)	Usable Range (miles)
Bus	492	314.88	156
Cutaway	157	100.48	79-114[1]
Trolley	127	81.28	54
Vans	120	76.80	91

CCRTA's network was analyzed on a route-by-route basis through the creation of "drive cycles" for several routes representing the authority's typical modes of fixed-route and demand-response operation, ranging from slower-speed urban routes to higher-speed routes through more rural areas. For each representative route, the full geography (horizontal and vertical alignment), transit infrastructure (location of key stops and transit hubs), and road conditions (vehicle congestion, traffic lights, stop signs, crosswalks, etc.) were modeled. The performance of battery-electric vehicles was simulated in worst-case weather conditions to create a drive cycle. These CCRTA-specific drive cycles were used to calculate battery energy consumption per mile. This analysis provided information regarding the total battery energy consumed by a vehicle on each route. The vehicles utilized for simulation were electric transit buses, cutaways, and trolleys, as appropriate for the route and the same size or similar to the fossil fuel vehicles currently operated on each route.

2.1 Fixed Route

CCRTA's summer Friday fixed-route operations were modeled because they represent both the most intensive service and the highest level of traffic congestion. Note that the Flex 2023 pilot program discussed in Section 1.1 was not considered in the operational analysis as results of the program have not been seen. In each case, the vehicles were assumed to depart from their origin locations (either the operations facility in Dennis or the seasonal "park-out" location in Provincetown) with a full battery and operate their entire schedule for the day. The remaining battery energy (accounting for the safety factors outlined above) was tracked over the course of the day. The remaining energy in each vehicle's battery at the end of the day is shown in Table 3, with blocks (sequences of trips operated by a given vehicle over the course of one day) suitable for electrification shown in black font and those unsuitable shown in red font.

Table 3 Fixed Route Block Energy Requirements

Route	Block	Mileage	kWh Req'd	Mileage Excess / Shortage	Vehicle Type
Sealine	**120**	148.62	296.16	9.27	Bus
	121	148.62	296.16	9.27	Bus
	122	148.62	296.16	9.27	Bus
	123	148.62	296.16	9.27	Bus
	124	148.62	296.16	9.27	Bus
	125	148.62	296.16	9.27	Bus
	126	83.51	164.64	74.38	Bus
	127	148.62	296.16	9.27	Bus
H2O	**200**	187.48	372.46	-28.51	Bus
	201	142.71	283.13	15.72	Bus

[1] The usable range for electric cutaways is represented with a mileage range because CCRTA operates seasonal services with cutaway vehicles; some routes using cutaways are operated during the summertime only. Those vehicles operated during the warmer months have longer range than those operated during the wintertime.

Route	Block	Mileage	kWh Req'd	Mileage Excess / Shortage	Vehicle Type
	202	187.48	372.46	-28.51	Bus
	203	187.48	372.46	-28.51	Bus
	204	177.48	354.46	-19.59	Bus
	205	142.71	283.13	15.72	Bus
	206	187.48	372.46	-28.51	Bus
	207	142.71	283.13	15.72	Bus
Provincetown Shuttle (Truro)	300	191.83	386.07	-35.24	Bus
	301	145.54	292.98	10.84	Bus
	303	130.63	260.24	27.05	Bus
Provincetown Shuttle (Beaches)	306	104.62	92.66	9.09	Cutaway
	308	104.62	92.66	9.09	Cutaway
Barnstable	400	117.76	146.38	-36.14	Cutaway
	402	84.46	104.14	-2.88	Cutaway
	403	73.72	90.45	7.90	Cutaway
Hyannis Crosstown	410	90.57	111.90	-8.99	Cutaway
	411	49.33	59.52	32.25	Cutaway
Sandwich	500	140.29	171.57	-55.98	Cutaway
	501	153.72	192.10	-72.14	Cutaway
	502	153.72	192.10	-72.14	Cutaway
	503	140.29	171.57	-55.98	Cutaway
Flex	600	66.55	133.00	90.04	Bus
	602	217.28	437.06	-60.48	Bus
	603	112.84	226.09	43.96	Bus
	604	217.28	437.06	-60.48	Bus
	608	217.28	437.06	-60.48	Bus
	610/ 611	324.52	653.07	-167.42	Bus
	612/ 613	361.12	725.11	-203.08	Bus
Bourne	700	164.00	200.63	-78.86	Cutaway
	701	164.00	200.63	-78.86	Cutaway
	702	200.85	246.22	-114.76	Cutaway
	703	141.35	170.66	-55.26	Cutaway
	704	141.35	170.66	-55.26	Cutaway
	705	141.35	170.66	-55.26	Cutaway
CapeFlyer	717	77.00	100.30	0.14	Cutaway
Hyannis Trolley	800	67.00	98.23	-11.22	Trolley
	801	50.80	73.76	4.98	Trolley
	900	136.64	196.89	-76.56	Trolley

Route	Block	Mileage	kWh Req'd	Mileage Excess / Shortage	Vehicle Type
Whoosh Trolley	**901**	110.76	157.81	-50.68	Trolley

Following the same assumptions, the decline in battery energy levels over the course of the day is presented in Figure 1 below. The lines that cross zero and enter into negative battery energy levels represent the vehicles that cannot make it through the day on a single charge.

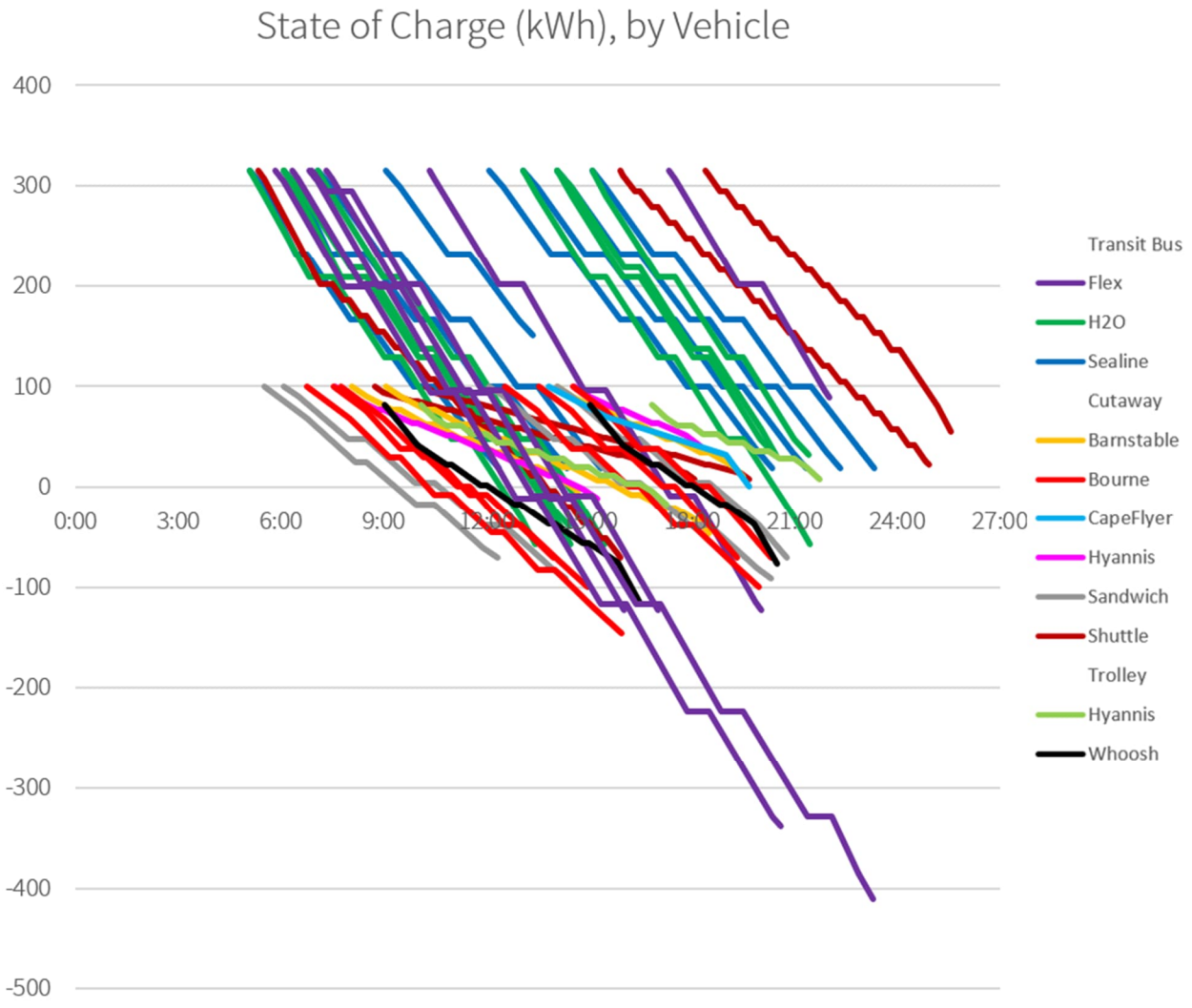

Figure 1 Battery Energy Levels by Vehicle Over the Course of the Day

Simulation results showed that of the 48 blocks modeled, 27 would be unsuitable for a full day of electric vehicle service with no other operational changes. In particular, the longer-distance routes operating cutaways (Bourne and Sandwich), as well the Flex route, present challenges for battery electric vehicle operation due to insufficient range of the battery electric vehicles. The two fixed route blocks least amenable for battery electric vehicle conversion are the two Flex route blocks that incorporate a "hot-

seat" (mid-trip driver swap), because these vehicles remain in service for the entire duration of two, full driver shifts.

For the 21 blocks modeled that were found feasible for battery electric vehicle operation, no operating changes are required for deployment of zero-emissions vehicles. For the remaining blocks, however, operational changes are necessary, as described in Section 5.

2.2 Demand-Response

Demand-response service is, inherently, more difficult to model because passenger demand is unpredictable and changes each day. To assess the suitability of electric vehicles for CCRTA's DART operations, a representative sample of trips was modeled as described above. The calculated vehicle energy consumption per mile was multiplied by the mileage for each trip to determine how much energy would be required to complete the trip. The remaining battery energy at the end of the day was computed for each vehicle, as shown in Table 4 below. Trips that could be served by today's electric vehicles are shown in black font, while those that could not are shown in red font.

