# *Zero-Emission Bus Implementation Plan*

December 2020

Prepared by:

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## Background

The Northern Arizona intergovernmental Public Transportation Authority (referred to as Mountain Line) contracted with the Center for Transportation and the Environment (CTE) to develop a Zero-Emission Bus (ZEB) Transition Plan to identify a zero-emission roadmap for full-scale deployment. The evaluation included analysis of multiple deployment scenarios as detailed below:

- Baseline Hybrid Diesel (current technology)
- Battery-Electric Bus (BEB) Depot Only Charging
- BEB On-Route and Depot Charging
- Fuel Cell Electric Bus (FCEB) Only
- Mixed Fleet (BEB and FCEB)

Results of the analysis were included in the *Zero-Emission Bus Fleet Transition Study* (August 2020, revised November 2020). Mountain Line staff reviewed the results and provided recommendations for further evaluation of the BEB On-Route and Depot Charging scenario to the Mountain Line Board of Directors. The recommendations were adopted by the Mountain Line Board of Directors on June 17, 2020.

This *Implementation Plan* was developed to provide further evaluation of the BEB On-Route and Depot Charging scenario for Mountain Line and to provide recommendations to support successful deployment of BEBs in service. The Implementation Plan was developed to support Mountain Line in understanding the challenges and managing the constraints associated with zero-emission technologies. The *Implementation Plan* was based on best-practice strategies for deploying ZEBs. The deployment will be focused on operating BEBs initially out of the Kaspar Drive Maintenance Facility with a total of ten (10) buses eventually moving to operate out of the new facility that may be co-located with Northern Arizona University (NAU). The schedule for development of the future facility is currently unknown and funding has not yet been identified.

On-route charging is proposed at the Downtown Connection Center (DCC). The DCC is a transit hub located in downtown Flagstaff that all Mountain Line routes pass through during the day. The DCC is currently undergoing design for redevelopment that is being funded by a Federal Transit Administration (FTA) Bus and Bus Facilities Grant. The redevelopment is expected to be completed by 2023; however, the DCC will remain operational during redevelopment. Details from this *Implementation Plan* will be critical in developing the full-scale design that is being completed by AECOM (under contract with Mountain Line) for the DCC. The *Implementation Plan* provides the following: a summary of the bus and route modeling that was completed to support technology selection; rate evaluation to understand the expected costs to operate the BEBs; a bus recommendation and procurement best practices; infrastructure requirements and recommendations; an updated total cost of ownership assessment; resiliency plan; deployment strategies; training recommendations; data collection plan; and analysis of other fleet vehicles including paratransit. The *Implementation Plan* is arranged in the following sections:

- Background
- Bus and Route Modeling
- Recommendations for Service Planning
- Rate Modeling and Utility Partnership Recommendations
- Bus Procurement Best Practices
- Bus Specifications and Fleet Recommendations
- Infrastructure Requirements and Recommendations
- Resiliency Plan
- Total Cost of Ownership Analysis
- Training
- Deployment Strategy
- Data Collection Plan
- Paratransit and Non-Revenue Service Vehicle Plan
- Project Schedule

## Route and Bus Modeling

CTE's ZEB Modeling Methodology, as detailed in the *Zero-Emission Bus Fleet Transition Study (*November 2020) was used to assess the feasibility of utilizing 35-foot (') BEBs and 60' articulated BEBs to operate the Mountain Line service. CTE developed route and bus models to run operating simulations for representative Mountain Line routes. CTE used Autonomie, a powertrain simulation software program developed by Argonne National Labs for the heavy-duty trucking and automotive industry. CTE modified software parameters specifically for electric buses to assess energy efficiencies, energy consumption, and range projections. Mountain Line collected GPS data from nine (9) Mountain Line routes. GPS data included time, distance, vehicle speed, vehicle acceleration, GPS coordinates, and roadway grade that are used to develop the route model. CTE used component-level specifications and the collected route data using a hybrid diesel bus and simulated the operation of an electric bus on each of the nine (9) routes. The seasonal Mountain Express route was not operating at the time of data collection.

The route modeling included analysis of several scenarios—varying passenger load, accessory load, and battery degradation—to estimate real-world vehicle performance, fuel efficiency, and range. The data from the routes, as well as the specifications for each of the selected bus types, was used to simulate operation of each type of bus on each respective route. The models were run with varying loads to represent "nominal" and "strenuous" loading conditions. Nominal loading conditions assume average passenger loads and moderate temperature over the course of the day, which places marginal demands on the motor and heating, ventilation, and air conditioning (HVAC) system. Strenuous loading conditions assume high or maximum passenger loading and either very low or very high temperature (based on agency's latitude) that require near maximum output of the HVAC system. This nominal/strenuous approach offers a range of operating efficiencies to use in estimating average annual energy use (nominal) or planning minimum service demands (strenuous).

While GPS data was collected for nine (9) Mountain Line routes, this transition analysis evaluated all ten (10) fixed service routes. As stated previously, data was not able to be collected for the seasonal Mountain Express route; however, for the purpose of ensuring enough ZEB buses are transitioned into the fleet for each scenario, Route 8 operating efficiencies were used to estimate the Mountain Express energy use. Route 8 was selected to estimate the Mountain Express energy use because it was modeled to have the highest energy use among 35' bus routes, and the Mountain Express route is predicted to have a similar high energy use due to the high speeds, grade, and elevation characterized by the route. Mountain Line will be collecting data from the Mountain Express route and CTE will complete route analysis as the route is now operational for the season. Results will be provided in an addendum to Mountain Line.

Route modeling ultimately provides an average energy use per mile (kilowatt-hour/mile [kWh/mi]) associated with each route, bus size, and load case as depicted in **Table 1**. A summary of each route simulated including speed, grade, and elevation profiles were included as an Appendix in the *Zero-Emission Bus Fleet Transition Study* (November 2020) for the first phase of the ZEB analysis.

*Table 1 – Modeling Results Summary*

| Bus Length [ft] | Route | Nominal Efficiency [kWh/mi] | Strenuous Efficiency [kWh/mi] |
|---|---|---|---|
| **35** | 2 | 2.0 | 2.7 |
| | 3 | 1.7 | 2.3 |
| | 4 | 2.0 | 2.7 |
| | 5 | 2.0 | 2.7 |
| | 7 | 1.9 | 2.5 |
| | 8 | 2.4 | 3.3 |
| | 14 | 2.1 | 2.8 |
| | 66 | 1.8 | 2.4 |
| | Mountain Express[1] | 2.4 | 3.3 |
| **60** | 5x | 2.8 | 3.9 |
| | 10 | 2.8 | 3.9 |

Using vehicle performance predicted from route modeling, combined with educated assumptions for battery electric and fuel cell technology, CTE analyzed the expected performance and range needed on every block in Mountain Line's fixed-route network and assessed the achievability of each block by BEBs and FCEBs over time, as range improves. Details of the block analysis for depot charged BEBs and FCEBs are included in the *Zero-Emission Bus Fleet Transition Study* (November 2020).

In addition to the block analysis for depot-only charged BEBs and for FCEBs, CTE also simulated on-route charging of the entire fleet, assuming charging occurs at the depot in the evening and on-route throughout the day at the DCC as each block passes through the DCC.

CTE modeled the New Flyer XCelsior Charge bus with a fast-charge battery to simulate on-route charging at the DCC. A specific model bus and charger configuration were selected to model because on-route charging performance varies by OEM, as the state of charge (SoC) at the time of charging affects the power delivered to the bus. **Table 2** provides details regarding the battery configurations modeled in the on-route charging analysis.

[1] GPS route data was not collected for the Mountain Express Route. Route 8 operating efficiencies were used to estimate the Mountain Express energy use.

*Table 2 - Modeled Battery Configurations*

| Description | Nameplate Capacity (kilowatt-hour [kWh]) | Service Energy (kilowatt-hour [kWh]) |
|---|---|---|
| **Fast-Charge New Flyer Battery – 35'** | 213 | 154 |
| **Fast-Charge New Flyer Battery – 60'** | 320 | 236 |

As depicted in the previous table, only a portion of the nameplate capacity of the battery is useable energy where the bus will perform as designed. This is referred to as the service energy. Unusable regions of the battery are designed to protect battery life and includes ranges at the top and bottom of the battery's capacity. In addition, an additional percentage at the bottom of the battery capacity is considered the de-rated region, where the bus does not have its full range of performance available. CTE recommends including a service reserve to allow the bus to return to the depot from the furthest point on the route, estimated at 10 kWh for this analysis.

For the New Flyer buses, the unusable region at the top of the battery's range used for this analysis is 10%, and at the bottom is 10%, for a total of 20% unusable. In addition, the de-rated region of the batteries used for this analysis is 3% of the battery's total capacity. The useable and unusable portions of the batteries are depicted in **Figure 1** and

**Figure** 2. These unusable regions vary by OEM and may change in future battery configurations. Alternate battery capacity/configurations are available from different OEMs and are provided in **Appendix A**.

*Figure 1 – Battery Service Energy Breakdown for 213 kWh New Flyer Fast Charge Battery*

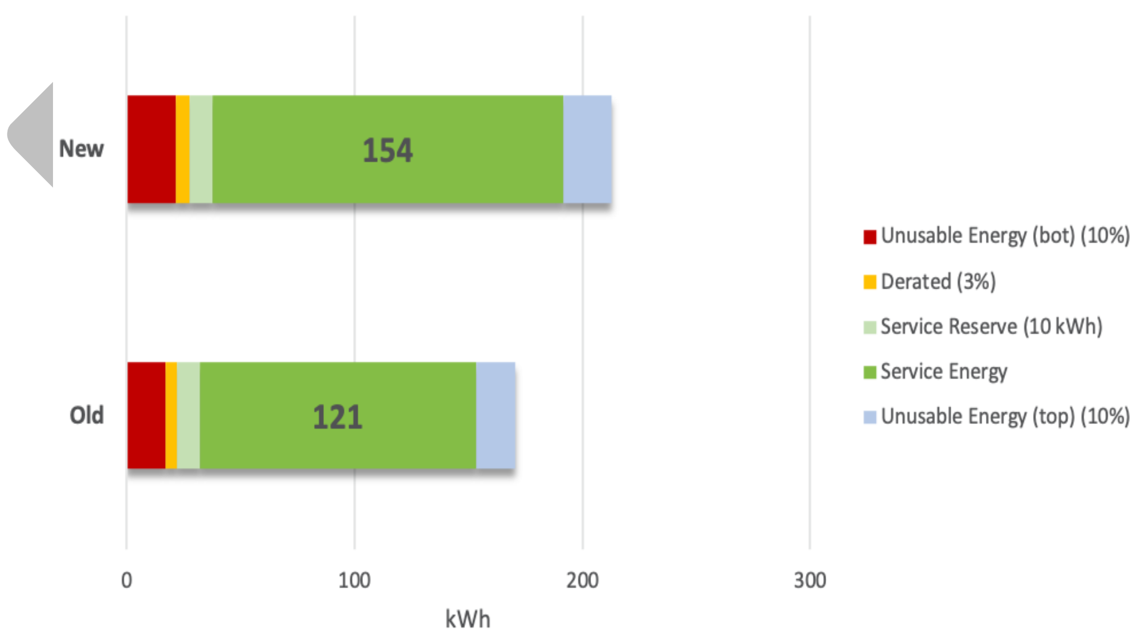
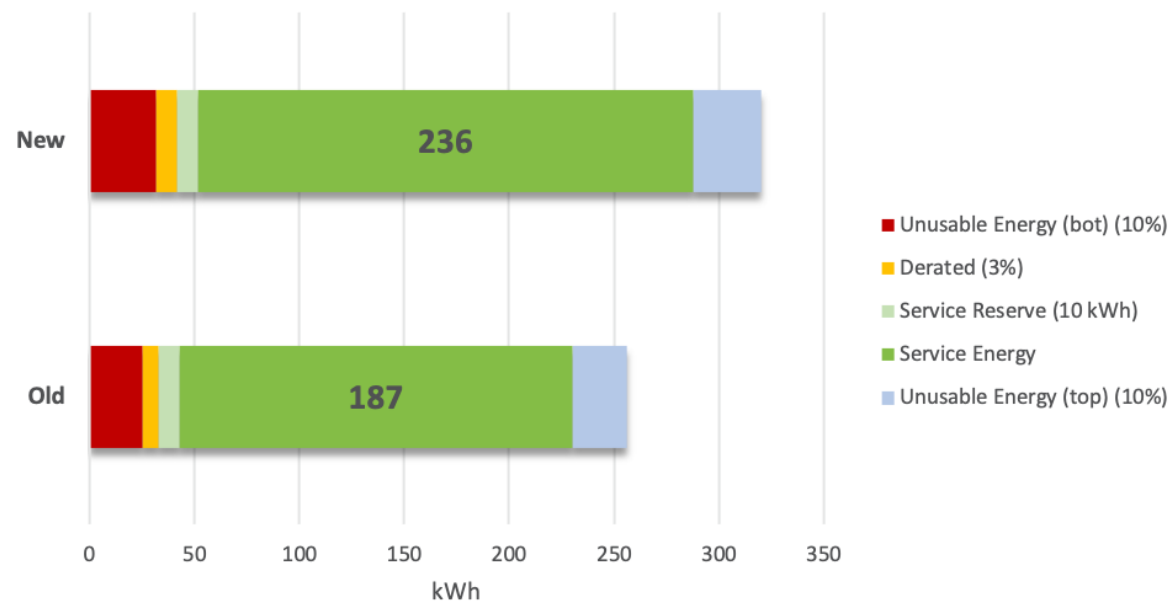


*Figure 2 - Battery Service Energy Breakdown for 320 kWh New Flyer Fast Charge Battery*




As a battery ages, less energy will be available for use. In CTE's analysis, an 'old' battery is estimated to have 80% of the capacity of a 'new' battery, because this is the standard levels to which OEMs will generally warranty the batteries. Currently, limited data is available regarding the rate at which battery degradation occurs.

In addition to understanding the on-route efficiencies of the buses, understanding the charging profile for the battery configurations selected was critical for developing the charging strategy. CTE worked with New Flyer and ABB, the manufacturer of a 450-kilowatt (kW) direct current (DC) on-route charger, to understand the charge profile, or the power provided to the battery at each SoC. The modeled New Flyer battery can accept up to 300 kW while the battery is at or below 74% actual SoC, 180 kW while the battery is between 75% and 87% actual SoC, and 60 kW between 88% and 100% SoC. The charge profile was used to develop a simulation for a bus for each route, including the longest block (by mileage) for each route throughout the day. The ABB 450-kW on-route charger was selected for the charging station modeling because the unit is currently commercially available and has been successfully demonstrated with multiple OEM's buses. CTE evaluated the current block schedule to determine if there was sufficient time to charge the battery during each layover at the DCC to allow a bus to finish each block under both nominal and strenuous load conditions, and with a new or degraded battery. Understanding the range under the most adverse conditions (strenuous with a degraded battery) is critical to successful planning and deployment on-route.

The on-route charging analysis was completed to determine the required charge time during layovers to sustain the level of charge throughout the day, referred to as charge sustaining mode. By sustaining the charge throughout the day, the bus operates in the SoC range where the most energy can be delivered to the bus per minute of charging and reduces or eliminates the need for top off charging at the depot in the evening.

**Figure 3** illustrates the charge sustaining effect, utilizing Block 2013 under strenuous operating conditions and a 7 minute charge per pass through the DCC. The figure indicates that the SoC of the vehicle remains constant between approximately 60% and 80% throughout the day, essentially allowing the bus to operate for perpetuity without running out of energy. The analysis assumes that the bus leaves the depot at approximately 70% SoC and is able to maintain that SoC throughout the day. Block 2013 was selected for this demonstration because it is the longest duration and most energy intensive block based on the modeling completed. A similar analysis was completed for the most challenging block for each route in Mountain Line service.

*Figure 3 - Charge Sustaining Effect Starting at 70% SoC*


**Error! Not a valid bookmark self-reference.** depicts the same charge sustaining effect utilizing Block 2013, under strenuous conditions and a 7 minute charge, assuming a 100% SoC when leaving the depot. As can be seen from the figures, starting at a 100% SoC at the depot at the beginning of the day is not required to finish the block when operating in a charge sustaining mode, assuming there is sufficient time on route to replace the energy needed to finish each block

*Figure 4 - Charge Sustaining Effect Starting at 100% SoC*

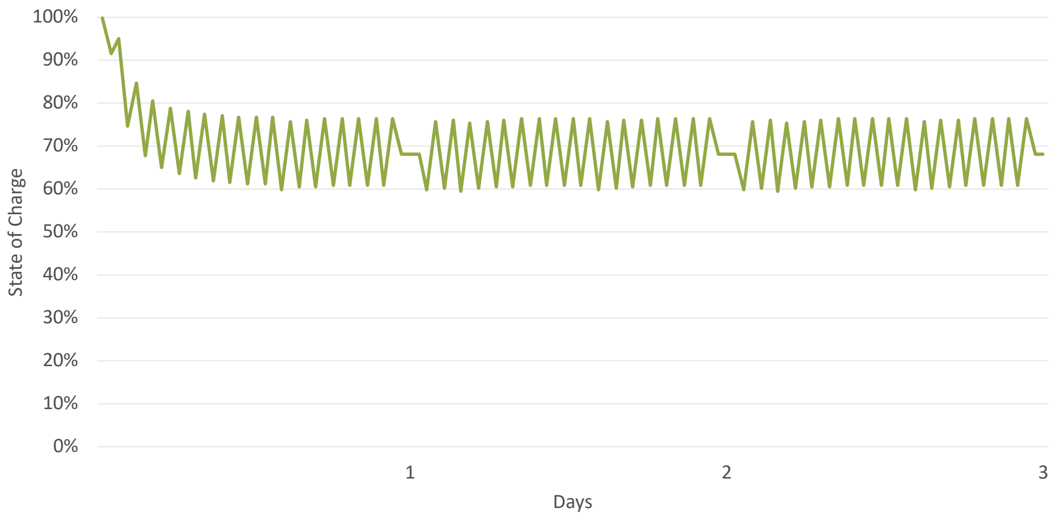





**Figure 5** and
**Figure** 6 depict the effect of missing a single charge and of missing every fourth charge through the DCC throughout the day, utilizing Block 2013, under strenuous conditions and a 7 minute charge, assuming a 70% SoC when leaving the depot. As can be seen from the **Figure 5**, missing a single charge during the day does not impact the ability of the bus to finish the block but requires additional charging at the depot at the end of the day.