Table 4 Demand Response Sample Trips Energy Requirements

Block	Mileage	kWh Required	Mileage Excess / Shortage
B16	87	95	5.05
B27	120	130	-27.33
B51	130	141	-37.34
B54	175	190	-82.51

Similar to the fixed-route services, operational changes will be needed to accommodate electric vehicle operation on the majority of demand-response blocks. These changes are discussed in Section 5.

3. Operations Planning

Because of the energy density of fossil fuel, transit operations do not need to account for fossil fuel vehicle's limitations. Vehicles can operate on a single tank of fuel for several hundred miles – sufficient for all but the most extreme transit services – and refueling only takes several minutes when it is required. This is not true for electric vehicles, which cannot travel the same distances and require substantially more time to recharge. Although CCRTA's primary mission is to provide reliable and efficient service to its passengers, as the authority electrifies its fleet, operations will have to change to accommodate the limitations imposed by today's electric vehicle technology.

3.1 Operations Strategies

When a new vehicle type is introduced without sufficient range to serve the blocks it is intended for, there are several operations strategies authorities can implement to maintain the same level of service. The simplest operating strategy – although not considered further in this report – is changing the vehicle type to one with higher range. For example, CCRTA could choose to replace a cutaway shuttle with a transit bus, which has three times as much battery capacity. Although this can provide a dramatic increase in vehicle range, there are several associated downsides. First, larger vehicles have higher capital and operating costs than smaller vehicles. CCRTA's current selection of vehicle types is generally optimized

for the passenger loadings on each route, so using a larger-than-required vehicle would increase cost and result in the operation of mostly empty vehicles. Also, smaller vehicles can operate on routes that are too space-constrained for larger ones. For these reasons, changes to vehicle type were not considered to mitigate vehicle range limitations.

Aside from changing vehicle type, there are several other strategies that CCRTA can use to address the range limitations of electric vehicles. High level options are:

- Shortening blocks
- Rearranging blocks to let vehicles charge at the depot midday, and
- Installing on-route charging so vehicles can charge throughout the day

Shortening blocks is the solution most like CCRTA's present operations. Today, most CCRTA vehicles operate for up to 8-10 hours to avoid excessively long driver shifts. Routes are generally served by two sets of blocks, with the first set operating between approximately 6am and 2pm and the second set from 2pm to 10pm. To accommodate electric vehicles, this block structure could be revised, so that each block operates for only six hours (with a corresponding decrease in daily mileage). Although this solution would be simplest for dispatchers and operators, it would require introducing a third set of blocks to maintain a full day of operation. Accordingly, the number of required drivers would increase significantly, impacting CCRTA's labor costs and further stressing an already constrained labor pool. Therefore, this solution was not considered further.

A third potential solution involves rearranging blocks to provide charging windows at the depot throughout the day. The primary advantage of such an approach is that, as with the previous strategy, charging infrastructure is only required at the depot. Also, if optimally scheduled, the number of additional drivers required would be less than for the first alternative, because most shifts would still be eight hours long. However, because EVs require comparatively long charging windows, and because the Dennis operating facility is comparatively far away from most routes' terminals, sending vehicles to the depot to charge mid-shift would be time-consuming. This would require a large number of additional vehicles, and drivers, to maintain service while other vehicles are charging at the depot. Because of these inefficiencies and associated costs, this alternative was not considered further.

The final operating strategy – installation of on-route charging at route terminals – allows vehicles to remain in revenue service for a full eight-hour shift. Although on-route charging is insufficient to let vehicles maintain a constant state of charge throughout the day, it can provide enough additional battery energy for vehicles to avoid needing to return to the depot early. If available layover times are sufficient, existing operations can be maintained with no scheduling changes. However, particularly in a traffic-congested area like Cape Cod, this reliance on layover time poses significant risks. Because vehicles will no longer be able to truncate their layover time to recover from schedule delay (for fear of running out of battery energy mid-route), dispatchers will need to carefully monitor vehicles' battery energy levels to determine how much charging is required, and schedules will need to be written with sufficient safety margin to allow some charging to occur even if the vehicle arrives at the terminal behind schedule. Despite these potential risks, on-route charging is the recommended operating strategy for CCRTA's fixed-route operations.

For demand-response services, there is a similar range of operational mitigations that can be used to overcome vehicle range limitations. As stated previously, most demand-response vehicles operate further than today's electric vehicles can travel on a single charge. CCRTA could choose to shorten the trip length of each vehicle, distributing the same number of requested trips among a larger number of vehicles (and drivers). The agency could also shuffle vehicles to and from the depot throughout the day, perhaps during the driver's lunch break. However, each of these solutions would require additional capital and operating resources to deliver the same level of service. A third option, which would require fewer (or no) additional vehicles, would be to charge vehicles at locations around the Cape during their drivers'

lunch breaks. This would give each vehicle additional range. While this would not be sufficient for full electrification of the demand-response fleet, it would allow a majority of the fleet to be converted to zero-emissions operation. The remaining vehicles could remain fossil fuel vehicles or could be replaced with EVs and have their trip lengths shortened as necessary. For the purposes of this study, on-route charging was selected for demand-response services as well, with some vehicles remaining fossil fuel powered to mitigate range issues on the longest runs.

3.2 On-Route Charging Locations

With on-route charging selected for both fixed-route and demand-response operations, a key decision is the selection of on-route charging locations across the Cape. This requires examining both fixed-route and demand-response operations.

For fixed-route operations, on-route charging is only appropriate at a small number of locations. Because stopping a vehicle mid-route, with passengers onboard, for charging is infeasible and inconvenient, charger installation is only practical at route terminals and overnight parking locations. Figure 2 below shows the main hubs on CCRTA's fixed-route network.

Demand-response operation, however, has no fixed terminals where on-route chargers can be installed, as each vehicle's combination of trips served differs from day to day. Across the CCRTA service area, however, there are several areas of concentrated demand-response ridership. This is due to the distribution of population; especially the transit-dependent population. Because these areas are likely to be near where drivers take their mid-shift lunch breaks, it is logical to consider these areas for installation of charging stations. The heatmap in Figure 2 below, created from the representative sample of demand-response trips used for this study, shows these high-ridership areas across the Cape.

The terminals for fixed route operations shown in Figure 2 on the left are:

- Provincetown
- Orleans
- Harwich
- Dennis
- Hyannis Transportation Center
- Mashpee
- Falmouth
- Bourne

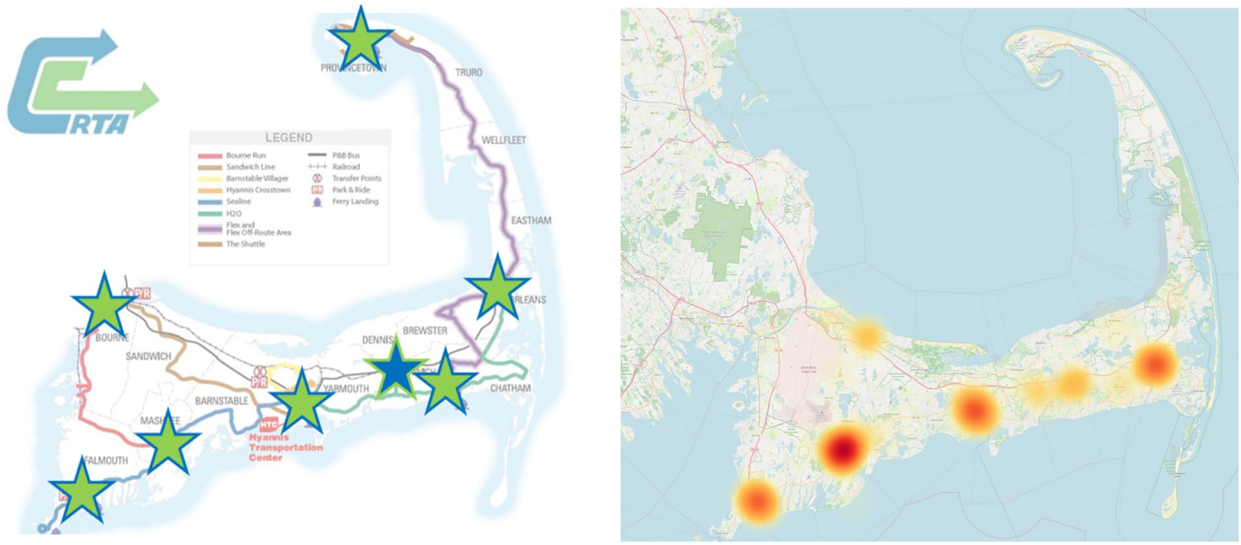

Figure 2 Fixed Route Operation Terminal Locations (left), Demand Response Trip Heat Map (Right)

Comparing the left and right image in Figure 2 shows that there is significant overlap between the terminals for fixed-route operation and the areas of highest demand-response ridership. This aligns closely with the densest areas on Cape Cod and allows the selection of several charging locations to serve the entire breadth of the Cape.

Hyannis

Hyannis, the primary hub for fixed-route operation and a key base for DART ridership, is an obvious place for a charging station. In particular, Hyannis Transportation Center (HTC) is already owned by CCRTA and has the available real estate for installation of charging infrastructure. There are currently 20 L2 chargers (ten dual head L2 chargers) for both CCRTA and public use located at HTC. In addition, CCRTA applied for Eversource's Make Ready Incentive Program and has plans to expand charging infrastructure at the terminal which would enable on-route charging for both fixed route and DART vehicle use. Eversource's approved contractors, Maverick Electric Vehicle Services, provided proposed design drawings for HTC which are currently under review.

Mashpee

Mashpee, as the largest hub of demand-response operation and the terminal of the Bourne fixed route, is another clear candidate for a charging station. However, unlike Hyannis, there is no CCRTA-owned land in the area; therefore, installation of any charging station will require negotiation with local landowners. Fortunately, Mashpee Commons – the large mall that serves as the area's commercial hub – has ample parking space available where chargers could be installed and is already the site of multiple charging stations for personal vehicles. Although these are likely not suitable for CCRTA use – because they have Tesla's proprietary charging connectors or have insufficient charging speed – their presence suggests that utility capacity is available in the area and that the mall's landowner is amenable to charging installation. For these reasons, CCRTA is encouraged to pursue development of a charging station at Mashpee.