**Figure** 6 indicates that the bus can also finish the block, under strenuous conditions, by missing every fourth block throughout the day but would require significantly more charging to replenish the lost energy at the end of the day.

*Figure 5 - Effect of Missing a Single On-Route Charge During Day*

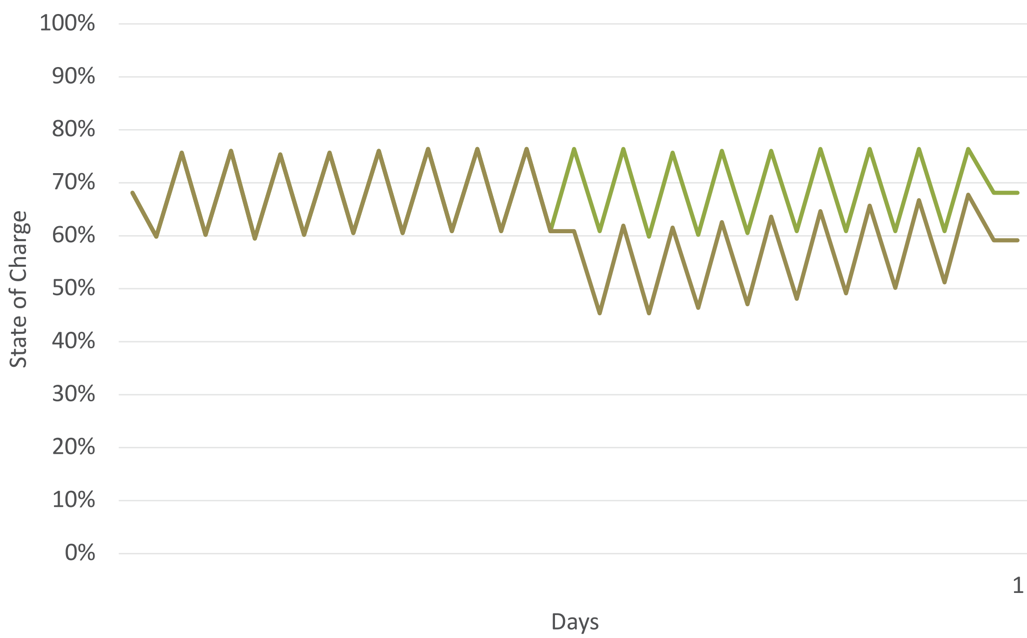
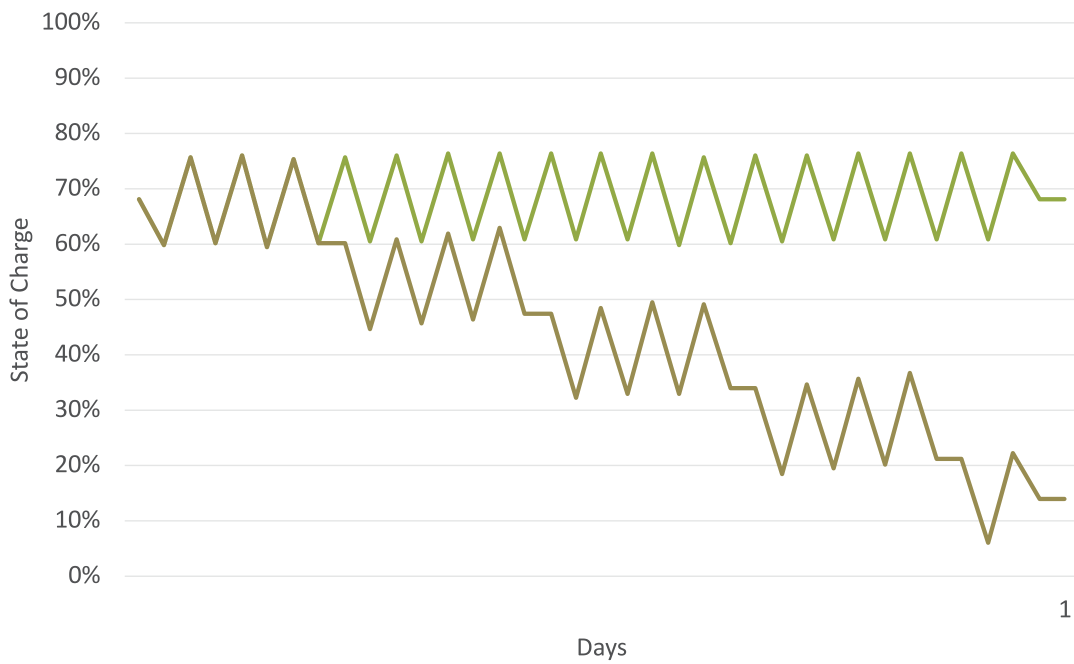



*Figure 6 - Effect of Missing Multiple On-Route Charges During Day*




Please note that the impact of missing charges throughout the day is specific to each block as well as the operating conditions (ambient temperature, loading, traffic). As discussed previously, Block 2013 was utilized for this analysis because it presents the most difficult conditions based on the route modeling completed.

## Recommendations for Service Planning

Results from the charging analysis indicate that a typical charge time between 3 and 8 minutes is required during each layover at the DCC, depending on the route and block as well as service conditions, to achieve charge sustaining mode throughout the day as described in the previous section. Minimum required layover time by route, based on the nominal and strenuous condition analysis, are included in **Table 3**.

*Table 3 - Layover Charging Time Requirements by Route*

| Route | Maximum Charging Time (Strenuous) | Maximum Charging Time (Nominal) |
|---|---|---|
| **2** | 7 | 5 |
| **3** | 8 | 6 |
| **4** | 5 | 4 |
| **5** | 8 | 5 |
| **7** | 5 | 4 |
| **8** | 4 | 3 |
| **10** | 6 | 4 |
| **14** | 5 | 4 |
| **66** | 7 | 5 |

An example weekday peak service charging schedule is provided in
**Table** 4. The schedule represents the time (3 PM – 4 PM) when the most vehicles would be charging at the DCC. This charging schedule is representative any hour during peak service from 6 AM to 6 PM daily. Based on the charging analysis completed, between five (5) and seven (7) chargers could be operated simultaneously at the DCC to meet service requirements.

*Table 4 - Peak Charging Schedule (3PM - 4 PM)*

| Charger | Route | :00 | :05 | :10 | :15 | :20 | :25 | :30 | :35 | :40 | :45 | :50 | :55 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 2 | 2 | | | 2 | | | | 2 | | | | 2 |
| 2 | 3 | | 3 | | | | | | 3 | | | | |
| 3 | 4 | 4 | | | | 4 | | | | 4 | | | |
| 4 | Interlined | 7&5 | 8,14&7 | | | 5&7 | | | 8,14&7 | 7&5 | | | |
| 5 | Interlined | 7&5 | 14&8 | | | | | | 14&8 | | | | 7&5 |
| 6 | 66 | | 66 | | | | | | 66 | | | | |
| 7 | 10 | 10 | | 10 | 10 | | 10 | 10 | | 10 | | 10 | 10 |

*Note: Green blocks represent charge sessions. Numbers inside charge sessions represent routes.*

- Peak service operates from 6:00 am – 6:00 pm on weekdays
- APS peak demand and energy rates are in effect from 3:00 pm – 8:00 pm on weekdays
- Delays in service and strenuous service days can lead to delayed and/or longer required charging times
- Required charging times can also vary with time of day for interlined blocks based on the route in operation for the given time of day

Mountain Line will need to account for impacts to scheduling and service delivery for on-route charging in current routes and future planning efforts as it modifies routes and blocks. Based on the charging analysis completed, Mountain Line may need to adjust the layover times to reliably account for charging at the DCC; however, CTE suggests working with the selected bus OEM prior to making adjustments to route/block structure to ensure that the buses can reliably complete the daily service requirements.

It is assumed that each bus will charge during each pass through the DCC, although as discussed in the previous section, buses may be able to periodically skip a charge or multiple charges throughout the day and complete the required block. The current layover time available at the DCC for each block is sufficient to maintain the battery charge throughout the day and complete the required service based on the analysis completed. The only exception observed was the 1001 block (Route 10 with 60' articulated bus) where there was insufficient time for the charge profile to remain in charge sustaining mode throughout the day; however, with six (6) minutes of charging during each pass through the DCC the bus was still able to complete the block. As the first articulated bus is not expected to be replaced until 2029 at the earliest, it is possible that the buses will be more efficient, have more available on-board battery storage, and require less charge time.

**Table** 5 provides a comparison of the current layovers at the DCC for each non-interlining route compared to the required nominal and strenuous charging times based on the modeling completed. The required charge times for each route hold true for all blocks servicing each route. Alternatively, interlining routes vary in terms of required nominal and strenuous charging times. Therefore, each interlined block and required charging times are provided in **Table 6.**

*Table 5 - Layover Charging at the DCC by Non-Interlining Route*

| Route | DCC Layover (min) | New Battery Nominal | | New Battery Strenuous | | Old Battery Nominal | | Old Battery Strenuous | |
|---|---|---|---|---|---|---|---|---|---|
| | | Sustain SOC | Charge Time (min) | Sustain SOC | Charge Time (min) | Sustain SOC | Charge Time (min) | Sustain SOC | Charge Time (min) |
| 35’ Electric Bus | | | | | | | | | |
| 2 | 9 | 69% | 5 | 68% | 7 | 68% | 5 | 66% | 7 |
| 3 | 9 | 69% | 6 | 68% | 8 | 68% | 6 | 66% | 8 |
| 4 | 5 | 70% | 4 | 67% | 5 | 69% | 4 | 65% | 5 |
| 66 | 10 | 70% | 5 | 69% | 7 | 68% | 5 | 68% | 7 |
| 60’ Articulated Electric Bus | | | | | | | | | |
| 10 | 5 | 72% | 4 | 71% | 6 | 71% | 4 | 70% | 6 |

*Table 6 – Layover Charging at the DCC by Interlining Block*

| Block | DCC Layover (min) | New Battery Nominal | | New Battery Strenuous | | Old Battery Nominal | | Old Battery Strenuous | |
|---|---|---|---|---|---|---|---|---|---|
| | | Sustain SOC | Charge Time (min) | Sustain SOC | Charge Time (min) | Sustain SOC | Charge Time (min) | Sustain SOC | Charge Time (min) |
| 35’ Electric Bus | | | | | | | | | |
| 701_501 | 5/17 | 72% | 4/5 | 71% | 5/7 | 69% | 4/5 | 68% | 5/7 |
| 702_501 | 5/17 | 60% | 4/5 | 61% | 5/8 | 57% | 4/5 | 58% | 5/8 |
| 501_701 | 17/5 | 69% | 5/4 | 66% | 7/5 | 66% | 5/4 | 63% | 7/5 |
| 801_1402_703 | 10/8/0 | 50% | 3/3/0 | 40% | 4/4/0 | 43% | 3/3/0 | 31% | 4/4/0 |
| 1401_802 | 8/10 | 64% | 3/3 | 61% | 4/4 | 61% | 3/3 | 57% | 4/4 |
| 5011_14011 | 17/8 | 75% | 4/4 | 73% | 5/5 | 73% | 4/4 | 70% | 5/5 |
| 14011_5011 | 8/17 | 65% | 4/4 | 61% | 5/5 | 63% | 4/4 | 58% | 5/5 |
| 7011_8011 | 10/0 | 67% | 6/0 | 64% | 8/0 | 66% | 6/0 | 62% | 8/0 |

**Figure 7** and **Figure 8** depict the charging needs at the Kaspar Drive Maintenance Facility and the NAU or other separate facility, respectively, at the end of each service day. The analysis assumes a 20 minute top off charge with two vehicles charging simultaneously at each facility.

*Figure 7 - Charging at the Kaspar Drive Maintenance Facility*

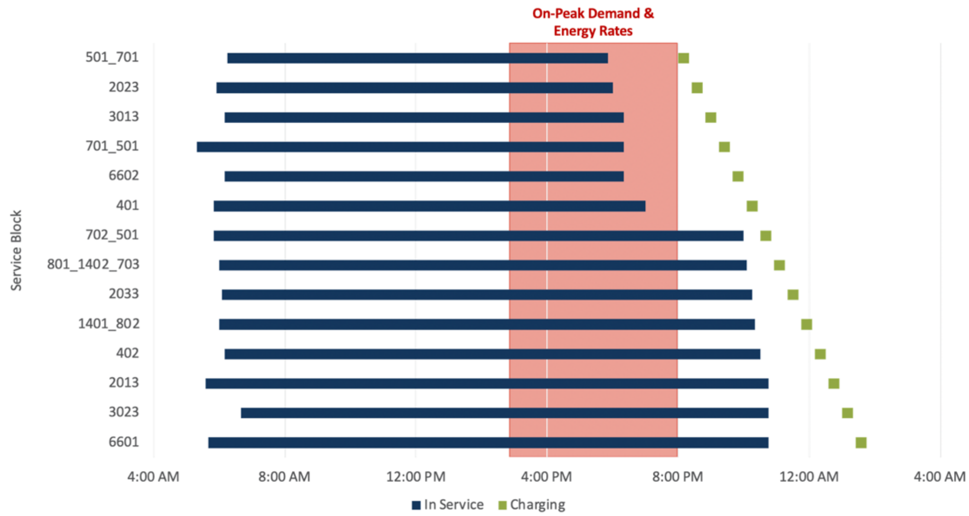
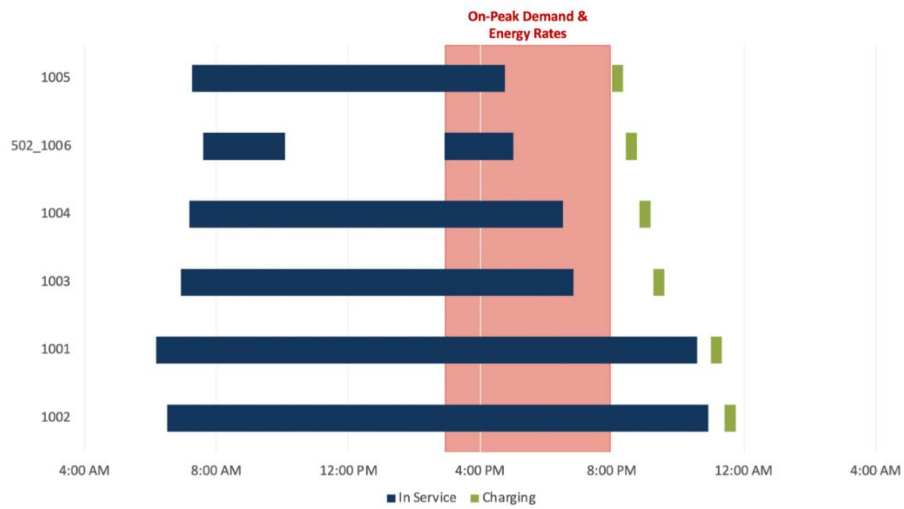



*Figure 8 - Charging at the NAU or Other Separate Facility*




CTE recommends utilization of a sophisticated charge management system that will take into account the buses current SoC and block requirements and determine where charges may be skipped throughout the day. Charge management will also optimize the charging necessary and determine when it can be completed at the lowest utility rates, though because on-route charging is proposed much of the charging will still occur during peak charging rates. CTE is not aware of any current commercially available products for optimization of on-route charging; however, multiple charge management vendors have indicated that they are currently developing products to address this void. The need for charge management is limited during the initial deployment with only a single charger operating at the DCC, but will become more important during future charger deployments as charging capacity is added to the DCC after

2026. Charge management solutions should be included as part of the procurement solicitation for charging equipment.

## Rate Modeling and Recommendations

CTE utilized results from the route modeling to develop a charging strategy to meet the energy requirements necessary to operate the BEBs in the Mountain Line service. The charging scenario was modeled as detailed in **Table 7**:

*Table 7 - On-Route and Depot Charger Modeling Scenario*

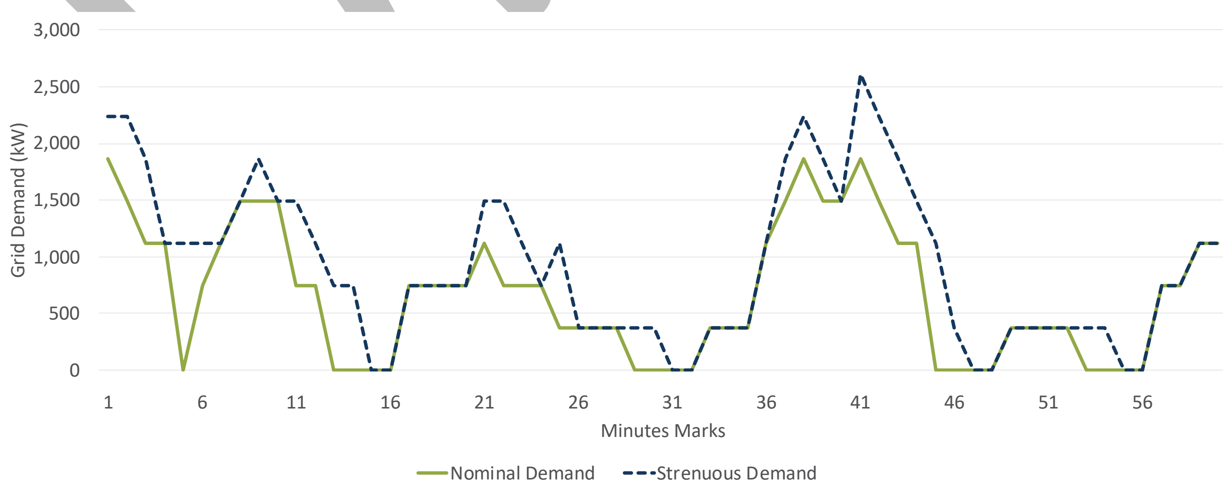
| Facility | Chargers in Operation | Charging Period |
|---|---|---|
| **Kaspar Drive Maintenance Facility** | 2 x 450 kW overhead chargers | Up to two (2) chargers operating simultaneously when buses return to the depot after peak service |
| **NAU or Other Separate Facility** | 2 x 450 kW overhead chargers | Up to two (2) chargers operating simultaneously when buses return to the depot after peak service |
| **DCC** | 7 x 450 kW overhead chargers | Up to seven (7) chargers operating simultaneously at full-build out during peak operations between 6:00 AM and 6:00 PM; one (1) additional charger included for redundancy. |

The following assumptions were used in development of the charging strategy and associated rate modeling:

- Charging is assumed to be 90% efficient; for example, a total of approximately 333 kW of energy is required from the grid to supply 300 kW to the BEB.
- Each bus is assumed to leave the depot each day at full charge; energy will be replaced each night at the depot through the use of the high-power overhead charger (450 kW) prior to servicing each evening.

**Figure 9** provides the energy demand profile during peak service hours at full build out. Review of the figure indicates that up to approximately 2.6 MW of demand are estimated if all seven (7) chargers are operating at the same time at maximum power.

*Figure 9 - Energy Demand Profile during Peak Service*



CTE utilized the Arizona Public Service (APS) Large General Services E-32TOU rate structure to determine the expected energy costs associated with operating Mountain Line's BEB Fleet. A summary of E-32TOU fees, including demand charges and energy charges, is included in **Table 8** and **Table 9**, respectively.

*Table 8 - APS E-32TOU Demand Charges*

| On-Peak | | Off-Peak | |
|---|---|---|---|
| **First 100 kW** | **Any Additional kW** | **First 100 kW** | **Any Additional kW** |
| **$17.508/kW** | $11.795/kW | $6.396/kW | $3.370/kW |

*Table 9 - APS E-32TOU Energy Charges*

| On-Peak | | Off-Peak | |
|---|---|---|---|
| **Summer** | **Winter** | **Summer** | **Winter** |
| **$0.07018/kWh** | $0.05552/kWh | $0.05730/kWh | $0.04264/kWh |

Details regarding the rates structure include:

- APS E-32TOU Large General Service rate structure applicable to monthly loads greater than 401kW
- Summer season includes May through October
- Winter season includes November through April
- On-Peak hours are from 3:00 PM to 8:00 PM Monday through Friday
- Demand charges are applicable for the highest demand (kW) averaged in a 15 minute period for the month and are applicable to both the peak and off-peak periods

Monthly fuel costs (electricity) for operating the full Mountain Line service utilizing on-route and depot charging, including a comparison to diesel fuel costs, are provided in **Table 10**.

*Table 10 - Estimated Monthly Fuel Costs to Operate 100% BEB Mountain Line Service*

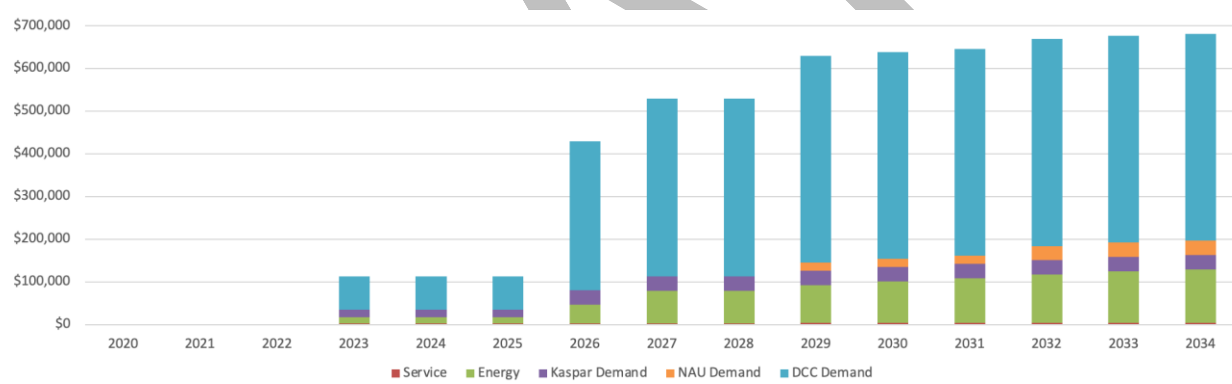
<table>
<tr><th colspan="2">Scenario</th><th>Demand</th><th>Energy</th><th>Service Fee</th><th>Total</th></tr>
<tr><td rowspan="3">On-Route and Depot Charging</td><td>2 x 450 kW @ Kaspar Drive</td><td>$2,811</td><td rowspan="3">$10,393</td><td rowspan="3">$358</td><td rowspan="3">$56,766</td></tr>
<tr><td>2 x 450 kW @ NAU or Other Facility</td><td>$2,811</td></tr>
<tr><td>7 x 450 kW On-Route @ DCC</td><td>$40,387</td></tr>
<tr><td colspan="5">Baseline Hybrid Diesel</td><td>$47,009</td></tr>
</table>

A review of the results indicates that the fuel costs to operate BEBs utilizing on-route and depot charging are considerably higher than the estimated costs to continue to operate hybrid diesel vehicles. Approximately 81% of the estimated cost of fueling BEBs is from demand charges to supply the energy and only 18% of the cost is associated with actual cost of the energy. In addition, a significant portion of the demand charges are driven by on-peak demand, as Mountain Line is charging during APS on-peak hours approximately 20% of the time as the on-route charging strategy requires charging at the DCC during each layover, including during on-peak hours from 3:00 PM to 8:00 PM, in order to meet daily service requirements. **Table 11** and **Figure 8** provide the estimated electrical costs over the transition period as BEBs are added to the fleet.

*Table 11 - Estimated Electrical Costs Throughout Transition Period*

| | 2020 | 2021 | 2022 | 2023 | 2024 | 2025 | 2026 | 2027 | 2028 | 2029 | 2030 | 2031 | 2032 | 2033 | 2034 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Service | $0 | $0 | $0 | $2,862 | $2,862 | $2,862 | $2,862 | $2,862 | $2,862 | $4,292 | $4,292 | $4,292 | $4,292 | $4,292 | $4,292 |
| Energy | $0 | $0 | $0 | $13,464 | $13,464 | $13,464 | $44,213 | $75,911 | $75,911 | $88,308 | $96,483 | $104,055 | $112,313 | $120,499 | $124,714 |
| Kaspar Demand | $0 | $0 | $0 | $18,684 | $18,684 | $18,684 | $33,737 | $33,737 | $33,737 | $33,737 | $33,737 | $33,737 | $33,737 | $33,737 | $33,737 |
| NAU Demand | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $18,684 | $18,684 | $18,684 | $33,737 | $33,737 | $33,737 |
| DCC Demand | $0 | $0 | $0 | $78,224 | $78,224 | $78,224 | $349,172 | $416,909 | $416,909 | $484,646 | $484,646 | $484,646 | $484,646 | $484,646 | $484,646 |
| **Total** | **$0** | **$0** | **$0** | **$113,233** | **$113,233** | **$113,233** | **$429,983** | **$529,418** | **$529,418** | **$629,666** | **$637,841** | **$645,414** | **$668,724** | **$676,910** | **$681,125** |

*Figure 10 - Breakout of Electrical Costs Throughout Transition Period*




## Recommendations for Rate Structure and Utility Partnerships

Utilities across the country are developing strategies and specific rate schedules to address the electrification of the transportation sector. For example, Avista Corporation in Washington and Idaho, has proposed a rate schedule that would be effective until 2030 that requires a surcharge for on-peak energy use (varies by time of year) of $0.0575/kWh over the current Large General Service rate structure. In addition, the proposed Avista rate completely eliminates the current demand charge of $550 for the first 50 kW of demand and $7 per kW over 50 kW of demand. These rates are applicable up to 1 MW of demand. The proposed Avista rate schedule has not been approved by the Public Utilities Commission; however, it is expected to be approved and implemented in March 2021.

Similar to Avista, San Diego Gas & Electric (SDG&E) has developed an Electric Vehicle (EV) rate schedule that introduces a subscription fee, increases energy costs (per kWh), and eliminates demand charges to encourage acceptance of electrification of the transportation sector, particularly the heavy duty sector. The proposed SDG&E rate structure increases average energy costs during peak hours by between $0.23 and $0.25/kWh; during off-peak hours by $0.04 and $0.05 per kWh; and during super off-peak hours by $0.01 and $0.02/kWh, depending on the time of year (summer or winter months). The proposed rate eliminates demand charges estimated on average at approximately $17/kW. **Table 12,** below, provides examples of additional utility programs across the country that have developed alternative rate structures to support heavy-duty fleet electrification.

*Table 12 - Utility EV Program Examples*

| Utility | Program Strategy |
|---|---|
| **Hawaiian Electric Company** | • Time-of-use revisions<br>• Demand charge reductions |
| **Xcel Energy (Colorado)** | • Time-of-use revisions<br>• Seasonal energy rates<br>• Demand charge reductions |
| **Pacific Gas & Electric (PG&E)** | • Demand charge elimination<br>• Time-of-use revisions<br>• Fixed kW subscription fee implemented |
| **Southern California Edison (SCE)** | • Temporary demand charge elimination, followed by a reinstatement of demand charges at a reduced level compared to previous rates |
| **City of Ames Electric** | • Demand charge elimination for specific time of use |

Substantial operational savings could be realized if a new rate schedule is adopted that provides relief from demand charges. For example, a 30% reduction in the demand charge rate for both on-peak and off-peak, during both the summer and winter season, reduces the annual fuel costs associated with operating BEBs to be approximately equal to the cost of operating hybrid diesel vehicles at an average diesel cost of $3/gallon. CTE recommends engagement with APS to develop an EV rate structure that will be both beneficial to Mountain Line by reducing or eliminating demand charges but still allow APS to generate sufficient revenue through increased energy charges to pay for the necessary upgrades to support transportation electrification as well as provide a return on investment to shareholders.

In addition to rate structures, utilities across the country offer a variety of infrastructure programs to support fleet electrification. Examples of utility infrastructure electrification programs are provided in **Table 13.**

*Table 13 - Utility Infrastructure Electrification Programs*

| Utility | Program Strategy |
|---|---|
| **Portland General Electric (PGE)** | • Charging equipment owned and maintained by utility |
| **Southern California Edison (SCE)** | • Rebates to help cover agency infrastructure costs |
| **Potomac Electric Power Company (Pepco)** | • Charging equipment owned by utility<br>• Technical assistance from utility |
| **Entergy Corporation (Entergy)** | • Rebates based on expected service use |
| **Pacific Power** | • Charging station grants |
| **Duke Energy Carolinas (DEC) and Duke Energy Progress (DEP)** | • Charging equipment installed and owned by utility |

Similar to most utilities, APS typically offsets the cost of new electrical infrastructure (transformers, distribution panels, conductors) based on the anticipated revenue from the project. Electrification of the DCC, as well as the Kaspar Drive Maintenance Facility and NAU or other separate facility, is expected to yield significant revenue for APS. In addition, the revenue is guaranteed for the life of the buses purchased, as FTA requires a 12-year service life. APS typically utilizes a 6-year payback period to determine what portion of the infrastructure that they will pay for; however, Mountain Line has requested that APS consider a longer payback period for these projects due to the guaranteed service life to off-set capital infrastructure costs.

Partnership opportunities and revenue offsets provided by APS can be used for local match on electric infrastructure grants. At a minimum, Mountain Line expects that APS-funded infrastructure would include the following:

- Feeders from substation to the site
- On-site transformers and switching panels owned by APS
- Utility meter

In addition, Mountain Line has requested additional information from APS regarding opportunities to provide resiliency/redundancy to the electrical system feeding the site. Options discussed include redundant feeds from different substations as well as on-site microgrid opportunities. The potential for APS to off-set the cost of these infrastructure elements is less clear. Additional information regarding infrastructure requirements is included in the **Infrastructure** section of this *Implementation Plan*.

## Bus Procurement Best Practices

Mountain Line intends to initially purchase two (2) battery electric buses (BEBs) in 2023 as grant funding has been secured, and eventually is interested in replacing all hybrid diesel vehicles with BEBs by 2034. The fleet includes twenty-three (23) 35' BEBs and six (6) 60' articulated BEBs. Additional discussion regarding paratransit vehicles and non-revenue service vehicles is included later in this *Implementation Plan*. Heavy-duty transit buses will likely be purchased through a competitive Request for Procurement (RFP) process or by purchasing off of an authorized state contract such as those offered by Virginia, Georgia, or California. CTE provided links to the referenced state contract documents to Mountain Line via email (Kylie McCord to Bizzy Collins on December 17,2020).

### BEB Contracting

The fundamental goal in BEB contracting is to ensure expectations are clear between the bus OEM and Mountain Line. This applies to the bus configuration, technical capabilities, build and acceptance process, and other contract requirements.

#### Contract Structure

For the ease of contract review by all parties, it is good practice to use a numbering system to itemize all terms and specifications of the contract. If possible, the numbering system used in the American Public Transportation Association (APTA) *Standard Bus Procurement Guidelines* (May 2013) is recommended to promote consistency across the industry. To ensure that each individual requirement is addressed, it is also best to subdivide sections as much as possible. This avoids requirements being missed in large blocks of text in the document.

If the Agency should choose to start with an already established bus contract, it is highly recommended that the Agency refer to the APTA Guidelines not only to identify additional or unnecessary content, but also for industry-standard language.

#### Agency and OEM Review

When an Agency has received comments on the contract from the OEM, it is vital to ensure that all deviations from the proposed terms, conditions, and specifications have been addressed. It is possible for the Contractor to miss critical items that can result in a misspecification of a vehicle, and potential conflict later during the bus build and acceptance process. CTE recommends tracking all deviations from the contract terms and specifications in a Deviation Log that is accepted by all parties prior to execution of the bus contract and becomes part of the contract package.

### Contract Terms and Conditions

#### Purchasing with Low or No-Emissions Vehicle Program Grant Program Funds

If the bus purchase is being made with Low or No-Emission Vehicle Program Grant Funds, then state it in the scope of work. Example language:

> *"The Contractor shall manufacture and deliver up to [insert number of buses] [insert model of buses] battery electric buses as specified in and in full*

*accordance with Grant No. [Grant Number], awarded by the Federal Transit Administration Low or No Emission (Low-No) Vehicle Deployment Program."*

*Further, the contract should include FTA terms and conditions language which can be found in the APTA Bus Procurement Guidelines."*

### Data Access Rights

Over the service life of the vehicles, it is useful for agencies to analyze the operations and performance of their vehicles using on-board data collectors. Some OEMs have been reluctant to provide Agencies with access to such data generated by the buses. It is recommended that the Mountain Line negotiate ownership, at no additional charge, of all data generated by the buses in their procurement contract. Mountain Line may grant a license for the data to the OEM in the event that the OEM would like to monitor the vehicle to support their own product development. This should include both proprietary and non-proprietary data. Inclusion of this material is especially important if Mountain Line plans to have a third-party system handle data monitoring, which is highly recommended. Companies that currently provide third-party monitoring include, but are not limited to, Viriciti and Electriphi.