Provincetown

On the other end of the Cape, Provincetown is a strategically important node for CCRTA operations. Although it does not see high demand-response activity, it is far enough from other areas of the Cape that a demand-response vehicle would likely be unable to complete a full day of service that includes a round trip to Provincetown. Additionally, it is the terminal for the Flex and Shuttle routes and sees vehicles "parked out" overnight during the summer season. For these reasons, it is an important area for

installation of a charging station for both midday and overnight use. For midday use, it is important that the chargers be located close to the terminal at MacMillan Pier, so that vehicles (particularly on the Flex route) can charge during short layovers. For overnight use, however, the charging station needs to be in a secure location and needs to be large enough to accommodate several vehicles charging at once, including spare vehicles that may remain there during the day. Because of the busy nature of downtown Provincetown, identifying a location that meets all of these requirements is challenging, and will require discussion with the Provincetown municipal government and the local community. For the purposes of this study, the town wastewater treatment plant on Route 6 was selected as a conceptual charging location; however, CCRTA is encouraged to review all possible locations in the area before beginning construction.

Falmouth

Falmouth and the Woods Hole area also see concentrated demand-response ridership and are the terminals of the Sealine and the Whoosh trolley. The trolley route, in particular, poses challenges for EV operation because CCRTA does not currently own or operate any charging infrastructure along this route and because electric trolleys have comparatively limited battery capacity. However, given the proximity to the Mashpee charging station and the seasonal, one-vehicle nature of the Whoosh service, it is likely uneconomical for CCRTA to build a separate charging station in the area. Instead, demand-response vehicles could deadhead to Mashpee when necessary to charge during the driver's lunch break, and the Whoosh trolley could use the Steamship Authority's nearby Palmer Avenue Parking Lot in Falmouth for charging. CCRTA is encouraged to negotiate with the Steamship Authority to arrange this access before electrifying the Whoosh route.

These four charging locations, together with the Dennis operations facility, are expected to provide adequate coverage across the Cape to support CCRTA operations. Although some operating changes will still be required, because of short layover times or to let DART vehicles deadhead to a charging location midday, such a charging network will help ensure CCRTA's smooth transition to an electric fleet.

3.3 Fixed-Route Operations with On-Route Charging

With the charging locations (Hyannis, Mashpee, Provincetown, and Falmouth) identified, the feasibility of electrifying CCRTA's fixed-route service could be reassessed. For this study, changes to passenger-facing schedules were not considered; all changes were assumed to only affect vehicle assignment to existing passenger trips.

With the charging locations listed above, each fixed route would have access to a charger near (for the trolley and Flex routes) or directly at (for all other routes) one of its terminals. Given this access, charging windows were allocated throughout the day to correspond to vehicles' layover times at those terminals. Deadhead time was considered when the chargers were not located directly at terminals, charging time reduction factors were considered to account for delays due to traffic congestion, and charge rate reduction factors were included to account for charging rate ramp-up and ramp-down, and other factors. Accounting for these reduction factors, charge rates of 60 kW and 150 kW were assumed for cutaways and transit buses, respectively, instead of the maximum possible rates of 80 kW and 220 kW respectively.

In some cases, simply replacing fossil fuel vehicles with the electric equivalents available today, and adding on-route charging during layovers, would still not allow a full day of operation. Several mitigation strategies were used in these cases. For those blocks where vehicles would have nearly enough energy to complete a full shift, the most practical option is to defer procurement of vehicles for those routes. Because CCRTA will not be replacing its entire fleet in one year, and because battery capacity has been improving at approximately 3% annually, it is often more practical to wait several years to replace vehicles on a certain route than to purchase additional vehicles (or chargers) to cover a small deficit in battery capacity. For this analysis, vehicles on the Sandwich, Flex, Barnstable, and Whoosh routes were assumed to have battery capacities expected in 2025, 2027, 2030, and 2032 respectively, aligning with the estimated procurement timelines detailed below. For larger deficits in battery capacity, some shuffling of trips between blocks can increase electrification feasibility. For example, in the current schedule

cutaway #500 is scheduled to make one and a half round trips on the lengthy Sandwich route, with limited layover time at Hyannis Transportation Center. Accordingly, it is expected to be unable to complete its full shift. At the same time, cutaway #402 is scheduled to operate on the Barnstable Villager route, which is less energy-intensive and has frequent layovers at Hyannis Transportation Center. Reassigning the first half-round trip on the Sandwich route from vehicle #500 to vehicle #402 can, therefore, make #500's block feasible for EV operation without exceeding #402's maximum range. For the most substantial energy deficits, where such adjustments are insufficient, additional vehicles were assumed to be added to those routes, enabling all vehicles on those routes to dwell longer at the terminal and thus make more use of on-route charging. For the Sandwich, Bourne, and Flex routes, this analysis assumed two, one, and one additional vehicle respectively.

With these operating changes implemented, all fixed-route vehicles are able to complete a full shift of service, as shown in Figure 3:

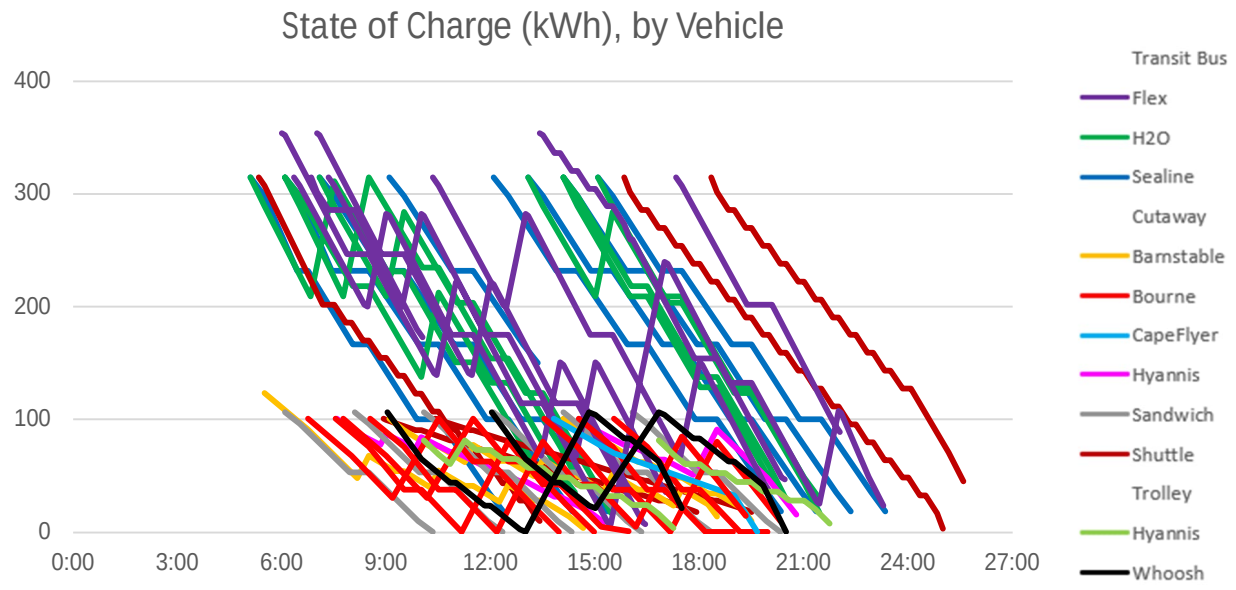

Figure 3 Battery Energy Levels by Vehicle Over the Course of the Day with On-Route Charging

To accommodate fixed-route operation, two chargers would be required at Hyannis Transportation Center and at Mashpee. One charger would be needed for daytime use at Provincetown, though two chargers (three dispensers each) would be required for overnight park-out during summer months. At Falmouth, use of one Steamship Authority-owned charger would be needed.

3.4 Demand-Response Operations with On-Route Charging

Demand-response operations can be modeled similarly to fixed-route services. Once the duration of each representative block's lunch break is determined, the energy gained from charging during that break can be calculated, and the proportion of vehicles suitable for electrification estimated.

As for fixed-route service, the energy gained through charging must be conservatively estimated to account for required deadheading to and from the charging location, traffic congestion, and other sources of variability. For this analysis, a DC fast charging rate of 80 kW was assumed for half of the duration of the lunch break of each representative block. Table 5 below shows the remaining battery energy for each block after lunchtime recharging is accounted for.

Table 5 Demand Response Sample Trip Energy Requirements with On-Route Charging

Block	Mileage	kWh Required	Lunch Duration	kWh Gained During Lunch	Reduced kWh Required	Mileage Excess / Shortage
B16	87	95	49 min	33	62	35.47
B27	120	130	55 min	37	93	6.89
B51	130	141	96 min	64	77	21.64
B54	175	190	64 min	43	147	-42.88

To accommodate demand-response operation, approximately three chargers each would be needed at both Hyannis and Mashpee, yielding a total of five chargers at each location.
Table 6 shows the total required chargers by location, and type. These chargers are strategically laid out based on the needs of the operation. For example, dedicated single dispenser chargers are specified to ensure maximum charging during layovers and operator breaks. In comparison, high-power level 2 chargers are recommended at the depot for cutaway vans as regular, dual-head level 2 chargers would not have sufficient power.

Table 6 Summary of Total Required Chargers

	Depot	HTC	Provincetown	Mashpee	Total
19.2 kW Level 2	101				101
150 kW DCFC (3 Dispensers)	15		2		17
100 kW DCFC (Single Dispenser)		3		5	8
300 kW DCFC (Single Dispenser)		2	1		3
Total	116	5	3	5	

4. Estimated Procurement Timelines

The choice of an authority's ZEV operating model is inherently linked to the procurement timelines for vehicles and supporting infrastructure.