An alternative to third-party data monitoring is for the OEM to provide a data logging and telematics solution, however, it would be in the Mountain Line's best interest to ensure they have rights to access and use the data through any system of their choosing to protect the Agency in the event that the OEM-provided solution becomes untenable. Example language for this requirement is as follows:

"*The Agency shall own all data produced by the Buses. The Agency is willing to grant the Contractor a license to the data produced by the buses. The Contractor reserves the right to present data to third parties without the prior consent of the Agency; provided, however, that the Agency's authorization to share such data shall be required if the Agency is identified as the source of such data.*

*The Contractor shall provide the Agency access to all data generated by the bus at no additional charge for the duration of the Agency's ownership of the bus. Data generated by the bus includes CANbus, e.g. J1939, battery management system networks, etc., or other communication protocols. The Agency reserves the right to grant access to operational and/or maintenance data stored on the bus, on charging equipment, on Agency servers, or on Contractor and supplier servers where such data is accessible by the Agency through an on-line portal to third parties for the purposes of analysis and research, the results of which may be publicly presented.*

Outlined below are types of data for the Agency to request access to on the buses.

- Electric bus energy consumption, in total and per major systems (e.g. propulsion, HVAC, electric heating, power steering, air compressor, dc-dc converter, etc.)
- Distance traveled between charging sessions, with timestamp and GPS tracking
- All charging sessions, with timestamp, initial SoC, final SoC, duration of charge, energy consumed, and method of charge (overhead or plug-in)

- Odometer distance
- Accumulated operating hours
- Charging status (charger connected or not, plug-in or pantograph, charge power)
- Vehicle speed
- Operation state (Proponent-defined, e.g. running, faulted, charging)
- Traction motor speed
- Traction motor/inverter power (sign indicates motoring/regeneration) and energy consumption
- Traction motor temperature
- Auxiliary inverters (e.g. air compressor, power steering), HVAC, and DC-DC converter power and energy
- High voltage battery pack indicated state of charge and actual state of charge, if different
- High voltage battery pack voltage
- High voltage battery pack current
- Battery energy throughput (in units of kWh)
- Gross energy discharge throughput per pack
- Estimated battery health percentage
- Drive/reverse switch position
- Parking brake switch position
- Day/run switch position
- Accelerator pedal position
- Brake pedal position or pressure
- Heater, defroster, and/or air conditioning status (Proponent-defined
- Transmission gear, if applicable
- Total energy consumed, regenerated, and net
- Motor torque (sign indicates regeneration or motoring)
- Air system pressure
- Air compressor flow rate
- HVAC inlet air temperature
- HVAC outlet air temperature
- Interior temperature
- Exterior temperature
- Interior/exterior humidity
- Inclinometer/accelerometer
- Longitudinal road grade
- X-Y-Z acceleration

- Automatic passenger counter
- GPS position and altitude
- Fault codes and troubleshooting/repair information for all sub-systems
- Battery management system-calculated charge and discharge current limits
- Battery management system-reported temperature of coldest and hottest cell.
- Position of rear and front doors"

### Payment Terms

Payment options include payment upon delivery, payment upon delivery with retention, and progress payments. The OEMs typically prefer progress payments, however, full payment upon delivery allows agencies to have more leverage over any issues that may arise. Regardless of agreed upon payment method, it is recommended that final payment for the bus should be made following an agreed upon number of hours of revenue service, or shadow service, for each bus without defects present.

### Delivery Timeline

Mountain Line should require that the buses not be delivered until the charging infrastructure is complete to ensure they can be operated and evaluated for acceptance. OEMs are typically accommodating of this as long as the timeline is established during contracting, and contingencies are established in the event of delay. This is critical with build out of the new DCC facility and infrastructure at the Kaspar Drive Maintenance Facility in conjunction with the delivery of new BEBs.

If late delivery of the buses will result in loss of grant funds, it should be stated in the contract, and the expectations established should the buses be delivered late. For example, Mountain Line can reserve the right to refuse delivery of any buses not received by the agreed upon date. To avoid any conflict, it is imperative this risk be discussed during contracting.

### Bus and Charger Modeling

Mountain Line may require that the bus OEMs prepare a technical proposal that includes a model (service demonstration) of how the proposed buses will operate in Mountain Line service with the proposed charging equipment. Bus OEMs should be provided the current utility rate structure and requested to provide recommendations for ways to mitigate demand charges during utility peak hours. The OEM model results may be validated as part of acceptance testing discussed below.

### Bus Acceptance

CTE recommends that Mountain Line prepare an *Inspection and Acceptance Plan* prior to delivery of buses in accordance with APTA Guidance BTS-II-RP-001-11. The test plan should reference the applicable specifications for each test identified and should be reviewed with the OEM prior to completion. Following completion of BEB fabrication and prior to delivery, the BEB OEM should conduct pre-delivery testing including visual and measured inspections as well as total bus operations. The testing program should be completed and documented in accordance with the agreed upon *Inspection and Acceptance Plan*. The pre-delivery testing should be scheduled such that it may be observed by an Agency inspector or maintenance staff (or other third-party inspector contracted by the Agency).

A minimum of 30 days from delivery for completion of post-delivery testing, along with a verification of system(s) functionality in accordance with the *Inspection and Acceptance Plan* to determine acceptance. Post-delivery testing should include service demonstration on routes/blocks in Mountain Line's service; however, if desired this will need to be included in the bus contract.

Post-delivery tests should be conducted on all delivered equipment (bus and chargers) to ensure they meet the contracted expectations and will perform acceptably in agency service. Typical acceptance periods for standard hybrid diesel buses are fifteen (15) days, however, the complexity of acceptance of BEBs merits additional time and scrutiny. CTE recommends thirty (30) days to allow for additional activities that must occur during the acceptance window that aren't required for standard buses such as:

- Refitting parts removed for trailered shipment as trailered shipment may require removal of some components. Refitment of those components can add complexity to the delivery and acceptance process.
- Commissioning an unfamiliar bus: Mountain Line must equip the bus with any agency-supplied equipment (e.g. fareboxes) this process can take several days per bus, and potentially longer due to unforeseeable nuances of installing on an unfamiliar vehicle model. This commissioning period will detract from the time available to fully evaluate the bus prior to acceptance.
- Commissioning chargers: before the chargers can be used, they must be commissioned with the buses by charger and bus OEM staff to ensure successful operation. This process may take about several hours or up to a day per charger, during which a bus is not available for commissioning or evaluation. In some cases, CTE has seen the commissioning process stretch into weeks for unproven pairings of bus and charger models. A commissioning plan should be developed by the charger manufacturer, in coordination with the bus OEM, and provided to Mountain Line a minimum of 60 days prior to delivery of the first bus. All buses should be commissioned with each available charger at Mountain Line facilities.
- Training Operators and Maintenance Staff: before the bus can be evaluated, operators and maintenance staff must be trained on the operation and construction of the vehicle. This training can take a number of days, delaying the start of actual bus evaluation. Training is discussed further in the **Training** section of this *Implementation Plan*.
- Shakedown issues: BEBs are a developing technology. As such, there is a greater likelihood of encountering issues in early operations (e.g. warning lights, unanticipated component failure). It is important to ensure that the OEM has ample time to address these issues within the acceptance window to ensure these issues are satisfactorily resolved prior to forcing an acceptance decision from the agency.

Mountain Line should consider a number of testing strategies prior to acceptance, all of which should be detailed in the contract:

- While it is typical that the OEM will not allow the buses to enter revenue service before acceptance, it may be possible in some cases to negotiate authorization to run the bus in revenue service prior to acceptance. If not, it is recommended that Mountain Line test the buses through shadow service to ensure they operate acceptably in the intended operational conditions.
- Mountain Line should consider testing upon delivery for expected performance on aspects such as range, acceleration, gradeability, highway performance, maneuverability, etc. as appropriate. Any such performance requirements must be included in the technical specification portion of the contract to be binding for the OEM.
- It is recommended that Mountain Line specify some level of testing for charging reliability (i.e. ten consecutive charge sessions without errors). This can be associated with charger acceptance if the chargers are being provided by the same vendor.
- The state of health of the battery and usable SoC should be confirmed. The OEM can propose a method for this confirmation. It is not uncommon that a third party performs this confirmation upon approval from the OEM.
- Specifications for extreme weather operations may be of interest for certain service environments. Mountain Line can specify requirements for component functionality or cabin temperature.

BEBs that fail to pass the post-delivery tests are subject to non-acceptance. Mountain Line should record details of all defects on the appropriate test forms and notify the OEM of acceptance or non-acceptance within five (5) days of completing the testing. Any defects detected during the testing should be repaired according to procedures defined in the contract after non-acceptance.

Additional information on acceptance can be found in section 6.5 of the *TCRP Guidebook for Deploying Zero-Emission Transit Buses*.

## Typical BEB Procurement Process

The following section provides a typical bus procurement process assuming buses are purchased through an RFP. A typical RFP evaluation should include the following phases:

- Proposal & Bidder Qualification
- Technical Evaluation
- Vendor Evaluation
- Price Evaluation
- Final Evaluation

For a typical BEB RFP, the Agency releases the RFP to known BEB OEMs and issues public notice. The solicitation remains open for the designated time period (i.e., 45 days) as required by Agency procurement requirements. During the solicitation period, the Agency may conduct a pre-bid meeting (or conference call) to present the project and address any proposer questions. In addition, the Agency may collect questions and issue responses to all proposers during the solicitation period.

Solicitations will not be opened until the due date and time, at which time a public opening is held during which the Procurement Officer reads aloud the name of each submitting OEM and the proposals meet the minimum submission requirements, prior to allowing the evaluation team to review the proposals. No other information shall be publicly released until award of the contract. The Agency may require that the technical proposals include a model (service demonstration) of how the proposed buses will operate on the route with the proposed charging equipment as discussed previously in this section as a best practice for BEB contracting. OEM model results may be validated as part of acceptance testing. The Procurement Officer then provides qualified technical proposals to the evaluation team.

The Evaluation Team then reviews, evaluates and scores qualified technical proposals. The technical evaluation should include demonstrations of the proposer's product, interviews of the proposer, and review of route modeling of the proposer's solution. The evaluation team scores each proposal based on the proposer's compliance with the technical specifications. Proposals are ranked as a result of the scoring by the evaluation team. Highest ranked proposals are considered during the vendor evaluation stage, the next stage of the procurement process.

Vendor Evaluation includes reference checks of existing customers as well as other sources to qualitatively evaluate manufacturing quality, product reliability, service and support, financial statements, and stability. The Agency should evaluate each OEM based on the ability to deliver a quality product, provide service and parts, and likelihood of being an on-going concern for the life of the bus.

The price evaluation should consider bus price, charger price if included in the purchase, warranty, spare parts, maintenance schedule and related costs, and proposer service offerings.

During the final evaluation, the Agency combines previous scores to establish a final ranking of proposers. The Agency may then proceed to solicit Best and Final offers if they so choose. The final BEB OEM selection should be based on the results of the final evaluation.

A Buy America pre-award must be completed prior to award of the contract if federal money is being used to purchase the vehicles as part of the procurement. Once the solicitation process and Buy America pre-award audit are completed, the Agency may negotiate final contract terms with the selected BEB OEM and execute a contract. Following contract execution, a Notice to Proceed is issued to the BEB OEM to begin the build process.

The BEB OEM must design the bus in accordance with the technical specifications and accepted deviations. The BEB OEM should review the bus configuration with the Agency before finalizing the design. The Agency and the BEB OEM participate in a pre-production meeting, typically at the OEM's manufacturing facility. The purpose of the pre-production meeting is to:

- Verify the vehicle configuration/specifications
- Verify the terms of the production process
- Set up the resident inspection process (if applicable)

- Discuss Quality Assurance/Quality Control (QA/QC) requirements and associated inspections (if applicable)
- Establish lines of communication between STA's designated representative and the BEB OEM representative.
- Review and clarify required documentation/paperwork for the vehicles
- Clarify acceptance and delivery procedures
- Discuss change management procedures
- Discuss build schedule

If Mountain Line elects to purchase the buses through an FTA-accepted state contract, the pricing and terms will be provided in accordance with the contract; however, the bus design, build, and delivery process will be substantially the same.

## Technical Specifications and Fleet Recommendations

Developing technical specifications and negotiating specification language collaboratively with bus OEMs during contract negotiation will allow Mountain Line to customize the bus to their needs as much as possible, ensure the acceptance and payment process is fully clarified ahead of time, fully document the planned capabilities of the bus to ensure accountability, and generally preempt any conflict or unmet expectations.

### Specification Development

The development of a BEB specifications should begin with one of the two starting points, either;

- A previously established bus contract from Mountain Line, or
- The APTA *Standard Bus Procurement Guidelines* are a valuable tool that should be referenced in preparing a BEB contract. As an additional resource, this document outlines information that CTE has found to be pertinent and agencies should consider in regards to BEB contracts. The version of the APTA *Standard Bus Procurement Guidelines* containing BEB guidance is not publicly available; however, CTE provided a draft copy to Mountain Line via email for reference (email form Kylie McCord to Bizzy Collins on December 17,2020).

Starting from one of these source documents reduces the burden of generating a new specification format. The technical specifications should always be included as part of the contract document, either in the contract itself or as a separate referenced attachment, even if buying off of an established state contract.

### Design Operating Profile

Mountain Line should include a Vehicle Performance/Operating Profile section that specifies the expected capability of the buses to be delivered in the specifications. This section should include details regarding the block structure and duty cycle of the vehicles (e.g. amount of time the buses are in service versus not in service) and how many miles and hours they operate on a typical day. Information about the charging requirements (on-route charging) should be provided as well. CTE has completed modeling and provided recommendations for minimum bus technical capabilities and charging strategies to support on-route charging; however, OEMs may provide alternatives during the procurement process that may be considered. Based on the current route and block structure, the following requirements must be met for the vehicles procured by Mountain Line to successfully complete the required daily service.

*Table 14 - BEB Daily Service Requirements*

| Vehicle Type | Maximum Daily Mileage Required | Maximum Daily Hours of Operation Required | On-Route Charged | Overnight Charge Window |
|---|---|---|---|---|
| 35’ | 262 miles | 17:10 hours | Yes | ~ 6.5 hours |
| 60’ Articulated | 171 miles | 16:50 hours | Yes | ~ 6.5 hours |

### Turning Geometry, Approach and Departure Angles

BEBs may have different steering systems and chassis geometries than conventional bus models. As such, it is recommended to confirm the vehicle can maneuver in the required operating environment. This is best done quantitatively in the specification to ensure contractual accountability for maneuvering performance. BEB dimensions are typically very similar to diesel hybrid vehicles; however, dimensions should be confirmed during procurement.

### Energy Storage System and Controller

Communication of cell data to the bus level information systems is vital for tracking when a faulty battery cell is limiting pack performance and needs to be replaced. The requirement regarding balancing the cells ensures that the full capacity of the battery can be utilized. The Battery Management System (BMS) is the primary method to thermally control lithium-ion batteries and is designed to maintain the batteries in a safe operating condition and prevent the potential for a thermal event that could cause a fire.

The High Voltage BMS must:

- Be able to communicate all data to the bus level information system for storage and communication
- Balance the lithium ion cells or indicate and log which cells cannot be balanced
- Notify the operator in the event of a thermal event

The BMS does not require active monitoring by the operator; the BMS will interface with the Controller Area Network (CAN) present on the bus and will communicate alarm conditions to the operator through a local alarm on the dash of the vehicle. In addition, out of compliance conditions will be reported through the cellular system to operations. Typically these communications are real time; however, if a bus is out of cellular range, the conditions will be stored and communicated as soon as service is available.

### Electronic Propulsion System Controls

The Electronic Propulsion System (EPS) should contain built-in protection software to guard against severe damage (e.g. bus shutdown due to an overheated traction inverter from a broken coolant pump) and an emergency operator override to be used in the event of an emergency that requires moving the bus from a hazardous circumstance or location.

### Regenerative Braking

Regenerative braking can considerably affect energy efficiency, driving feel, and passenger safety due to potentially harsh deceleration as regeneration initiates. Mountain Line can request that regeneration be configurable and that regeneration shall be applied in proportion to the operator's inputs rather than in discrete steps to reduce this risk. Regeneration should be verified during acceptance testing.

When automatic braking system (ABS) activates in a BEB, the regenerative braking system typically must deactivate to avoid skidding. If the ABS remains inactive for an extended period, it has been shown to reduce efficiency and range significantly. Mountain Line should specify that OEMs employ strategies to safely maximize regeneration to the greatest extent possible in slippery conditions to avoid significant loss of operating range.

### Hill Hold

When specifying the transmission, hill hold operation and requirements to oppose rollback on hills when the bus is at a stop should be detailed. The OEM may not offer automatic hill hold capabilities but, instead, may propose a switch that the driver would use to initiate hill hold, however, it is recommended that Mountain Line request an automatic hill hold brake application system. Some agencies specify the hill hold system should be capable of holding the bus loaded to GVWR on a hill of 20% grade. Hill hold operations should be verified during acceptance testing.