4.1 Vehicle Procurement Timeline

The vehicle procurement timeline outlined in Figure 4 and discussed in Section 4.1 takes into account vehicle age, current vehicle mileage, and CCRTA's Ten Year Strategic Plan and Supporting Five Year Capital Plan. It is recommended that CCRTA consolidate the procurement timeline as outlined below. There will be a spike in electric vehicle procurement in 2024 to kick start the transition. This is also due to the fact that there are a large number of CCRTA vehicles that are past due for replacement. The number of electric vehicles recommended for procurement in 2024 does not take into account the 20 MassDOT Mobility Assistance Program (MAP) vehicles arriving for CCRTA use in fiscal year 2024.

Fossil fuel vehicle procurement in year 2024 and 2025 are highlighted to show the years where gasoline powered vehicles are required to support CCRTA's DART services. As discussed in Section 3.1, these gasoline vehicles are required to mitigate range issues on some of the longest DART runs. The feasibility of electrifying these vehicles, which make up the last 24% of DART vehicles, can be reconsidered during their subsequent procurement cycles and as battery technology improves.

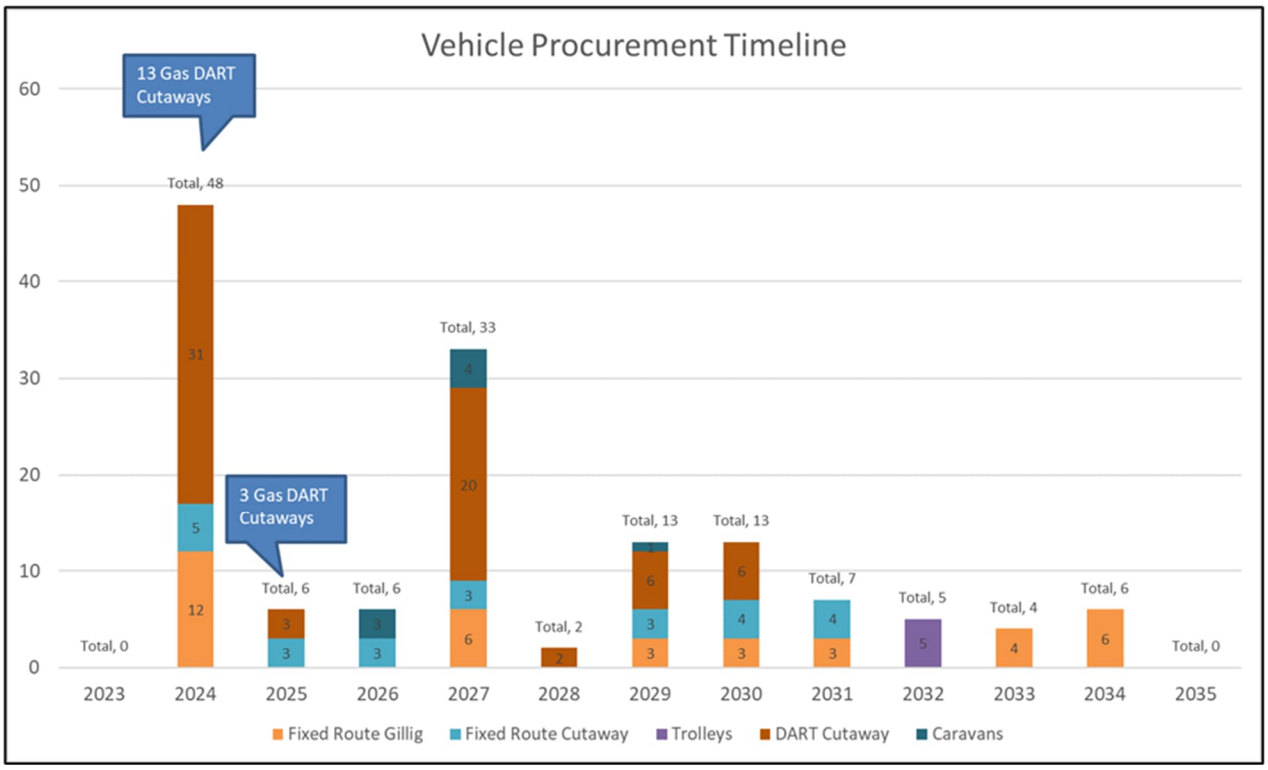

Figure 4 Vehicle Procurement Timeline

Refer to Appendix A for a detailed vehicle replacement schedule.

Figure 5 illustrates how CCRTA fleet composition will change over time as the vehicles are procured according to the above schedule. By 2035, CCRTA's fleet will be made up of 11% fossil fuel vehicles with 89% of the total fleet composition electric. An increase in fleet size by four vehicles is projected.

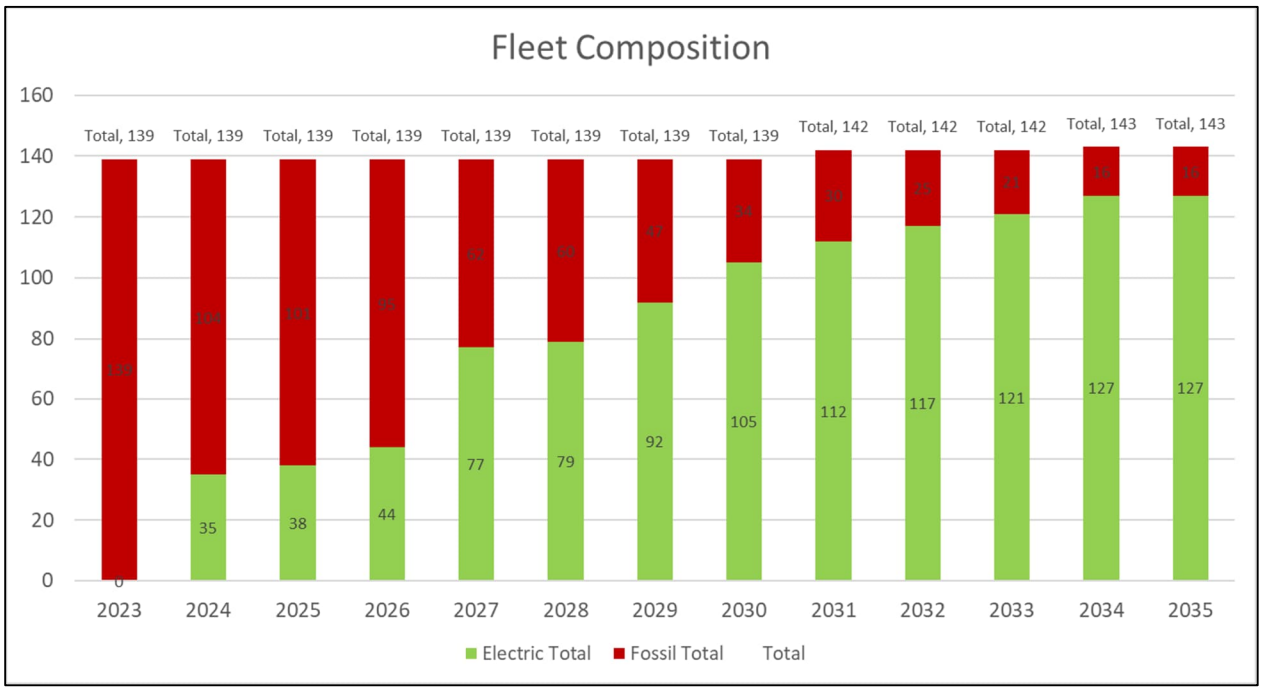

Figure 5 Fleet Composition Through Transition

4.2 Charger Procurement Timeline

A major consideration for CCRTA's fleet electrification timeline is the availability of supporting charging infrastructure. It is anticipated that the 35 electrical vehicles procured in 2024 will charge overnight at the depot (first of the locations to receive charging equipment) with installation of 36 Level 2 chargers, and four centralized chargers with three dispensers each, resulting in 48 available charging plugs that same year.

However, because the depot and HTC (terminal location) are relatively far from one another when accounting for peak summer-time traffic, the addition of on-route charging infrastructure at HTC provides an opportunity for both fixed route and DART vehicles to remain in service without returning to the depot early should problems arrive with vehicle range and operations. Since DCFC charging infrastructure is planned for installation at HTC in 2024 as well, this will provide the on-route fueling needed to support the acquisition of electric vehicles that may otherwise be unable to complete their runs. As shown in Figure 6, to align with the kickstart of electric vehicle procurement in 2024, the largest number of chargers will be installed at the depot and HTC that same year to support the first batch of vehicles.

The next largest round of charging infrastructure build up will be in 2027. This is because the vehicles purchased prior to 2027 can be supported by the charging stations located at the depot and HTC. This also allows CCRTA several years to evaluate locations for on-route charging and forge partnerships for eventual negotiations with local landowners. Purchases in 2027 include additional chargers at the depot for overnight charging but will also include the procurement of equipment for on-route charging in Mashpee, and in Provincetown. As discussed in Section 3.2, Mashpee is the largest hub for demand-response operation and the terminal of the Bourne fixed route. Provincetown is an important area for

installation of a charging station for both midday and overnight use as it is the terminal for the Flex and Shuttle routes and sees vehicles “parked out” overnight during the summer season.

For remaining transition years, depot chargers will be procured as the electrical vehicles are purchased.

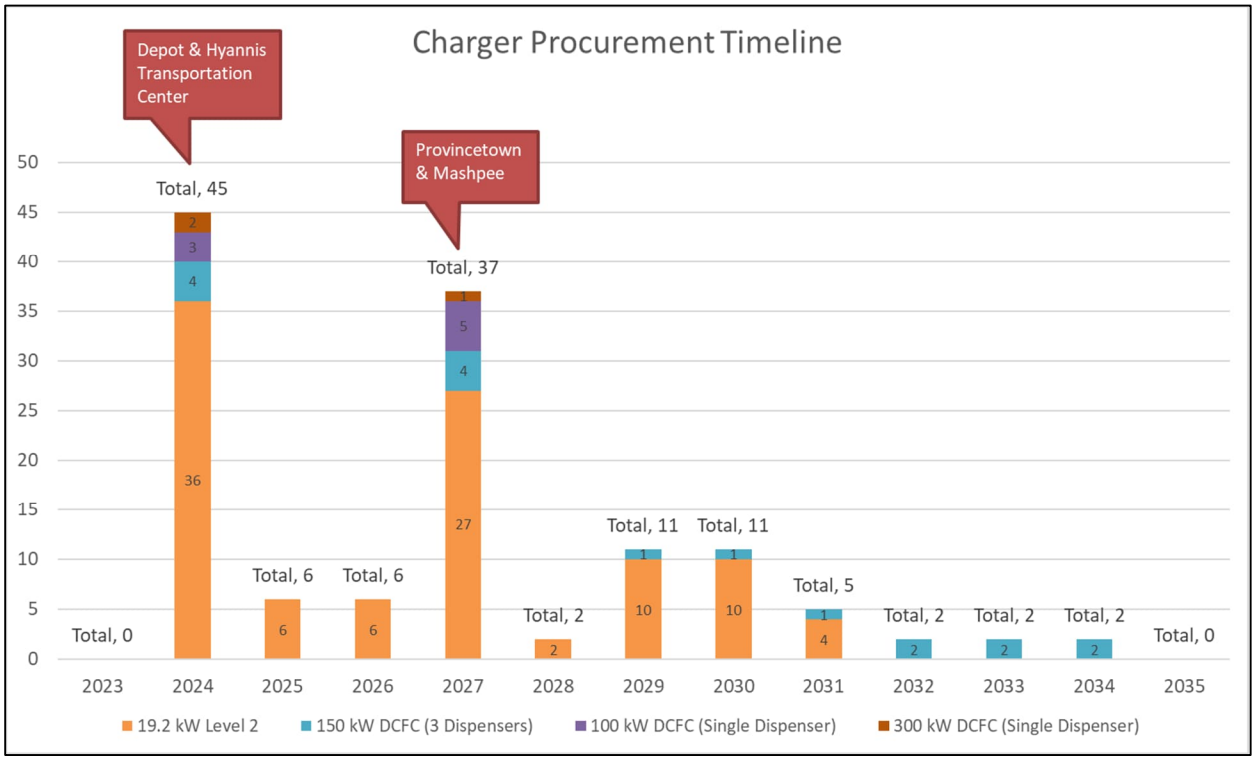

Figure 6 Charger Procurement Timeline

Refer to Appendix B for a detailed breakdown of the required types and number of chargers by location.

5. Life Cycle Cost Analysis & Capital

To understand the financial impact of transitioning to a new technology, it is important to consider all of the costs involved with acquiring and operating the new technology and compare it to the cost of acquiring and operating the current system in kind. To do this, a life cycle cost (LCC) model was constructed. The LCC includes initial capital as well as operations and maintenance costs of the battery-electric and fossil fuel vehicles and supporting infrastructure that would make up the future fleet. These costs can then be compared to the costs of replacing the existing fossil fuel-based operation with another round of fossil fueled vehicles. The operations and maintenance costs are based on the peak service levels analyzed above and scaled to account for off-peak.

Table 7 outlines the LCC model components, organized by basic cost elements, for fossil fuel and battery electric vehicle technologies.

Table 7 Primary Cost Categories by Vehicle Type

Category	Fossil fuel	Future Fleet
Capital	Vehicle purchase	Vehicle purchase
	Mid-life overhaul	Mid-life overhaul
		Battery replacement/warranty
		Charging infrastructure
		Electrical infrastructure upgrades
		Utility feed upgrades
Operations	Fossil fuel	Electricity
	Operator's cost	Operator's cost
		Demand charges for electricity
		Diesel fuel for auxiliary heaters
Maintenance	Vehicle maintenance	Vehicle maintenance
		Charger maintenance

For the above cost categories, certain base assumptions were developed to ensure that the cost model reflected real-world practices. These assumptions were derived from various sources including industry practices, CCRTA stakeholder inputs, and CCRTA's strategic plan.

Capital Investment

- The lifespan of a bus is 12 years.
- The lifespan of other vehicles including cutaways, trolleys, and vans is seven years.
- The electric service infrastructure installation cost, including conduits and wires from control box panel to charging stations section, was assumed to be covered by the Eversource Make Ready Incentive Program.
- Installation costs for the chargers is excluded from this estimate as a detailed infrastructure analysis, including a cost benefit analysis comparing building a new maintenance facility with modifying the existing facility, will be completed later in the study.
- 12-year battery warranties are purchased with the bus, so battery replacement at vehicle midlife is unnecessary

Costs

- 3% year-over-year inflation
- The utility rates structure is assumed to be the large General Service rate (G-3 – M.D.P.U. No. 31) from Eversource

Note that Eversource is developing an EV specific rate structure (EV-2) which should further reduce the operations cost of electric vehicles by employing charge management strategies and avoiding demand charging. It is recommended that the lifecycle cost model is updated with the new rate inputs when Eversource makes the EV specific rate structure available.

Table 8 lists the operating and capital costs assumed for this study. These are based on CCRTA's figures and general industry trends and have been escalated to 2023 dollars where necessary.

Table 8 Estimated Costs

Asset	Estimated Cost Per Unit	
	Fossil	Battery-Electric
29' Transit Bus	$531,000	$960,000
35' Transit Bus	$546,000	$960,000
21' Cutaway	$70,000	$125,000
23' Cutaway	$70,000	$170,000
26' Cutaway	$80,000	$295,000
28' Cutaway	$80,000	$295,000
32' Trolley	$325,000	$960,000
Van	$40,000	$70,000
Bus Maintenance, per mile	$1.30	$0.96
Other Vehicle Maintenance, per mile	$1.25	$0.92
Bus Battery Warranty	$75,000	
19.2 kW Level 2	$7,500	
150 kW DCFC (3 Dispensers)	$150,000	
100 kW DCFC (Single Dispenser)	$110,000	
300 kW DCFC (Single Dispenser)	$200,000	
Operator Wages, Benefits, and Overhead, per hour	$43.00	
Diesel Fuel, per gallon	$4.50	
Gasoline Fuel, per gallon	$3.50	
Energy Cost (per kWh)	$0.1235	

Because the transition to zero-emissions vehicles will be gradual, LCC calculations necessarily overlap multiple bus procurement periods. This was addressed by setting the start of the analysis period to the year after the transition to future fleet composition is complete (2034), with the analysis period stretching for a full bus lifespan (12 years). Gasoline vehicles have a useful life of six to seven years. In order to compare the current baseline fleet with the future fleet over a lifecycle of 12 years, two procurement cycles were considered for gasoline vehicles.

For vehicles that are already part of the fleet at the beginning of the analysis period, or for buses with remaining life at the end, a residual value was calculated and added or subtracted as appropriate.

The LCC analysis determines the relative cost difference between the baseline (fossil fuel) case and the proposed case (electric). Therefore, it only includes costs which are expected to be different between the options. Costs common to both alternatives, such as bus stop maintenance, are not included as they do not have a net effect on the LCC comparison. Thus, the model indicates the most economical option but does not represent the full or true cost of owning either of the options. Table 9 and Figure 7 compares the LCC of the future fleet with the current fossil fuel baseline.

Table 9 Lifecycle Cost Estimates

	Fixed Route		DART	
	Fossil Baseline	Future Fleet	Fossil Baseline	Future Fleet
Vehicle Capital Cost	$31,527,867	$67,596,985	$13,086,779	$35,323,723
Infrastructure Capital Cost	$0	$3,455,882	$0	$1,623,177
Vehicle Maintenance Cost	$42,054,180	$31,803,379	$33,323,374	$24,763,479
Infrastructure Maintenance Cost	$0	$976,663	$0	$642,428
Operations Cost	$105,903,325	$77,441,779	$104,207,956	$99,921,500
Total	$179,485,372	$181,274,688	$150,618,109	$162,274,307

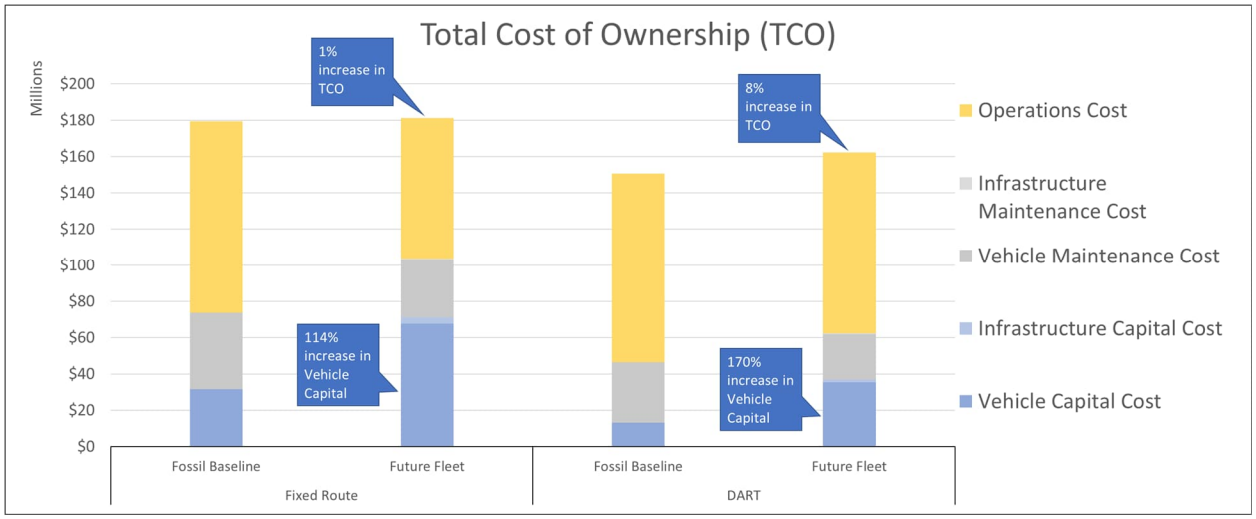

Figure 7 Lifecycle Cost Estimates

As shown in the Figure 7, there is a significant increase in the upfront capital requirement for vehicle procurement. CCRTA will need an additional capital investment of 114% and 170% to procure future fixed route vehicles and demand response vehicles, respectively. In addition, CCRTA will need additional capital investment in charging infrastructure at the four locations discussed previously in this report.