### Charging Receptacles

Mountain Line should specify the number, type, and location of charging receptacles on the buses to ensure compatibility with their planned parking and charger layouts. Based on the planned operations using on-route charging, all buses should be equipped with rooftop charge bars that will mate with a dropdown overhead pantograph in accordance with the SAE J3105-1 standard for *Electric Vehicle Power Transfer System Using Conductive Automated Connection Devices (Infrastructure-Mounted Pantograph [Cross-Rail] Connection*. In addition, CTE recommends requiring SAE J1772 CCS Type 1 – *Electric Vehicle and Plug In Hybrid Electric Vehicle Conductive Charge Coupler* compliant charge receptacles on both sides of the bus to allow potential future plug in charging at the depot or during service.

### Manuals and Schematics

Manuals and/or schematics of the following should be required:

- Bus schematics
- Energy Storage System schematics
- Operator instructions
- Training materials
- Final parts
- Spare parts
- Component repair
- Diagnostic procedures
- Preventative maintenance
- First responder reference sheets

### Paint

Bus paint can lead to conflict during the acceptance phase and ultimately delivery delay. It is imperative to confirm expectations for the paint design implementation, quality, and evaluation process between Mountain Line and the OEM to avoid issues during bus build and acceptance. Alternatively, bus wraps can present a less risky alternative.

### Preconditioning

BEB range benefits from preconditioning (i.e. warming) the bus cabin and battery system while still charging to ensure that the considerable energy draw from initial warm-up is accommodated with energy from the grid, rather than battery energy. Preconditioning is typically only applicable if the vehicle is connected to a charger for plug-in charging. As the vehicles at Mountain Line will be stored inside a climate controlled building, preconditioning is likely unnecessary. However, in the event that plug-in chargers are installed anywhere in the Mountain Line system, buses and chargers should be equipped with the functionality to precondition.

### Auxiliary Heater and Control Strategy

Currently diesel-fired heaters are the only available auxiliary heat system being offered by BEB OEMs. If diesel heaters are selected, the control strategy should be designed to minimize the use of electric power for heat to ensure minimal range impact of heating energy demand.

Due to the comparatively low volume of auxiliary heater-equipped BEBs, the installation design of such systems on BEBs has resulted in challenges on previous buses. It is recommended, that 1) OEMs demonstrate a thorough application design process was conducted with the manufacturer of the heater, and all pumps, tubing/hoses, and valves; and that 2) no parts forward of the firewall have a service life shorter than the life of the bus (e.g. rubber hoses). As Mountain Line buses are expected to be charged on-route, the need for diesel-fired heat is minimized. Modeling of the on-route charging scenario for Mountain Line was completed assuming that no auxiliary heat was utilized or needed.

### Specialized Equipment

Specialized equipment necessary to maintain BEBs is typically health and safety equipment necessary to conduct work on high voltage systems. As Mountain Line already maintains a hybrid diesel fleet, there should be few additional requirements (e.g. safety gloves for working on high voltage system, fire protective clothing, etc.). Bus OEMs may recommend the purchase of a lift table to change out batteries as necessary; however, the need for replacement or repair of batteries is typically very limited and is generally done under warranty, and as such the equipment and service is provided by the OEM.

A diagnostic computer, adapter (specified by the OEM), and OEM supplied program will be required to complete diagnostic testing and complete maintenance on the vehicles. It is recommended that the diagnostic equipment be purchased with the vehicles.

### Fire Protection

Auxiliary fire protection systems (e.g. Fogmaker) that are often employed on transit buses are not designed to extinguish a lithium-ion battery fire as these fires burn very hot and are difficult to control. Auxiliary fire protection systems may be employed to temporarily mitigate the spread of a fire that allows more time for passengers and the operator to safely exit the vehicle. As discussed previously, the primary method to thermally control lithium-ion batteries is through the Battery Management System that is designed to maintain the batteries in a safe operating condition and prevent the potential for a thermal event that could cause a fire. In addition, the batteries are generally assembled in packs that are designed to resist the spread of fire.

### Operator Displays and Controls

Operator displays and controls are typically similar to a standard diesel hybrid bus as OEMs such as Gillig and New Flyer have attempted to maintain consistency between models. OEMs typically include the SoC of the vehicle in a dashboard indicator unless otherwise specified by the Agency. A light to indicate if regenerative braking is engaged is also useful for inclusion on the dashboard. CTE also recommends requesting the OEM to provide a range indicator that provides estimated remaining range on the dashboard; however, to date these efforts have been unsuccessful.

## Battery Warranty and Leases

### Battery Warranty

While warranty options are specific to each OEM, Mountain Line may be offered an option to select between a 6-year or 12-year extended warranty for the propulsion system. A 6-year warranty allows Mountain Line to take advantage of potential battery technology improvements, and the 12-year warranty is generally the more cost-effective approach.

At a minimum battery warranty terms should specify:

- The usable capacity of the battery that is guaranteed throughout the warranty period; CTE recommends a minimum guaranteed battery capacity of 80% of useable energy.
- How usable capacity is measured and that Mountain Line can utilize maintenance tools or third part tools to conduct and/or access those measurements independently to track battery capacity.

### Battery Lease

Battery leasing is a strategy that allows the cost of a typical BEB to be reduced to closer to that of a traditional fossil-fuel vehicle by paying for the battery lease through operational funding that normally would have been used to pay for fuel. If Mountain Line is considering leasing batteries, it is crucial that the lease terms are clearly understood and adjusted to suit the planned service life. A typical standard lease term is 12 years, which is not expected to cover the full operational life for the vehicles at Mountain Line (15 years). In addition, replacement terms for the battery lease should also be understood. Current battery leasing programs that CTE has reviewed typically allow one guaranteed replacement at the mid-life of the vehicle. Battery leasing of the first two (2) Mountain Line vehicles does not appear to provide a benefit to Mountain Line as grant funding is currently available for the purchase of the vehicles, and the cost for electricity (fuel) is expected to be higher than current diesel costs as on-route charging is necessary to meet service needs. As such, the cost of the battery lease would further increase the operating budget to operate the buses. If modifications are made to the rate structure by APS to reduce the cost to on-route charge buses and capital costs of BEBs are prohibitive for Mountain Line after the purchase of the first two vehicles, then battery leasing should be considered.

## Charging Equipment

Specific charging equipment recommended for Mountain Line operations is included in the **Infrastructure Requirements and Recommendations** section of this *Implementation Plan* Example specifications for charging equipment, including both plug-in and overhead on-route charging equipment, to address risks associated with chargers and charger deployment are included in **Appendix B.** Mountain Line should require that the charge vendor provide a method of controlling the charging to manage the use of power from the utility grid for reduction of peak demand charges and general fleet charging management. The proposed solution shall be able to be controlled by an Open Charge Point Protocol (OCPP)-compliant system, version 1.6 or later. Charge management is likely to be considerably more complicated for on-route charging than for plug-in charging at the depot; however, considerations should be made for ways to mitigate charging needs and costs.

## Infrastructure Requirements and Recommendations

Charging infrastructure is required to support the operation of battery electric buses (BEBs) in Mountain Line's service. In addition to the installation of the charging stations, improvements to existing electrical infrastructure including switchboard, service connections, etc. are required to support deployment of BEBs.

The details provided in this *Implementation Plan* for charging infrastructure are conceptual and do not represent the full design details necessary to deploy charging equipment in service. Engineering design, including electrical and civil, will be required to prepare the necessary design drawings and calculations to support permitting and ultimately construction of charging facilities.

### Downtown Connection Center (DCC)

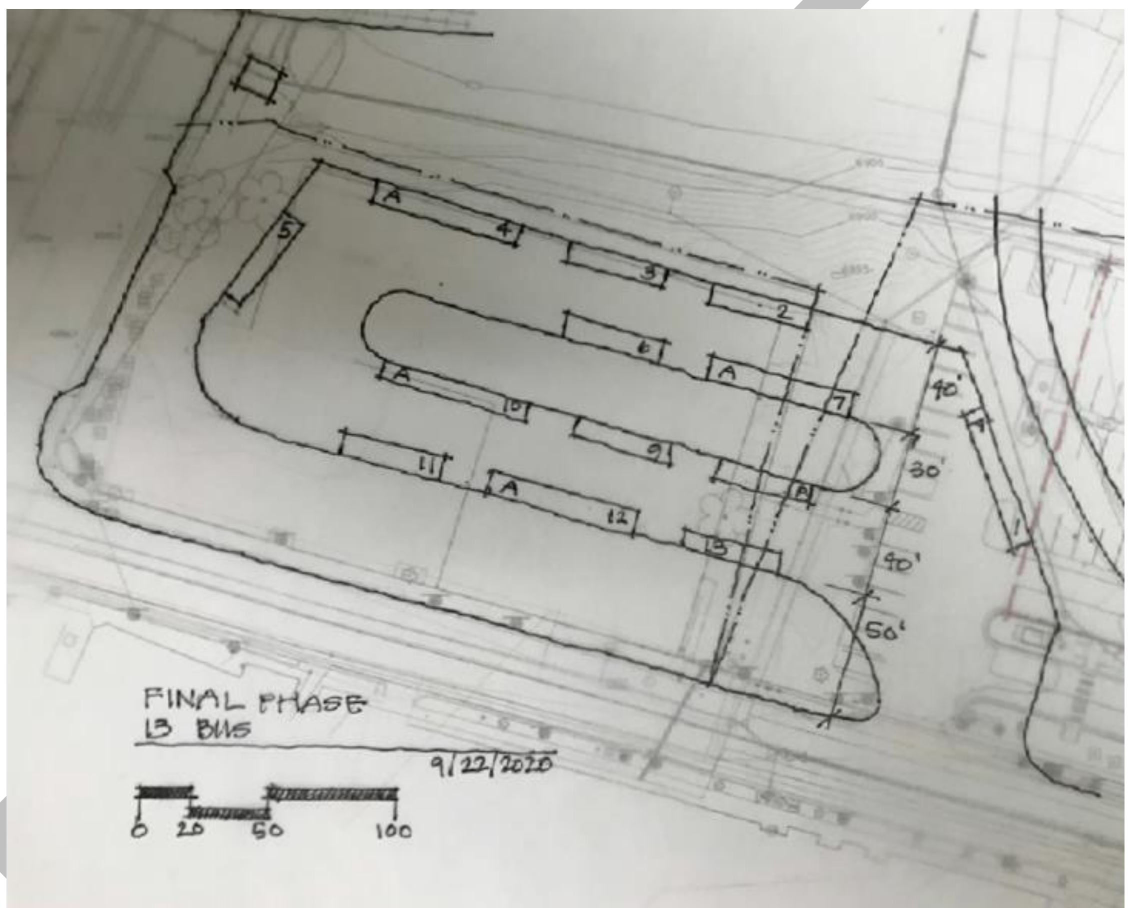
The DCC will be equipped with up to eight (8) 450 kW on-route chargers at full build out by 2034. A draft deployment schedule for charger installation at the DCC, as well as the Kaspar Drive Maintenance Facility and the NAU or other facility, is included in **Table 15** and is based on the proposed BEB procurement schedule. The deployment is based upon securing available funding for purchase of the BEBs as well as upgrading infrastructure at the DCC (and other facilities) to support BEB deployment. It is expected that charging equipment will be procured either through an RFP process directly by Mountain Line or through a construction RFP that covers purchase and installation of charging equipment. Typical lead time for on-route charging equipment is approximately 6 to 9 months.

*Table 15 - DCC Preliminary Charger Deployment Schedule – Cumulative Chargers*

| Facility | 2021 | 2022 | 2023 | 2024 | 2025 | 2026 | 2027 | 2028 | 2029 | 2030 | 2031 | 2032 | 2033 | 2034 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **DCC** | 0 | 0 | 2 | 2 | 2 | 5 | 5 | 5 | 8 | 8 | 8 | 8 | 8 | 8 |
| **Kaspar Drive** | 0 | 0 | 1 | 1 | 1 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| **NAU (or Other Separate Facility)** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 2 | 2 | 2 | 2 | 2 |

On-route chargers will operate with BEBs equipped with roof mounted charging rails and in compliance with the SAE J3105-1 overhead charging standard as discussed in the **Bus Technical Specifications and Fleet Recommendations** section of this *Implementation Plan*. Based on the modeling detailed in *the Zero-Emission Bus Transition Study* (November 2020) as well as the **Route Modeling** section of this *Implementation Plan*, the required charge duration for each vehicle is expected to be between three (3) and eight (8) minutes, depending on operating conditions (passenger loads, ambient temperature, snow, etc.). CTE recommends a total of eight (8) chargers eventually be installed at the DCC as there are seven (7) routes that may charge concurrently throughout the day during peak service and an eighth route, the Mountain Express, that charges concurrently during late December and January. Eight (8) chargers will also provide a level of redundancy if there is ever an issue with a single on-route charger. Short term schedule modifications could be incorporated to address equipment failure that could impact charging, including allowing buses on shorter blocks to skip charges throughout the day to free up charger space if necessary. A redundant charger will also allow charging to continue when preventative maintenance is being completed, though the chargers require limited maintenance and occasional software upgrades. A conceptual layout for the DCC is included as **Figure 11**. The specific bays required for charging are flexible; however, a total of six (6) bays for 35' buses and two (2) bays for 60' buses are recommended to support operations. The 35' buses could charge at 60' bay if necessary. A distance of 75' is recommended between charger masts to mitigate potential communication issues between chargers; however, as the technology develops these requirements are expected to be mitigated.

*Figure 11 - Preliminary DCC Parking Layout*

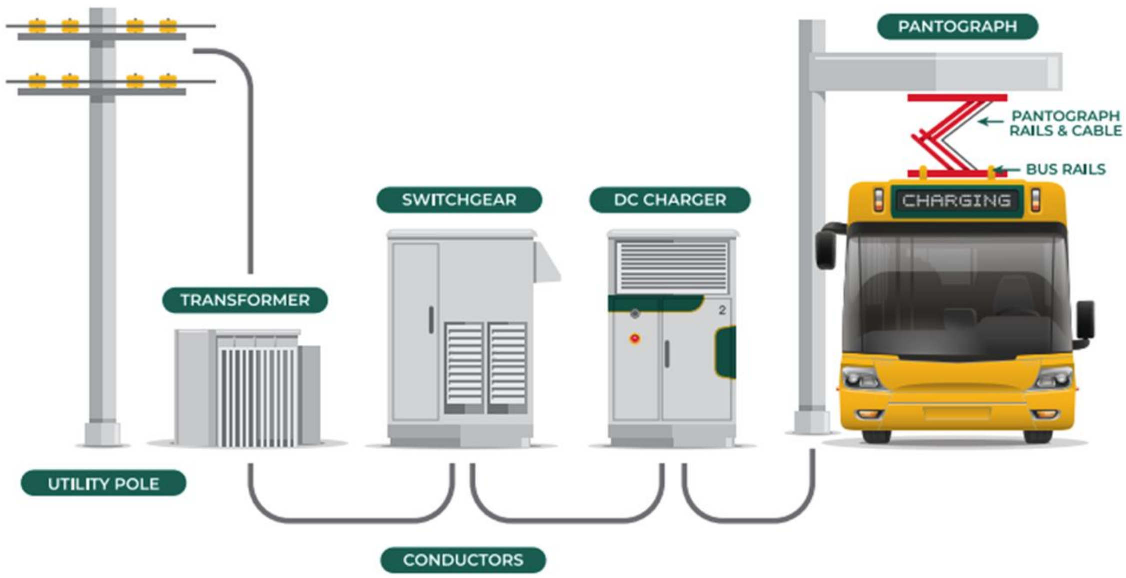



On-route chargers include the following equipment:

- Charging Mast
- Overhead Inverted Pantograph
- Direct Current (DC) Charging Cabinet
- Electrical Switchboard
- Utility Supplied Transformer

A schematic depicting typical on-route charging equipment is provided in **Figure** 12 below.

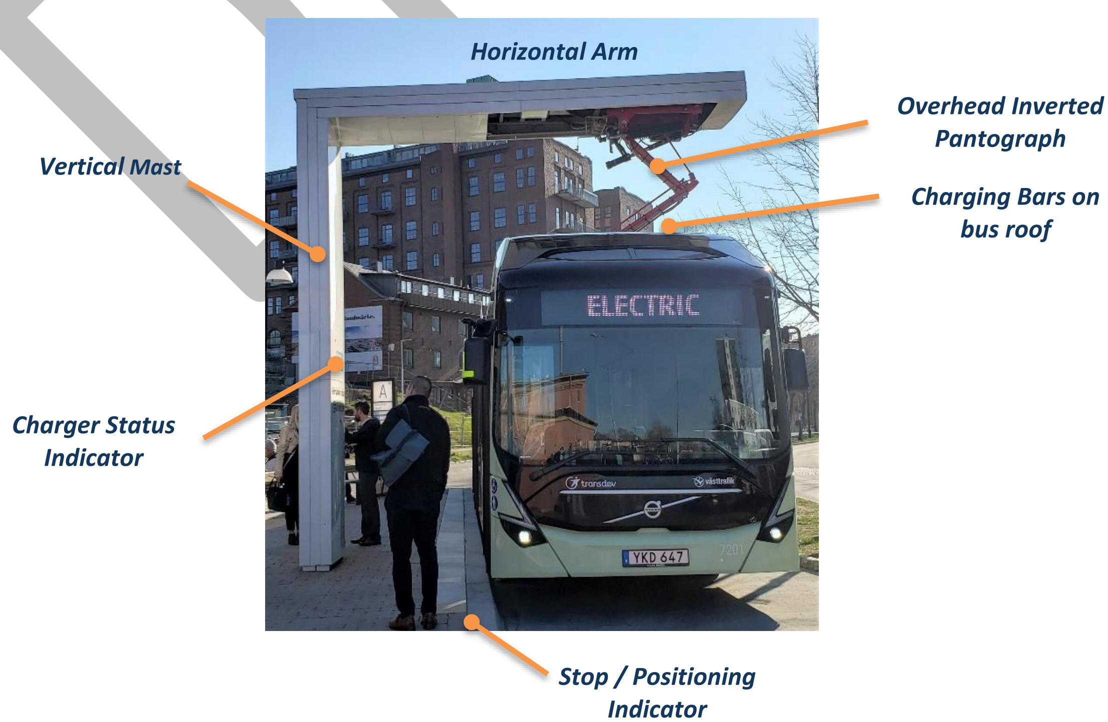
*Figure 12 - Typical On-Route Charging Infrastructure*




## Charging Mast

Located adjacent to the parked bus position and in line with the front axle of the bus, the charging mast supports the overhead charging pantograph. The vertical cross section of the pantograph holds and conceals the electrical power, control, and data cables that run from the DC Charging Cabinet to the Overhead Inverted Pantograph (Pantograph). The horizontal arm extends from the vertical mast, cantilevers over the bus parked in the charging position and holds the Pantograph over the charging bars located on the bus's roof.