However, battery-electric vehicles are expected to reduce recurring costs for both maintenance and daily operations. Maintenance costs will likely decline because of the simplified nature of electric vehicle's drivetrains, which reduces brake wear, eliminates several maintenance-intensive components, and enables more advanced vehicle diagnostics. Accordingly, vehicle maintenance costs for the future fleet, comprised primarily of electric vehicles, are estimated to decline by 25% when compared to the current fleet.

Moreover, the operating costs for the future fleet are also expected to decrease by 16% (assuming a well-designed charging schedule) as electricity costs are generally lower than diesel and gasoline costs. As a result, the overall cost impact of transiting CCRTA's fleet from fossil fuel based vehicles to predominantly electric vehicles is estimated to be only 4%.

As mentioned above, the LCC allows for a cost of ownership comparison for the two types of fleets. However, it lacks the details required to develop a capital spending plan to help guide CCRTA with financial planning for the increase capital investment requirements and funding applications. Therefore, in addition to the LLC, the following capital investment plan was developed based on the vehicles and charging procurement timeline. Figure 8 shows the amount of investments that CCRTA will need to plan for in order to achieve its zero emission transition goals in accordance with the timeline developed in this study.

As expected, there is a big spike in capital spending requirements for the year 2024 which aligns with the first round of vehicle procurement and associated charging infrastructure development at the depot and HTC. The next two years, 2025 and 2026 will see lower investment requirements. Since additional vehicle purchases will require on-route charging infrastructure at Provincetown and Mashpee Commons scheduled for installation in 2027, CCRTA will witness increased capital spending requirements in 2027. During years 2029 through 2033 this investment will even out year over year.

Overall, CCRTA will need to plan for a total of $79 million over the course of the 12-year transition period. Note that this number includes the cost of procuring gasoline cutaways for DART services. Should CCRTA's strategy change, for example if decisions are made to bring on-route charging to additional locations or if technology advances allow for added vehicle range such that gasoline vehicles are not necessary, then the capital plan will need to change accordingly.

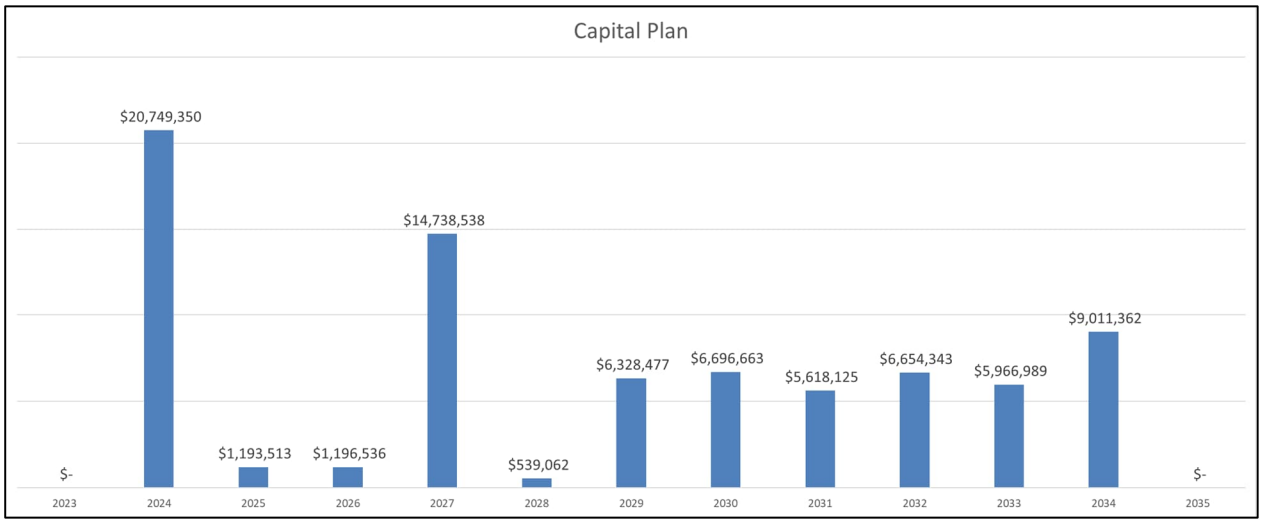

Figure 8 Capital Investment Timeline

6. Emissions Impacts

A primary goal for CCRTA's transition to zero-emission vehicles is to decrease the Authority's carbon footprint by reducing greenhouse gas (GHG) emissions. The anticipated emissions from CCRTA's future fleet and emissions from the current fleet were calculated and compared to quantify the Authority's overall

emissions reduction per the transition to battery electric vehicles. To provide a complete view of the reduction in emissions offered by the proposed transition strategy, the effects were analyzed based on three criteria:

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

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

The tank-to-wheel emissions impact considers the emissions reduction in the communities where the vehicles are operated. As a tank-to-wheel baseline, the 'tailpipe' emissions associated with CCRTA's existing diesel and gasoline vehicles were calculated. These calculations used industry emissions averages for gasoline vehicles and CCRTA's fuel economy data.

Battery electric vehicles have a third emissions source: grid electricity generation. To calculate the emissions associated with the grid, Hatch assumed an EPA and EIA average grid mix for Massachusetts.

Figure 9 summarizes the results of the emissions calculations; reflecting the total emissions that would result from operation of battery electric vehicles if the grid did not change from its current state. These results demonstrate that per the transition plan, the Authority will achieve 66% emissions reduction assuming the current grid mix. Further reduction can be expected because Eversource (CCRTA's utility provider) and Nextra Energy (CCRTA's current energy provider) have goals for decarbonizing the grid. In its 2021 Sustainability Report, Eversource aims to have a carbon neutral grid by 2030 and Nextra Energy has published its goal for 100% renewable energy by 2045. In March of this year, CCRTA signed a new Contract with Power Options to renegotiate electricity rates. The new provider is Constellation Energy Resources. In its 2022 sustainability report, Constellation Energy specified a goal to generate 95 percent clean energy by 2030 and 100 percent by 2040.

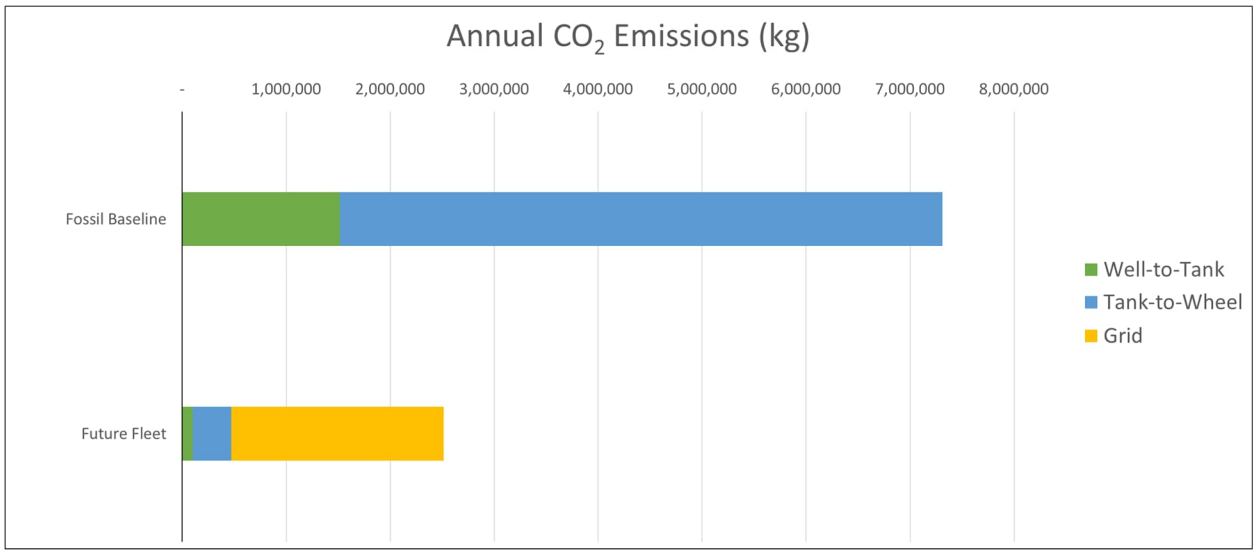

Figure 9 Annual CO2 Emissions (kg)

7. Market Options

There are many factors to consider when procuring electric vehicles and supporting charging infrastructure. As an additional complexity, CCRTA operates a mix of vehicle types. This is done to tailor the vehicle operated to the service type provided (fixed-route, demand-response, commuter, tourist-focused) however in the context of zero emission transition planning, it may pose a constraint on the number of possible vendors available to CCRTA. Although the market is changing quickly, and within the next few years more diverse electric bus, mini-bus, and van models are likely to be introduced, Hatch recommends that CCRTA consider broadening its specifications where possible to allow the largest possible range of vendors to participate; expanding the pool of competing vendors by considering such vehicles will likely save CCRTA money and could increase parts commonality with the fixed-route fleet.

To maintain a fair comparison, however, this analysis assumes that the existing fleet will be replaced during its expected retirement year with the same vehicle type as operated now. Although the recommended final fleet size is marginally higher than CCRTA's fleet size today, the increased reliability of electric vehicles and expected 12-year and 7-year replacement cycle (compared with some of CCRTA's existing vehicles which are operating well past their retirement years) will contribute to improved vehicle reliability and reduced spare factor.

Refer to Appendix C – CCRTA Vehicle Conversion Equivalents List for a complete list of existing CCRTA vehicles by type and class, and the electric conversion equivalent. This list provides purchase cost of the electric equivalent as well as seating capacity. Note that this list is not a comprehensive list of what is available on the market, nor is Hatch recommending certain manufacturers or vendors. This list is to provide CCRTA with market options to guide vehicle specification and procurement.

As discussed in 4.2, different types of charging infrastructure will be needed dependent on the charging location's requirements and capacity. Refer to Appendix B for a detailed breakdown of the required types and number of chargers by location. There are many options for charging equipment and CCRTA will most likely want to go through proper evaluation prior to finalizing procurement orders with vendors. In addition, CCRTA will be required to procure equipment from Eversource's qualified product lists (QPL) that are qualified to be eligible for rebates under the Make Ready Incentive Program. Refer to Appendix D – Eversource Qualified Product List for Eversource's QPL.