*Figure 13 - Charging Mast and Components*



The vertical portion of the charging mast also houses the charging status indicator. The indicator type varies by manufacturer but commonly uses color lights or text displays to indicate to the bus operator the charger status and actions such as:

- Charger Ready – Green
- Charging In-Progress – Yellow
- Error in Position – Red
- Charging Interrupted – Flashing Red

The Automatic Control System (ACS) module is located within the vertical portion of the mast. The ACS module manages the incoming electrical DC and alternating current (AC) power, interlocks and communications with the DC Charging Cabinet and coordinates these systems with the charging Pantograph's systems of WiFi / Radio Frequency Identification (RFID) bus interlocks, charging status indicator, emergency stop (E-Stop), pantograph heater, and pantograph actuators and control systems. A typical ABB charging mast occupies a footprint of approximately 4' x 2' and requires an approximate 3 feet of clearance in front of the mast for service and approximately 4" of clearance on all sides for installation. The mast extends almost 16' from the pole across the top of the bus.

*E-Stop (Emergency Stop)*

The charging mast will be equipped with an E-Stop button. Mountain Line protocol should be developed for responding to E-Stop activations including who (Facilities, Operations, Supervisor, etc.) responds, inspects charging system and re-energizes or resets E-stop in the event of an activation. There are multiple interlocks included within the J3105-1 standards that will stop flow of power to the pantograph if the bus is moved or charging error occurs. However, similar to a fire alarm pull box, an E-stop should be accessible to the public or Mountain Line staff to activate to stop the charging process in the event of an emergency. An intentional nuisance activation of an E-stop will be disruptive to the charging system and repeated activations could impact a daily route's operation due to charging time lost and labor spent inspecting charging system and resetting. By default, E-stops are located on the charging mast in view of the bus operator. Video surveillance equipment is recommended to monitor and record any activity around the E-stop.

*Stop Stripe/Position Indicator*

A key element of a successful on-route charger is the ability for a bus to pull up and stop at the correct position for charging. While there are electronic guides (tones or lights to indicate proximity to charging position) and automated docking systems on the market, a less costly and effective solution is visual stop / position indicators. Painted stripes, unique colored or special pavers patterns and textures are all viable options for a stop / position indicator.

*Figure 14 - Overhead Charging Visual Stop/Position Indicator Examples*

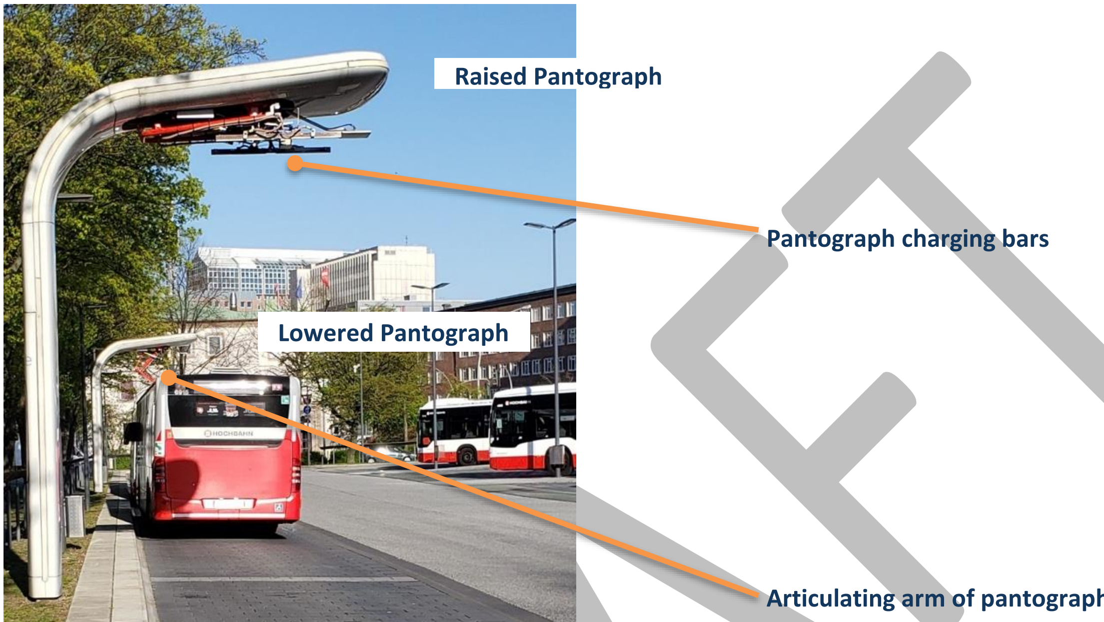



Note that heavy snow and leaves can obstruct ground mounted stop / position indicators. Consider training operators to stop based on orientation to vertical mast or to other vertical alignment indicators. The images in **Figure 14** are from the same charging position and utilize three stop indicators, color paver at front of bus, textured paver / pattern to align with bus front doors, and a vertical flag to allow driver to position without solely relying on ground mounted indicators. Flexible stop indicators that can be field adjusted and used to determine the best position relative to the fixed immovable mast position are recommended.

### Overhead Inverted Pantograph

The pantograph is the moving armature that raises and lowers from the horizontal arm of the mast and transfers the electrical power to the buses charging bars to charge the on-board batteries. The communications between the bus and the charger are set by the adopted charging standard and these standards must be matching and compatible for both the bus and pantograph for a successful charging session. The charging process is initiated automatically with the pantograph arm being lowered upon the charging bars on the bus's roof and transferring energy from the pantographs charging bars to the buses charging bars through direct contact.

*Figure 15 - On-route Overhead Inverted Pantograph*




Relatively level and plumb pavement is necessary at the charging position to allow for successful contact between the pantograph's charging bars and the charging bars on the bus roof.  Slope tolerances vary between charger OEMs but pavement cross slopes parallel to the bus of 5 percent and perpendicular to the bus of 3.5 percent are the anticipated maximums. These slopes are inclusive of kneeling buses and the additional angles of cross and parallel slope (road inclination) generated by a kneeling bus will need to be accounted for in the pavement slope design in the charging position. Heated pantographs are recommended for Mountain Line to keep the articulated arm and charging blades ice free during cold weather.

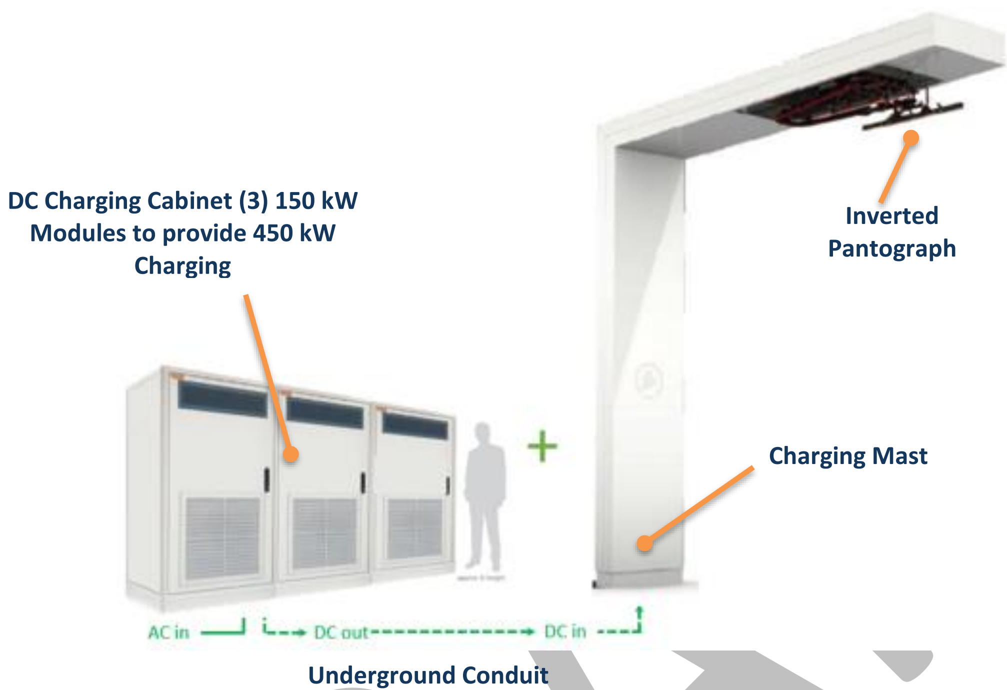
The pantograph can be installed on a charging mast as discussed previously, or can be incorporated into the roof structure of a canopy or building. An example of a facility mounted pantograph is included in **Figure E-3** in **Appendix E**.

### DC Charging Cabinet

The on-route charging systems (mast and inverted pantograph) utilize DC power to charge a bus. A primary limitation of DC power is the distance with which it can be distributed. The DC charging cabinet takes the utility provided AC power and converts it to DC by using a rectifier located within a DC charging cabinet. This DC power, along with control and signal power, and low voltage wiring, is then carried through a series of underground conduits to the charging mast, rising up within the vertical mast and across the horizontal arm to the pantograph. The maximum distance that DC power can be transmitted from the charging cabinet to the pantograph is between approximately 400 and 600 feet depending on the charge equipment

OEM. As a result, the charging mast can be placed a maximum of between 400 and 600 feet from the charging cabinet, depending on the manufacturer of the equipment.

*Figure 16 - Typical On-Route Charging System Including DC Charging Cabinet*




In addition to the underground conduits and conductors bringing 450 kW DC power from the charging cabinet to the charging mast, additional underground conduits and cabling are required. Underground conduits for AC controls, low voltage signal/data, and grounding are also included. Spare conduits should also be provided to allow future upgrades to the charging system to either higher power capacity or to accommodate new features. By including the spare conduit at the time of initial installation of underground conduit between the charging cabinet and charging mast, the requirements to dig up, trench and disturb the future active DCC is greatly reduced.  An example of a round mast support with required conduits is included in **Figure** 17.

*Figure 17 - Mast Support Structure Example*


Charging cabinets can be located outdoors like other pad mounted electrical equipment (e.g. transformers), or indoors to mitigate exposure to the elements. While the charging cabinets do not require major service (inspections and cleaning only), cabinets located inside will be easier to access during inclement weather or at night. Please note that cabinets supplied by OEMs such as ABB as well as others are designed to be air cooled where the heat from the rectification process of turning AC power into DC power is vented outside the cabinet enclosure through powered vents and fans. The overall ventilation requirements and position of the chargers in a charging room will need to be considered in the final design process if the charging cabinets are to be located inside. As an example, each 150 kW ABB charging cabinet is approximately 4’ wide by 2.5’ deep by 6.7’ tall and require a minimum of approximately 4’ of free space in front of the cabinet for door opening and 3” on both sides of the cabinet or rear of the cabinet for ventilation. Three cabinets are connected together to power a single 450 kW charger.

The location inside a locked room or compound will limit unauthorized access. Similar to most electrical cabinets and panels, charger cabinet’s doors lock but limiting access to the cabinets to the public waiting for buses on the transit center platform provides additional protection for the charging equipment.

### Switchboard (Electrical Distribution Panel)

The 450-kW ABB on-route chargers used for this analysis require 3-phase, 480/277-volt electrical service to be supplied to the chargers. As the chargers will be installed in phases, it is recommended that a smaller capacity switchboard is installed initially and upgraded as necessary to support the required load. For installation of the first charger that is expected to occur in 2023, a 1,600-amp switchboard is appropriate; however, CTE recommends installation of a 3,000 amp switchboard that will allow for expansion up to four (4) chargers (that are expected to be required in 2026). A typical footprint for a single 3,000 amp switchboard to support the installation of up to four (4) on route chargers is approximately 9’ long by 2.5’ to 3’ deep. Minimum clearance of 3’ is required at the front of the switchboard. A total of two (2) 3,000 amp switchboard would be required to support eight (8) on-route chargers. Installation manuals for on-route charging equipment from the selected OEM will be supplied to Mountain Line and their design engineer for reference and final design of the electrical system.

### Utility Supplied Equipment

APS, the local utility, will prepare load estimates based on the charging requirements and preliminary deployment schedule that has been provided to them for evaluation and is also included in this *Implementation Plan*. As previously detailed, the chargers are sized for a maximum load of 450-kW; however, current bus configurations typically accept a maximum of between 330 and 360 kW. Based on the deployment schedule and load estimates, APS will determine the sizing requirement for the transformers and APS owned switching cabinets. APS will also complete a cost evaluation to determine how much of the infrastructure that they will pay for and how much Mountain Line will be required to purchase. The payback estimates completed by APS are generally based on a 6-year payback; however, Mountain Line has requested that APS consider a guaranteed 12 years of operation as a result of FTA funding that requires that the buses operate for a minimum of 12 years. In addition to sizing of the equipment, APS will work with Mountain Line's design contractor (AECOM) to identify the locations of the primary feeds to the facility and required infrastructure locations, as well as the potential to provide a redundant feed or other resiliency means (e.g. backup generator for APS operated microgrid). Resiliency will be discussed further in the **Resiliency Plan** section of this *Implementation Plan*.

APS provided equipment will include the transformer and associated switching cabinet. The transformer powers the main switchboard, to be supplied by Mountain Line and located in a to-be-determined location at the facility, including a main breaker (or disconnect switch) that will serve the on-route charging equipment. The transformer size will be specified by APS based on the load requirements; however, based on preliminary discussions with APS it is expected that two 2,000 kVA transformer will be supplied to support up to eight (8) on-route chargers. APS may elect to install a smaller transformer during the first phase of the deployment when only up to two (2) chargers would be installed. According to APS, the typical footprint of a 2,000 kVA transformer is approximately 6.5' wide by 5.5' deep by 6' tall. A minimum of approximately 10 feet of level ground is required for the installation of each transformer, though there are alternate configurations that would allow the 10' of free space to be shared by the transformers. Clearance requirements for APS supplied equipment (transformers and switching cabinets) are included in **Appendix C.**

### Emergency Generator and Transfer Switch

Currently there are no provisions at the DCC for emergency backup power; however, Mountain Line has discussed options to include the APS Microgrid Program as well as bringing in power from multiple feeders/substations to mitigate the effects of power outages. Additional details regarding back up power and resiliency are included in the **Resiliency Plan** section of this Implementation Plan.

## Kaspar Drive Maintenance Facility

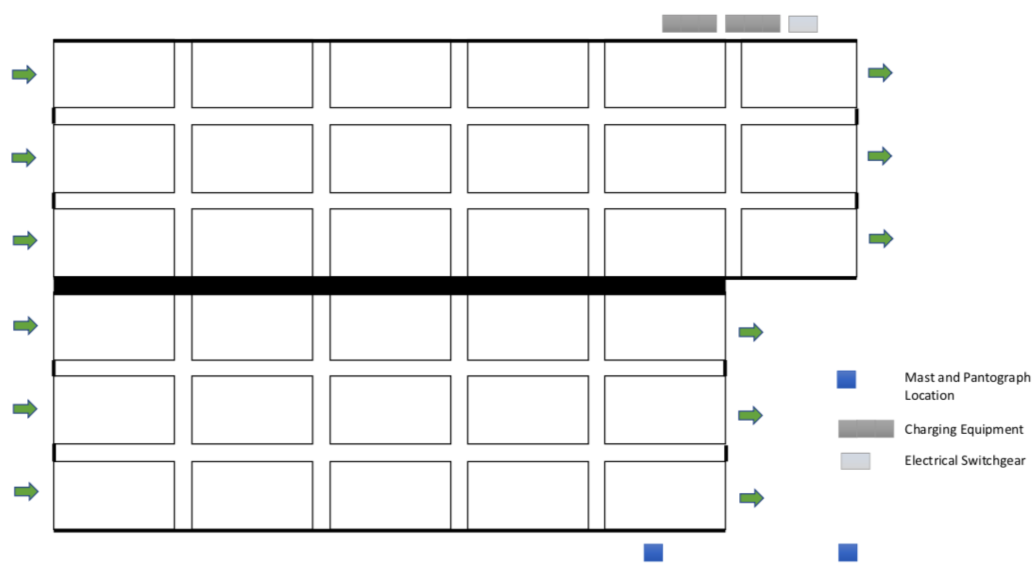
The Kaspar Drive Maintenance Facility is the current storage and maintenance facility for the entire Mountain Line fleet; however, a total of ten (10) buses are expected to eventually be moved to the NAU or other separate facility when/if it is constructed. This analysis assumes that a total of nineteen (19) buses will be stored and charged at the Kaspar Drive Maintenance Facility and ten (10) buses will charge at the NAU or other facility. If the NAU or other separate facility is not built in the future, then additional charging infrastructure identified in the NAU or Other Separate Facility section would be required at the Kaspar Drive Maintenance Facility.

Based on discussions with Mountain Line operations and maintenance staff, it was determined that Mountain Line would prefer to utilize 450-kW overhead chargers rather than 150-kW (or similar) plug-in style depot chargers to fuel buses at the end of each service day. Mountain Line selected this charging options for a number of reasons including:  (1) reduced changes necessary to operations as a bus will simply charge for between 15 and 20 minutes on the fast charger upon return to the depot rather than going through the diesel fueling island; (2) maintenance staff does not believe the current building design will allow for hanging of additional appurtenances (e.g. charge reels or pantographs) from the building roof structure due to snow load requirements though engineering design calculations would be required to confirm this assumption; (3) the existing storage building is equipped with a radiant heat system in the floor that they do not wish to damage with construction activities inside the building. Either approach is viable at the Kaspar Drive Maintenance Facility; however, using only overnight plug-in charging requires more coordination with overnight maintenance staff to ensure the buses are properly charged prior to the next morning pull-out and that the buses are parked in the storage building such that bus movement is not necessary deploy fully charged buses on the early blocks. High-capacity overhead charging can occur during the cleaning and maintenance process when a bus completes service for the day. A conceptual site layout and building schematic for the Kaspar Drive Maintenance Facility are included as **Figure 18** and

Figure 19, respectively.

*Figure 18 - Kaspar Drive Conceptual Charging Layout*

*Figure 19 - Kaspar Drive Building Schematic and Charging Equipment Location*




A review of the Mountain Line block structure indicates that two (2) 450-kW on-route chargers provide sufficient capacity to charge the buses returning to the depot and limit queuing to a single bus at peak return (approximately 6:30 PM and 10:30 PM) as detailed previously in **Figure 7**. Details of on-route charging systems were provided in the previous section.

In addition, Mountain Line has expressed interest in installing a single depot charger to provide charging in the service bays during maintenance activities. A single depot charger, equipped with a CCS-1 charging cable, is recommended for installation. Heliox manufactures a 25-kW or 50-kW portable charger, equipped with wheels, that can either be hardwired to a 480-V service or plugged in using a 480-V connector. Specification sheets for the Heliox portable chargers are included in **Appendix D**. Evaluation of the electrical system for the maintenance building would be required to determine if there is sufficient capacity to install the chargers or upgrades would be required. If upgrades are required, they could include connection to 480-V service (new utility supplied transformer discussed below) and breaker panel.

### Switchboard (Electrical Distribution Panel)

As detailed previously, the 450-kW ABB on-route chargers used for this analysis require 3-phase, 480/277-volt electrical service to be supplied to the chargers. For installation of the first chargers that is expected to occur in 2023, a 1,600-amp switchboard is appropriate and will allow for installation of the second charger in the future. A typical footprint for the switchboard to support the installation of two (2) on-route chargers at full build-out is approximately 9' wide by 2.5' to 3' deep. Installation manuals for on-route charging equipment from the selected OEM will be supplied to Mountain Line and their design engineer for reference and final design of the electrical system. Switchboard could be installed inside the existing maintenance building or on the exterior of the facility adjacent to the proposed charger cabinet locations as the switchboard is rated for exterior installation.

### Utility Supplied Equipment

APS will completed load estimates based on the charging information provided previously and included in this plan to determine the size requirements for the utility supplied transformer and switching cabinet and determine if the Mountain Line will be required to pay for any of the utility supplied infrastructure. The transformer powers the main switchboard for the chargers, including a main breaker (or disconnect switch) that will serve the charging equipment. The transformer size will be specified by APS based on the load requirements. From previous experience at other similar installations, it is expected that APS will supply a minimum 500 kVA transformer for the deployment of the first on-route charger. APS may elect to install a larger transformer during the first phase of the deployment rather than upgrade as capacity needs expand with the addition of more on-route chargers. A typical 500-kVA transformer has a footprint of approximately 3' wide by 4' deep by 5' tall. At full build-out, it is expected that a single 1,000 kVA transformer may be required to carry the load associated with the on-route chargers. According to APS, the typical footprint of these transformers is approximately 6.5' wide x 5.5' deep x 6' tall. A minimum of approximately 10 feet of level ground is required for the installation of each transformer. The preliminary location of the proposed utility transformer is included on **Figure 18.**

## NAU or Other Separate Facility

The NAU Facility, or another separate facility, is planned by Mountain Line but there is no current timeline or funding identified. For the purpose of this *Implementation Plan*, it was assumed that a total ten (10) buses will eventually be stored at the facility. Based on a review of the current block structure, a total of two (2) high capacity 450-kW on-route chargers will be sufficient to provide top off charging at the depot at the end of each service day. A conceptual layout has not been completed to date; however, the infrastructure needs are the same at the facility as previously discussed for the Kaspar Drive Maintenance Facility. Charger cabinets can be installed inside a future facility building or outside of the building as the charging cabinets are rated for exterior installation. Automatic DC plug-in chargers could be installed at the NAU or other separate facility and incorporated into the building design to mitigate the need for high-capacity on-route chargers at the depot. The roof structure could be designed to carry the load necessary to support overhead pantograph chargers or dispensers. The advantage to the plug-in chargers is that charge management software could be utilized to reduce the overall demand during overnight charging. A total of two (2) 150-kW chargers per bus, or a total of five (5) chargers are estimated for deployment. This option may be considered as plans for the design of a new facility are formalized in the future and as NAU determines their approach to ZEB deployment.

### Switchboard (Electrical Distribution Panel)

Switchboard needs for the NAU or other separate facility would be the same as required at the Kaspar Drive Maintenance Facility as the charging equipment is sized the same. The switchboard sizing assumes that the switchboard is only controlling equipment that is required to charge Mountain Line buses and not additional NAU charging equipment that may be installed.

### Utility Supplied Equipment

Transformer needs for the NAU or other separate facility would be the same as required at the Kaspar Drive Maintenance Facility, assuming the transformers are only feeding equipment used to charge Mountain Line buses and not additional NAU charging equipment that may be installed.

## Alternative Equipment Options

Although Mountain Line has selected an approach using 450-kW high-capacity overhead chargers for top off charging at the depots at the end of each service day, details of DC Automatic Plug-In charging systems and associated infrastructure have been included in **Appendix E**. The details are provided in the event that there are changes to the Mountain Line plan in the future for depot charging based on improvements in bus technology (range and efficiency) that would allow for one-to-one replacement of current hybrid diesel buses with depot charged BEBs or in the case that plug-in charging is determined to be the best choice for the NAU or other separate facility.

## Updated Infrastructure Costs

Updated infrastructure rough-order-magnitude (ROM) costs estimates for the DCC, Kaspar Drive Facility, and NAU or other separate facility were developed during completion of the *Implementation Plan*. ROM estimates are included in **Appendix F**. Cost estimates for multiple phases of deployment were also developed, assuming initial deployment of two (2) BEBs in 2023 for Phase I; expansion of the DCC to include five (5) on-route chargers in 2026, and full-scale deployment of eight (8) on-route chargers at the DCC in 2029. The DCC expansion coincides with addition of charging capabilities at the Kaspar Drive Maintenance Facility and the NAU or other separate facility.

*Table 16 - Updated Infrastructure ROM Cost Estimates*

| Phase | DCC | Kaspar Drive | NAU | Total Cost |
|---|---|---|---|---|
| **1 - 2023** | $ 1,892,000 | $ 988,000 | $ ---- | $ 2,880,000 |
| **2 - 2026** | $ 2,418,000 | $ 717,000 | $ ---- | $ 3,135,000 |
| **3 - 2029** | $ 2,185,000 | $ ---- | $ 1,950,000 | $ 4,135,000 |
| ***TOTAL*** | *$ 6,495,000* | *$ 1,705,000* | *$ 1,950,000* | *$ 10,150,000* |

## Resiliency Plan

Local power congestion or disruption may occur when local demand exceeds the system's capacity. The local power supply is also vulnerable to interruption from severe weather events or other reasons for grid failure. Battery electric bus (BEB) charging operations can be protected from power supply interruptions using energy production by back-up generators or photovoltaic panels and/or on-site energy storage batteries.

**Redundant Utility Feed:** In order for multiple feeders to be effective in providing redundancy they need to originate from separate utility circuits and/or substations. Use of multiple utility service is economically feasible then the local utility can provide two or more service connections over separate lines and from supply points that are not apt to be jointly affected by system disturbances, storms, or other hazards.[2] APS has indicated that there is a potential for redundant feeds for the DCC. This option is noteworthy because a failure of a component on the distribution line, or outage at the upstream substation would not affect charging operations at the DCC. If APS is able to confirm the existence of a loop/networked distribution in the local area surrounding the facility, it is possible a separate feeder can be utilized from another branch, thus giving the option of the facility remaining operational should a local fault or failure on the primary circuit occur. APS has indicated that they will complete an evaluation, to include a high level engineering evaluation and cost modeling, to determine if installation of a redundant feed is feasible or cost-effective.

**Back-up generators:** The conventional approach to energy resiliency is through back-up generators which are available in sizes up to 2,000 kW. A typical 800 kW generator, roughly sized to operate a single 450 kW high-capacity charger, has a footprint of approximately 15' long by 7' wide. Adding a sound attenuation cabinet and integrated fuel tank can increase the size to 20' or longer by 8' wide. Generators can be permanently installed at facilities for dependability and ease of operations or can be mounted on trailers to provide greater flexibility for fleet operators. A socket connection could be installed at the primary load center to allow for the connection of a portable generator to provide power in the event of an outage. Generators can be powered by diesel fuel or other liquid fuel sources like natural gas or propane. Renewable diesel is a hydrocarbon diesel fuel produced by the hydroprocessing of fats, vegetable oils, and waste cooking oils that could be substituted for standard petroleum diesel. According to industry sources

*Figure 20 - Mobile Diesel Generator*

*(Source: https://criticalpower.com/inventory/generators/hipower/)*

[2] IEEE Std 493, "IEEE Recommended Practice for the Design of Reliable Industrial and Commercial Power Systems."

like Neste (https://www.neste.us/neste-my-renewable-diesel), such a substitution reduces lifecycle emissions by up to 80% compared to petroleum diesel.

**Solar**: Solar power is becoming an increasingly viable source of power for BEB charging due to improving energy collection and storage technology, lack of carbon emissions, and resiliency due to independence from electrical grid disruptions during emergencies. Solar could be used to provide a limited off-set by installing photovoltaic canopies at the DCC; however, the large footprint required for solar would only off-set a small percentage of the power needs at the DCC full-build out. For reference, a typical 5 kW solar system for powering a home requires a minimum of approximately 275 square feet of solar panels. An average Mountain Line block has a daily energy demand between 360 and 480 kWh.

**Stored energy**: Battery energy storage (BES) systems can provide immediate backup power to a facility in the event of a complete utility outage. The size and ratings of the BES along with the amount of backed-up load will determine how much time the BES will provide power without need for recharging. BES systems can be coupled with on-site generation (e.g. generator or solar) or grid power to create additional resiliency or to be used to off-set peak charging needs. Energy can be stored in PEVs, which collectively can act as a large battery. A smart charger would control the flow of energy and can send energy from the grid to vehicle batteries, or draw energy from the bus batteries back onto the grid through bi-directional charging equipment. Along with cost, one challenge caused by energy storage is physical space as the area required for enough batteries to store the electricity produced may be prohibitive. A BES system with a capacity of 3,600 kWh (assuming 4 hours of backup storage for a 450 kW charger), would occupy an approximately footprint of 125 square feet, including working clearances, similar to that of the utility transformer and switching cabinet. For full backup capability of eight (8) chargers would require an estimated 14.4MWh system (assuming 4 hours of backup) and would require a substantially larger footprint.

**Bi-directional charging**: By enabling BEBs to provide backup power to buildings and the grid, this next-generation of charging infrastructure will enhance grid resilience and help future-proof the grid against disruptions, such as from natural disasters. First responders and public services can use BEBs fleets as swappable, mobile batteries for buildings during times of outage, providing power to key infrastructure by working together with on-site generators and solar. Bi-directional charging is still an emerging field that is progressing quickly, with reductions in storage costs and higher energy density storage technologies emerging rapidly that will advance the protocols and expansion of resilient microgrids.

**Microgrids**: In recent years, microgrid technology has been a valid resiliency measure for critical facilities such as military bases, hospitals, and campuses. A microgrid is a single, controllable, independent power system comprising distributed generation (DG), load, energy storage (ES), and control devices, in which DG and ES are directly connected to the user side in parallel.[3] As a resiliency tool, when BES systems are combined with on-site generation such as photovoltaic systems or an appropriately sized emergency generator, a microgrid can not only provide

[3] Fushend Li, Ruisheng Li, Fengquan Zhou (2015), *Microgrid Technology and Engineering Applications*, Elsevier Sceince and Technology

resiliency and redundancy, but assist in meeting net-zero emissions goals and be a proven, cost-saving measure.

APS has provided Mountain Line limited details regarding the APS Microgrid program, whereby APS would install generating capacity, in the form of a diesel generator(s) at the DCC. According to APS, the minimum microgrid system currently being considered for the program by APS is 1 MW. The microgrid would provide emergency power to the DCC to support charging in the event of an outage but would also be used to support generation/emergency needs in downtown Flagstaff. APS is developing rough-order cost and sizing estimates for providing microgrid opportunities at the DCC. It is unlikely that space and cost considerations would allow for the installation of backup generation to support all eight (8) chargers at full-build out; however, due to the limited outage time that APS typically experiences, backup of all eight (8) chargers is likely not required.

## Total Cost of Ownership Assessment

The Total Cost of Ownership (TCO) Assessment compiles and organizes the results from the Fleet, Fuel, Facilities, and Maintenance Assessments that were completed as part of the Phase I of ZEB Transition Analysis and were included in the *Zero-Emission Bus Transition Plan* (November 2020). It includes selected capital and operating costs of each transition scenario over the transition timeline. The TCO assessment was updated based on further cost review of infrastructure requirements completed by AECOM and also includes cost considerations for redundancy and resiliency.

No cost escalation is assumed nor does CTE assume any cost reduction due to economies of scale for ZEB technology because there is no historical basis for this assumption. Future changes to Mountain Line's service level, depot locations, route alignments, block scheduling, etc., are unforeseen. The sections below provide best estimates using the information currently available and the assumptions explained throughout this study.

### Costs by Scenario

The following sections show total cost comparisons between the Baseline Hybrid Diesel scenario and the battery electric bus (BEB) Depot and On-Route Charging scenario, broken down by assessment type.

#### Baseline Hybrid Diesel

The Baseline Hybrid Diesel scenario is used for comparative purposes only. It assumes no changes to the agency's current fleet configuration throughout the life of the study, i.e., no ZEB-related purchases. **Table 17** shows the fleet, fuel, facilities and maintenance costs for the Baseline Hybrid Diesel scenario in 2020 dollars. The costs assume a single replacement of the fleet between 2023 and 2034 and upgrade of the facilities necessary to support electrification. Mountain Line's total operating and capital costs are an estimated $34.3 million from 2020 to 2034. There are no facilities costs for this scenario. As Mountain Line is assumed to not add any additional buses other than those that are already included in the Baseline Hybrid Diesel scenario, no additional facilities are required.

*Table 17 – Total Costs, Baseline Hybrid Diesel [millions $]*

| | 2020 | 2021 | 2022 | 2023 | 2024 | 2025 | 2026 | 2027 | 2028 | 2029 | 2030 | 2031 | 2032 | 2033 | 2034 | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Fleet** | - | - | 1.3 | 0.7 | - | - | 5.2 | 3.9 | - | 2.3 | 1.3 | 1.3 | 2.0 | 2.0 | 1.0 | 20.8 |
| **Fuel** | 0.6 | 0.6 | 0.6 | 0.6 | 0.6 | 0.6 | 0.6 | 0.6 | 0.6 | 0.6 | 0.6 | 0.6 | 0.6 | 0.6 | 0.6 | 8.5 |
| **Facilities** | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| **Maintenance** | 0.5 | 0.3 | 0.4 | 0.3 | 0.3 | 0.4 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.5 | 5.1 |
| **Total** | **1.0** | **0.8** | **2.3** | **1.6** | **0.8** | **1.0** | **6.1** | **4.7** | **0.8** | **3.1** | **2.2** | **2.2** | **2.8** | **2.8** | **2.1** | **34.3** |

#### BEB On-Route and Depot Charging

**Table 18** shows the combined fleet, fuel, facilities, and maintenance costs for the BEB On-Route and Depot Charging scenario in 2020 dollars. The estimate includes the revised costs associated with infrastructure deployment as detailed in the **Infrastructure Requirements and Recommendations** section of this *Implementation Plan.* Costs associated with resiliency/redundancy (redundant feed and microgrid program) are currently being developed by APS and will be incorporated when they are available. The total estimated combined cost is approximately $53.6 million over the length of the transition, from 2020 to 2034. This scenario estimates a total of twenty-nine (29) BEBs in service by 2034.