8. Community Considerations

Environmental Justice (EJ) community considerations must be accounted for during ZEV transition planning and is also a requirement to receive federal funding. EJ is based on the principle that all people have a right to be protected from environmental hazards and burdens, with all members of a community provided the opportunity to live in and enjoy a clean and healthful environment regardless of their background. EJ communities are members of the population that are vulnerable or at risk of being unaware of or unable to participate in environmental decision-making or to gain access to environmental resources due to socio-economic disadvantages.

Zero-emission vehicle transition planning can support EJ communities through the improvement of air quality with reduced particulate matter, encouragement of community participation, reduction of greenhouse gas (GHG) emissions, improvement of overall transit service, and by providing cleaner transit facilities and infrastructure.

In order to ensure EJ communities were considered during the operations analysis, CCRTA's service area was first defined. From there, Hatch identified three different EJ programs to utilize in order to define EJ program indicators and screening methodology; the Federal Justice40 Initiative, the US Department of Transportation's (DOT) Equitable Transportation Community Explorer (ETCE), and the

Commonwealth of Massachusetts Executive Office of Energy and Environmental Affairs (EEA) Environmental Justice Populations. Once the EJ programs were decided upon, Hatch then defined EJ program indicators and screening methodology, followed by the identification of EJ communities in CCRTA's service area.

Notably, three Justice 40-designated disadvantaged communities (by census tracts) were identified in CCRTA's service area; two in Barnstable and one in Falmouth. About five percent of the total population, or 10,000 residents, of the CCRTA Service Area is part of a disadvantage community. These communities experience higher than average disadvantages when it comes to health (heart diseases); costs of living (increased spending on housing and energy); traffic proximity (live near major roads); income (low median income); and educational attainment. Notably, the Justice 40-designated have high rates of asthma, ranking around 90th percentile for asthma compared to Census tracts nationwide.

Based on the results of the operations and financial analysis, CCRTA's ZEV Transition Plan is poised to create benefits for riders and residents in Cape Cod. The first batch of electric vehicles deployed will be operating in Barnstable as charging infrastructure is planned for HTC as early as 2024. This will enable both fixed-route and DART vehicles to charge should range issues arise and will provide operational resiliency during the early transition period - the ridership should not experience any changes to their existing service, and electric vehicles will pollute less thereby reducing greenhouse gas emissions in these communities.

To ensure that community considerations are accounted for throughout the transition period and beyond, it is recommended that CCRTA continuously monitor and evaluate the transition plan's potential benefits and adverse impacts to the environment and public health including impacts of recommended infrastructure investments, asset procurement, and changes to services or programs, particularly to EJ communities. In addition, CCRTA should ensure level of service is adequate in EJ communities within the CCRTA service area. By planning for continuity, CCRTA will ensure environmental justice is considered beyond the plan development and through implementation.

9. Recommendations and Next Steps

As electric vehicle technology matures, climate concerns become more pressing, and fossil fuels increase in cost, many transit authorities will transition their fleets towards battery-electric technology. Because of comprehensive ZEV transition planning efforts, CCRTA stands well-positioned to begin this process in the next few years. Through fleet electrification, CCRTA will be able to reduce emissions, noise, operating cost, and other negative factors associated with fossil fuel operations, while operating sustainably for years to come.

For CCRTA to achieve sustainable fleet electrification, Hatch recommends the following steps:

- When the first electric vehicles of each type are received, run the vehicles on their corresponding routes to obtain accurate energy consumption data.
- Incorporate energy modeling into the operations planning process. This includes tracking energy consumed by each trip and energy available after every trip.
- Consider real-time monitoring of vehicle battery energy.
- Consider the mitigation strategies identified in 5.3:

- Delay or defer procurement of vehicles for routes on which small energy deficits exist today. Advances in battery technology may make it more practical and economical to wait several years.
- Reallocate trips between blocks to make maximum use of available energy capacity.
- Add extra vehicles to route if necessary.

+ Consider the installation of on-route charging for fixed-route services at locations discussed in Section 3.3: HTC, Mashpee, Provincetown, and Falmouth in the quantities recommended.
+ Consider the installation of charging for demand-response services at locations discussed in Section 3.4: HTC and Mashpee in the quantities recommended.
+ Negotiate an agreement with the Steamship Authority (SSA) to arrange CCRTA access to the Palmer Avenue Parking Lot in Falmouth for charging.
+ Begin discussions with the Provincetown municipal government and the local community to ensure a comprehensive review of potential real-estate for on-route charging and overnight charging locations prior to beginning construction.
+ Begin discussions with local landowners in Mashpee for future on-route charging locations.
+ Periodically re-evaluate the feasibility of electrifying the last 24% of DART vehicles, either through technology advances or on-route charging infrastructure.
+ Update the lifecycle cost model with the new rate inputs when Eversource makes the EV specific rate structure available to ensure accurate data informs CCRTA's capital planning.
+ Update capital plan as ZEV technology advances and/or CCRTA's transition strategy changes.
+ Broaden CCRTA vehicle specifications where possible to allow the largest possible range of vendors to participate.
+ Monitor and evaluate the transition plan's potential benefits and adverse impacts to the environment and public health including impacts of recommended infrastructure investments, asset procurement, and changes to services or programs.
+ Ensure level of service is adequate in EJ communities within the CCRTA service area.

Appendix A – Detailed Vehicle Replacement Schedule

	Fixed Route Gillig	Fixed Route Cutaway	Trolleys	DART Cutaway: CDL	DART Cutaway: non-CDL	Caravans
2023						
2024	1034, 1035, 1036, 6281, 6282, 6283, 6284, 6285, 6297, 8230, 8231, 8232	501, 502, 503, 504, 506		415*, 416, 417, 421, 422, 423, 425*, 429, 432*, 433*, 434*, 437, 438, 439*, 446, 473	449, 451, 452, 453*, 455*, 456, 457, 460*, 462*, 463, 464*, 465*, 466, 467, 469*	
2025		500, 505, 507		430*, 426*, 428*		
2026		508, 512, 511				225, 226, 227
2027	1300, 1301, 1302, 8226, 8228, 8229	509, 510, 513		424, 435, 436, 440, 441, 442, 443, 444, 445, 447	448, 450, 458, 470, 471, 472, 474	219, 220, 221, 223
2028				475, 479		
2029	2000, 2001, 2022	3 NEW vehicles		481	482, 483, 484, 485	224
2030	1900, 1901, 1902	514, 515, 516, 517		478, 477, 476	459, 461, 468, 486, 487, 488	
2031	1800, 1801, 1802	518, 519, 520, 521				
2032			T1803, T1804, T1805, T1806, T1807			
2033	1903, 1904, 1905, 1 NEW vehicle					
2034	2200, 2201, 2202, 2203, 2204, 2205					

*Vehicles to be replaced by another round of gasoline vehicles.

Appendix B – Detailed Charger Procurement Schedule

	19.2 kW Level 2	150 kW DCFC (3 Dispensers)	100 kW DCFC (Single Dispenser)	300 kW DCFC (Single Dispenser)
2024	36 (Depot)	4 (Depot)	3 (HTC)	2 (HTC)
2025	6 (Depot)			
2026	6 (Depot)			
2027	27 (Depot)	2 (Depot) 2 (Provincetown)	5 (Mashpee)	1 (Provincetown)
2028	2 (Depot)			
2029	10 (Depot)	1 (Depot)		
2030	10 (Depot)	1 (Depot)		
2031	4 (Depot)	1 (Depot)		
2032		2 (Depot)		
2033		2 (Depot)		
2034		2 (Depot)		

Appendix C – CCRTA Vehicle Conversion Equivalents List

Service Type	Vehicle # / Vehicle make	Vehicle Year	Total Vehicles	Vehicle Description	Max Seating	Retirement year	Cost of Electric Vehicle replacement	Electric Vehicle/ Seating capacity	Electric Vehicle Model
Fixed Route Cutaway	Ford E-450 E4FF	2019	8	Cutaway White Van 26 ft	15	2026	$170,000	Mid-Sized Cutaway/ 12	Ford E-Transit Cutaway
Fixed Route Cutaway	Chevrolet Express	2020	6	Arboc White Van 28 ft	17	2027	$295,000	Large sized Cutaway / 14	Lightning ZEV 3 VAN /Ford Transit 350HD Passenger Van
Fixed Route Cutaway	Chevrolet Express	2021	8	Arboc White Van 28ft	20	2028	$295,000	Large Sized Cutaway/ 14	Lightning ZEV 3 VAN /Ford Transit 350HD Passenger Van
Fixed Route Bus	Gillig	2010	3	Rear engine/ 29ft	30	2022	$960,000	Bus 29 ft/ 30	Gillig/ New Flyer,30 ft
Fixed Route Bus	Gillig	2013	3	Rear engine 29 ft	30	2025	$960,000	Bus 30 ft/30	Gillig/ New Flyer,30ft
Fixed Route Bus	Gillig	2018	3	Rear engine 29 ft	28	2030	$960,000	Bus 29 ft /28	Gillig/ New Flyer,30ft
Fixed Route Bus	Gillig	2019	6	Rear engine (2) 29 ft & (4) 35 ft	33	2031	$960,000	Bus 29 & 35 ft /30 & 35	Gillig/ New Flyer,35ft
Fixed Route Bus	Gillig	2021	3	Rear engine 35ft	33	2033	$960,000	Bus 35 ft /33	Gillig/ New Flyer,35 ft
Fixed Route Bus	Gillig	2022	6	Rear engine (3) 29 ft & (3) 35ft	33 & 28	2034	$960,000	Bus 29 & 35 ft / 30 &35	Gillig/ New Flyer,35ft
Fixed Route Bus	Gillig	2006	6	Rear engine 29ft	25	2024	$960,000	Bus 29 ft /25	Gillig/ New Flyer,30ft
Fixed Route Bus	Gillig	2008	6	Rear engine 29 & 35 ft	30 &35	2026	$960,000	Bus 29 & 35 ft /30 & 35	Gillig/ New Flyer,35ft
Trolleys	Ford F-53 Villager	2018	5	Villager, front engine 32ft	28	(2) 2025, (3) 2026	$960,000	Replace with Gillig bus 29 ft	Gillig/ New Flyer,35ft/ Green Power Heavy Duty Class 4 Electric Capacity 25

Service Type	Vehicle # / Vehicle make	Vehicle Year	Total Vehicles	Vehicle Description	Max Seating	Retirement year	Cost of Electric Vehicle replacement	Electric Vehicle/ Seating capacity	Electric Vehicle Model
DART Non CDL Cutaway	Ford E-450 Phoenix	2017	1	Cutaway white Van 25.75 ft	15	2024	$170,000	Mid-sized Cutaway/ 12	Ford E-Transit Cutaway
DART Non CDL Cutaway	Ford E-350 Phoenix	2017	18	Cutaway Van White 21.5 ft	12	2023	$125,000	Small Sized Cutaway/ 8	Ford E-Transit Cutaway
DART Non CDL Cutaway	Ford E-350 Phoenix	2018	3	Cutaway White 21.5 ft	8	2024	$125,000	Small Sized Cutaway/ 8	Ford E-Transit Cutaway
DART Non CDL Cutaway	Ford E-350 E3FX	2019	2	Cutaway White Van 21.5 ft	8	2025	$125,000	Small Sized Cutaway/ 8	Ford E-Transit Cutaway
DART Non CDL Cutaway	Ford E-350 E3FX	2021	1	Cutaway White Van 21ft	8	2026	$125,000	Small Sized Cutaway/ 8	Ford E-Transit Cutaway
DART Non CDL Cutaway	Ford E-350 Phoenix	2023	7	Cutaway White Van 21 ft	12	2029	$125,000	Small Sized Cutaway/ 8	Ford E-Transit Cutaway
DART CDL Cutaways	Ford F-450 Elkhart	2016	28	Cutaway White Van 26 ft	17	2023	$295,000	Large sized Cutaway/14	Lightning ZEV 3 VAN /Ford Transit 350HD Passenger Van
DART CDL Cutaways	Ford E-450 Econoline	2019	1	Cutaway White Van 26ft	16	2026	$295,000	Large Sized Cutaway/14	Lightning ZEV 3 VAN /Ford Transit 350HD Passenger Van
DART CDL Cutaways	Ford E-450 Econoline	2021	2	Cutaway White Van 26 ft	16	2028	$295,000	Large sized Cutaway/14	Lightning ZEV 3 VAN /Ford Transit 350HD Passenger Van

Service Type	Vehicle # / Vehicle make	Vehicle Year	Total Vehicles	Vehicle Description	Max Seating	Retirement year	Cost of Electric Vehicle replacement	Electric Vehicle/ Seating capacity	Electric Vehicle Model
DART CDL Cutaways	RAM 3500 Promaster	2020	3	Cutaway White Van 23 ft	14	2027	$170,000	Mid-Sized Cutaway/ 12	Ford E-Transit Cutaway
DART CDL Cutaways	Ford E-450 Econoline	2022	2	Cutaway White Van 26ft	16	2029	$295,000	Large Sized Cutaway/14	Lightning ZEV 3 VAN /Ford Transit 350HD Passenger Van
Caravans	Dodge Caravan	2018	1	Van 16.9 ft	3	2024	$70,000	SUV/3	Chevy Electric EQUINOX EV/Rivian R1S
Caravans	Dodge Caravan	2017	2	Van 16.9 ft	3	2023	$70,000	SUV/3	Chevy Electric EQUINOX EV/Rivian R1S
Caravans	Dodge Caravan	2019	2	Van 16.9 ft	3	2025	$70,000	SUV/3	Chevy Electric EQUINOX EV/Rivian R1S
Smart Dart Caravans	Dodge Caravan	2019	3	Van 16.9 ft	5	2025	$70,000	SUV/3	Chevy Electric EQUINOX EV/Rivian R1S

Appendix D – Eversource Qualified Product List

Commercial Project Electric Vehicle Charger Qualified Product List

This qualified product list (QPL) includes all electric vehicle charging network software and hardware providers that have been qualified to be eligible for rebates under the program, as of the effective date shown at the bottom of the document. Customers may select from any approved network software provide and any approved hardware provider. Customers should note that not all network software and hardware is compatible. Please confirm software and hardware compatibility with the vendor.

Qualified Charging Network Software Providers

Provider	Level 2 or DCFC Support
AmpedUp!	Both
AmpUp	Both
Blink	Both
ChargeLab	Both
ChargePoint	Both
ChargeUP	Level 2
Driivz	DCFC
Enel X	Both
Energy5 Network	Level 2
EV Connect	Both
EV Gateway	Both
EverCharge	Level 2
EVgo	DCFC
Evoke	Both
EVPassport	Both
FLO	Both
Ford Pro Depot Charging Software	Both
In-Control Network	Both
Leviton	Both
Livingston Energy Group	Both
Loop	Both

NovaCHARGE	Both
Nuvve	Both
PowerPump	Level 2
SemaConnect	Both
Shell Recharge Solutions	Both
SWTCH	Both
Xeal	Level 2
Zevtron	Both

Qualified Charging Hardware Providers

Level 2 Electric Vehicle Supply Equipment	
Hardware Manufacturer	**Hardware Model**
ABB	Terra AC Wallbox 40A, 80A
Aispex	PLTM-48, GOLD-48, SLVR-48
Atom Power	AP3P400
Atom Power	AS2P-60-EVSE, AS2P-100-EVSE
Blink (Lite-On)	HQ 200 Smart (HQW2-50C*)
Blink (Lite-On)	IQ200 Advanced (IQW2)
Blink (Lite-On)	MQ 200 (MQW2-50C*)
BreezeEV (Light Efficient Design)	EVC-L2-48A-L1-1*
BTCPower	EVP-2001-30*, EVP-2002-30*
BTCPower	L2W/P 30A, 40A, 70A
ChargePoint	CPF50
ChargePoint	CT4000
ChargePoint	CT6000 (fleet only)
Clipper Creek	HCS-40R
Enel X	JuiceBox Pro 32, 40, 48
Enel X	JuicePedestal 32, 40, 48

EverCharge	EV002
EvoCharge	iEVSE
EvoCharge	iEVSE Plus
EVPassport (Phihong)	Ezra (AW Series)
EVPassport (Phihong)	Rosa (AX Series)
EVSE LLC	3703
EVSE LLC	3704
EVSE LLC	3722
FLO (AddEnergies Technologies Inc.)	CoRe+
FLO (AddEnergies Technologies Inc.)	CoRE+ MAX
FLO (AddEnergies Technologies Inc.)	SmartTWO
Ford (Siemens)	Pro Charging 48A, 80A fleet (NL38-10C823-AA)
JuiceBar	JB3.0 32, 40, 48, 80
InCharge Energy (Lite-On)	ICE-40AC, ICE-80AC
Leviton (ChargePoint)	EVR Green 4000 (CT4000)
Lite-On	L2-LPWF
Livingston Energy Group	CP-203
Livingston Energy Group	CP-208
Livingston Energy Group (EVSE LLC)	3703-103+ IHD (3703)
Livingston Energy Group (EVSE LLC)	3704-10 IHD (3704)

Level 2 Electric Vehicle Supply Equipment	
Hardware Manufacturer	**Hardware Model**
Loop	EVS-32A-L2*
Loop	EVS-80A-L2*
NovaCHARGE	NC7000, NC8000
Nuvve	Power Port
Phihong	AW Series

Phihong	AX Series
PowerCharge	E20 XXE/XXP
PowerPump (CCM International)	AC5500-G
SemaConnect	Series 6
SemaConnect	Series 7
SemaConnect	Series 8
Siemens	Versicharge G3
Siemens	VersiCharge 40A, 48A
SWTCH (Lite-On)	EX-1762-1A30, EX-1193-1A13
Tellus Power Green	UP 160J
US Energy / Energy5 (Lite-On)	PowerPump C32-01 (EX-1762)
Wallbox	Pulsar Plus

DC Fast Chargers	
Hardware Manufacturer	**Hardware Model**
ABB	HVC 100, 150
ABB	T54 HV
ABB	Terra 184, 124, 94, 54
ABB	Terra HP 175, 350
ADS-TEC	ChargeBox 320 KW
BTCPower	HPC 100, 150, 200
BTCPower	HPCD1-350
BTCPower	L3R-100-480
BTCPower	L3R-50-208
BTCPower	L3S-50-208
BTCPower	L3S-50-480
BTCPower	100 kW AIO, 180 kW AIO, 180/240/360 kW Split System
ChargePoint	Express 250
ChargePoint	Express Plus[1]
Delta	100kW, 350kW
Enel X	JuicePump 50, 75
EVPassport (Phihong)	Larry (DSWU601*)
EVPassport (Phihong)	Ruth (DSWU122*)
EVPassport (Phihong)	Zeus (DSWU182*)
FLO (AddEnergie)	SmartDC 100kW
FLO (AddEnergie)	SmartDC 50kW
FreeWire	Boost Charger 150
Leviton (ChargePoint)	EVR Green DCFC (Express 250)
Nuvve (Rhombus)	RES-HD60-V2G, RES-HD125-V2G

Phihong	DSWU122*
Phihong	DSWU601*
Phihong	DSWU901*
Phihong	DS60, DS90, DS120, DS150, DS180, DO360
Rhombus	RES-DCVC- 60, 125
Rhombus	Res-HD125-V2G
Rhombus	Res-HD60-V2G
SemaConnect (Phihong)	SemaConnect 60, 90, 150, 180, 360 kW
Siemens	Ultra50
Signet	350kW
Tellus Power Green	TP-EVPD 60kW, 120kW, 160kW, 180kW, 200kW, 240kW, 300kW, 360kW
Tritium	PKM 100, 150
DC Fast Chargers	
Hardware Manufacturer	**Hardware Model**
Tritium	PKM 360-PU
Tritium	RT 175-S
Tritium	RT 50, 75, 150, 175
Tritium	RTM 50, 75

[1]ChargePoint's Express Plus must be installed with a minimum of two power modules per site

The equipment will differ on charger models, software, costs, and manufacturer details. Eversource does not offer preferences or recommendations for any of the approved equipment. Program participants are responsible for determining the suitability of these products and services.