*Table 18 – Total Costs, BEB On-Route and Depot Scenario [millions $]*

| | 2020 | 2021 | 2022 | 2023 | 2024 | 2025 | 2026 | 2027 | 2028 | 2029 | 2030 | 2031 | 2032 | 2033 | 2034 | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Fleet** | - | - | 1.6 | 0.8 | - | - | 6.4 | 4.8 | - | 2.9 | 1.6 | 1.6 | 2.6 | 2.6 | 1.3 | 26.2 |
| **Fuel** | 0.6 | 0.6 | 0.6 | 0.6 | 0.6 | 0.6 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.7 | 0.7 | 0.7 | 10.4 |
| **Facilities** | - | - | 3.6 | - | - | - | 4.6 | - | - | 1.9 | - | - | - | - | - | 10.1 |
| **Maintenance** | 0.5 | 0.3 | 0.6 | 0.4 | 0.3 | 0.4 | 0.9 | 0.7 | 0.3 | 0.5 | 0.5 | 0.4 | 0.3 | 0.4 | 0.5 | 6.9 |
| **Total** | **1.0** | **0.8** | **6.4** | **1.8** | **0.9** | **1.0** | **12.7** | **6.3** | **1.0** | **6.1** | **2.8** | **2.8** | **3.7** | **3.7** | **2.5** | **53.6** |

## Total Estimated Costs

**Table 19** provides the detailed cost totals, total cost increase over Baseline Hybrid Diesel, and the number of ZEBs in the fleet in 2034.

*Table 19 – Total Estimated Transition Costs*

| | Baseline Hybrid Diesel | BEB On-Route + Depot |
|---|---|---|
| Fleet | $ 20,800,000 | $ 26,200,000 |
| Fuel | $ 8,462,000 | $ 10,396,000 |
| Facilities | – | $ 10,150,000 |
| Maintenance | $ 5,065,000 | $ 6,853,000 |
| **Total** | **$ 34,327,000** | **$ 53,599,000** |
| **Incremental Cost Over Baseline Hybrid Diesel** | | $ 19,272,000 |
| **ZEBs in 2034** | **29** | **29** |

## Training

Battery electric bus (BEB) training is recommended to include the following to ensure safe and efficient operation and maintenance of the vehicles by properly trained staff:

- BEB operation, which includes detecting and resolving in-service problems and emergencies that result in minimal delays.
- Maintenance of components or assemblies, which includes inspections, lubrication, adjustments, repairs, and replacements normally performed at the Maintenance Shop.
- Special tools and test equipment used during maintenance
- First Responder training

Mountain Line should identify operations and maintenance staff that require training and work with the OEM to develop the internal training requirements and program training materials. Operator training shall be provided by the OEM to Mountain Line Operator Training staff and to any selected drivers necessary to conduct the initial bus validation testing. Operator training is recommended to be completed upon delivery of the first BEB. A schedule for full rollout of training to all required operators should be prepared by the Mountain Line training staff once a schedule for delivery of the first set of vehicles is known. Training should consist of both classroom and hands-on activities, and cover, at a minimum, the following topics:

- General BEB orientation
- Normal operating procedures
- Emergency operating procedures
- Moving a BEB with a problem (fault)
- Revenue service preparation

Maintenance training should be completed by a combination of bus OEM and component OEM staff. Maintenance training should be provided to Mountain Line Maintenance Training staff as well as specific Mountain Line maintenance staff that are expected to conduct initial maintenance activities on the BEBs upon delivery. A schedule for full rollout of training to all required maintenance staff should be developed by the Mountain Line.

Maintenance training should address the following BEB components, at a minimum:

- Multiplex systems
- Entrance and exit doors
- Wheelchair ramp
- Brake systems and axles
- Air system and ABS
- Front and rear suspension and steering
- Body and structure
- Towing and Recovery
- Propulsion System
- Articulation Joint (where applicable)
- High Voltage Systems
- Charging Stations

- HVAC

Final operation and maintenance manuals, in hard copy and electronic version if requested, should be provided by the bus OEM in accordance with the procurement contract. Mountain Line should coordinate training for local first responders with the bus OEM and their subcontractors, as well.

Minimum recommended training hours and the associated description of the training are included in **Table 20**.

*Table 20 – Recommended Training Requirements*

| Description | Quantity (Hours) | Training Entity |
|---|---|---|
| Operator Orientation | 4 | Bus OEM |
| Maintenance Orientation | 4 | Bus OEM |
| Multiplex Systems | 32 | Bus OEM |
| Entrance and Exit Doors | 8 | Bus OEM |
| Wheelchair Ramp | 4 | Bus OEM |
| Brake System and Axles | 16 | Bus OEM |
| Air Systems and ABS | 8 | Bus OEM |
| Front and Rear Suspension and Steering | 4 | Bus OEM |
| Body and Structure | 8 | Bus OEM |
| Towing and Recovery | 4 | Bus OEM |
| Articulation Joint | 8 | Bus OEM |
| Propulsion & ESS Familiarization/High Voltage Safety | 24 | Bus OEM/Component OEM |
| Propulsion & ESS Troubleshooting | 16 | OEM/Component OEM |
| Depot Charger Familiarization & Troubleshooting | 16 | OEM/Charger OEM |
| HVAC Familiarization & Troubleshooting | 16 | OEM/Component OEM |

Training hours may be shifted between topics at the discretion of Mountain Line to ensure staff receive the training necessary for safe and efficient operation and maintenance of the BEBs. Some equipment may be the same as on current Mountain Line vehicles and thus require limited additional training (e.g. wheelchair ramps, entrance/exit doors, etc).

CTE recommends including training requirements as part of the bus specifications. A copy of draft requirements for inclusion in the specifications are included in **Appendix G**.

## Deployment Strategy

Battery electric bus (BEB) deployment includes all tasks necessary to deploy the buses on the routes and includes the following:

- Delivery
- Inspection
- Acceptance
- Charger Commissioning with BEBs
- Service Demonstration

CTE recommends that Mountain Line prepare an *Inspection and Acceptance Plan* prior to delivery of buses in accordance with APTA Guidance BTS-II-RP-001-11. The test plan should reference the applicable specifications for each test identified and should be reviewed with the OEM prior to completion. After delivery of the buses, the OEM should commission the buses with all charging equipment at each facility. Charger commissioning should include demonstration that all chargers are capable of fully charging the buses without faults. A commissioning plan should be developed by the charger manufacturer and provided to Mountain Line a minimum of 60 days prior to delivery of the first bus for review. Additional requirements for charger commissioning are included in the recommended charger specifications included in **Appendix B**.

As discussed in the **Bus Procurement Best Practices** section of this *Implementation Plan*, CTE recommends a minimum of 30 days from delivery for completion of post-delivery testing, along with a verification of system(s) functionality in accordance with the *Inspection and Acceptance Plan* to determine acceptance. Post-delivery testing should include service demonstration on routes/blocks in Mountain Line's service; however, if desired this will need to be included in the bus contract.

BEBs that fail to pass the post-delivery tests are subject to non-acceptance. Mountain Line should record details of all defects on the appropriate test forms and notify the OEM of acceptance or non-acceptance within five (5) days of completing the testing. Any defects detected during the testing should be repaired according to procedures defined in the contract after non-acceptance. Following acceptance inspections, route validation should be completed to compare results to models developed by CTE and by the OEM during the RFP process to ensure that the buses will perform as specified and that changes to service operations (e.g. on-route charge time) are not required. In order to complete the route validation, initial training for bus operators, maintenance personnel, and first-responders should occur. The initial training should focus specifically on the drivers and maintenance staff required to complete the bus validation testing. Training recommendations are discussed in the previous section and recommended specifications are included in **Appendix G**.

A service demonstration by the OEM is recommended during validation and acceptance of the initial buses. As discussed previously, the service demonstration should be included as a requirement in the bus contract. The service demonstration would be comprised of operations on the proposed route, including the required charging both on-route and at the depot (either using a high-capacity overhead charger as is currently specified or plug-in chargers), for a set number of days or miles. The service demonstration should be completed without faults occurring with the bus or charger. Upon successful completion of the service demonstration and the necessary operator, maintenance, and first responder training, the buses may be placed into revenue service.

## Data Collection Plan

CTE recommends that Mountain Line collect, analyze and report on key performance indicators (KPIs) to track and analyze the performance of the BEBs following deployment. A third-party data collection tool (e.g. Viriciti or similar) deployed on the buses to optimize data collection is recommended as discussed previously. These KPIs, when combined, will allow Mountain Line to fully understand operational metrics to determine the benefits that have been realized from the deployment of the BEBs, including impact on emissions, reductions in fuel consumption and cost, reductions in maintenance and costs, and any potential increase in ridership. The analysis will also help Mountain Line to understand any impact that range limitations or charging of the BEBs may have on service levels, operations, and on-time performance. By tracking and analyzing theses KPIs, project stakeholders will be fully informed regarding the overall impact of these vehicles on STA's service and implications for transition of the full fleet to ZEBs.

The following KPIs are a sample of the type of information that may be analyzed and tracked:

- Fuel Cost: The fuel cost analysis provides information regarding the cost of powering the BEBs in Mountain Line service compared to the cost of operating the hybrid diesel fleet on the same routes/blocks.
- Energy Performance and Fuel Efficiency: Mountain Line's energy performance provides an overall energy consumption and fuel efficiency comparison (to include hybrid diesel and electricity consumption) post-electric bus deployment. Overall $CO_2$ emissions can also be compared.
- Availability and Utilization: The bus availability data can be analyzed to determine the overall availability of the BEBs versus the hybrid diesel fleet, regardless of whether the buses are actually placed into service. This data can also be analyzed to determine the overall utilization rate of the BEBs when available.
- On-Time Performance: Analysis of on-time performance provides details on the impact, if any, BEBs have on the on-time route performance as compared to the hybrid diesel fleet operating on the same routes/blocks.
- Maintenance Costs: The maintenance cost analysis compares maintenance activities, time, and cost for the BEBs against the hybrid diesel fleet, regardless of whether the maintenance activity is covered by warranty.

Below is a summary of the vehicle, charging, and historical utility and hybrid diesel bus data that can be collected, the source of the information, and the proposed frequency for reporting.

### Vehicle Data

The following table outlines the data elements that should be provided on a **per vehicle** basis.

*Table 21 - Vehicle Data Elements*

| Data Element | Source | Format | Frequency |
|---|---|---|---|
| Daily Mileage | OEM or third-party tool | Database or Log, usually MS Excel | Monthly file with daily-level data |
| Daily Operating Time (hrs/min in operation) | OEM or third-party tool | Database or Log, usually MS Excel | Monthly file with daily-level data |
| Total kWh Consumed | OEM or third-party tool | Database or Log, usually MS Excel | Monthly file with daily-level data |
| Beginning State of Charge (SoC) | OEM or third-party tool | Database or Log, usually MS Excel | Monthly file with daily-level data |
| Ending State of Charge (SoC) | OEM or third-party tool | Database or Log, usually MS Excel | Monthly file with daily-level data |
| Auxiliary Loads (in kWh) | OEM or third-party tool | Database or Log, usually MS Excel | Monthly file with daily-level data |
| Average Speed | OEM or third-party tool | Database or Log, usually MS Excel | Monthly file with daily-level data |
| Max Speed | OEM or third-party tool | Database or Log, usually MS Excel | Monthly file with daily-level data |
| Maintenance Required – For each maintenance event, the following should be provided:<br>• Maintenance description<br>• Type of Maintenance (scheduled/unscheduled)<br>• Open date<br>• Close date<br>• Parts used<br>• Parts cost<br>• Labor hours<br>• Labor cost<br>• Odometer<br>• Road call required?<br>• Warranty? | Mountain Line | Database or Log, usually MS Excel | Monthly file with incident-level data |
| BEB Route Ridership | Mountain Line | Database or Log, usually MS Excel | Monthly (if available) |

## Charging Data

The following table outlines the data elements that should be provided for the charging infrastructure deployed.

*Table 22 - Charger Data Elements*

| Data Element | Source | Format | Frequency |
|---|---|---|---|
| Utility Costs for Charger(s) at Depot | Mountain Line or third-party tool | Utility Bill | Monthly |
| Utility Costs for Charger(s) on-route at DCC | Mountain Line or third-party tool | Utility Bill | Monthly |
| Maintenance Required – For each maintenance event, the following should be provided:<br>• Maintenance description<br>• Type of Maintenance<br>• Open date<br>• Close date<br>• Parts used<br>• Parts cost<br>• Labor hours<br>• Labor cost<br>• Warranty? | Mountain Line | Database or Log, usually MS Excel | Monthly with incident-level data |
| Total Energy Consumed at Depot | Mountain Line or third-party tool | Submeter Database or Log, usually MS Excel | Monthly |
| Total Energy Consumed on-route | Mountain Line or third-party tool | Submeter Database or Log, usually MS Excel | Monthly |

## Legacy Fuel Data

The following table outlines the hybrid diesel bus and depot utility data that is needed to assess the impact that the BEBs have on operational performance and reliability and operations and maintenance costs through the transition.

*Table 23 – Legacy Fuel Data Elements*

| Data Element | Source | Format | Frequency |
|---|---|---|---|
| Monthly/Annual Mileage by Bus | Mountain Line | Database or Log, usually MS Excel | Monthly |
| Average Miles per Gallon of Fuel (Diesel Gallon Equivalent) | Mountain Line | Database or Log, usually MS Excel | Monthly |
| Monthly/Annual Fuel Consumption by Bus | Mountain Line | Database or Log, usually MS Excel | Monthly |
| Monthly Fuel Costs by Bus | Mountain Line | Database or Log, usually MS Excel | Monthly |
| Maintenance Required – For each maintenance event, the following should be provided:<br>• Maintenance description<br>• Type of Maintenance (scheduled/unscheduled)<br>• Open date<br>• Close date<br>• Parts used<br>• Parts cost<br>• Labor hours<br>• Labor cost<br>• Odometer<br>• Road call required?<br>• Warranty? | Mountain Line | Database or Log, usually MS Excel | Monthly with incident-level data |
| Route Ridership | Mountain Line | Database or Log, usually MS Excel | Monthly (if available) |

Reports and source data should be prepared for internal distribution and may be shared with project stakeholders including the FTA. Mountain Line may also choose to publish this information publicly as well, as a number of different transit agencies have set up websites to report on ZEB deployments.

## Paratransit Fleet and Support Vehicles

Mountain Line's paratransit fleet that operates in revenue service is comprised of eight cutaways that have been in service between five (5) and ten (10) years. Mountain Line's non-revenue support vehicle fleet include thirteen (13) vehicles that serve a variety of on-road purposes including driver lunch vehicles, field supervisor vehicles, and service trucks that also operate as snowplows. All of these vehicles are currently gasoline powered. The support vehicles also include a number of off-road vehicles and tools, such as forklifts, snowblowers, and lawn mowers. For the sake of the battery-electric vehicle analysis, only the on-road vehicles are considered; however, details regarding available electric on-road and off-road vehicles and tools are included in **Appendix H**.

### Existing Vehicle Profiles

This section describes the on-road vehicles included in the paratransit fleet and support vehicle fleet, including physical characteristics and operating profiles of the vehicles relevant to assessing suitable electric alternatives. Analyzing the following variables is important for understanding whether a zero-emissions alternative is available to replace Mountain Line's vehicles:

- Passenger capacity
- ADA compliance
- Typical daily distance traveled
- Typical annual energy use

#### Vehicle Types

The vehicles have been categorized into four main types: cutaways, light-duty vans, SUVs, and utility trucks.

- **Cutaways:** Cutaways are incomplete vehicles with a front end and cab design in which the body ends behind the driver and front passenger seats; it can then have a specified body placed onto the common chassis design[4]. Mountain Line operates a total of thirteen (13) cutaways between the paratransit revenue fleet (8) and non-revenue support vehicle fleet (5).

- **Light-Duty Vans:** Light duty vans are typically built with a tall, rectangular body to accommodate 7 to 15 passengers or space for light utility equipment. Light duty vans can be equipped with space for a wheelchair and a wheelchair ramp, making them ADA compliant. Mountain Line operates three light-duty vans in the non-revenue support vehicle fleet for use by Field Supervisors.

- **Sport Utility Vehicles (SUVs):** SUVs are often built on a light-duty truck chassis with a larger-volume body. These vehicles typically accommodate five to seven ambulatory

[4] https://ogs.ny.gov/system/files/documents/2018/08/psbid22904template.pdf

passengers and can be equipped with a wheelchair lift. Mountain Line has one SUV in the non-revenue support vehicle fleet for use by Administration.

- **Utility Trucks:** Utility trucks are motor vehicles designed to carry small loads and carry out a specific task. The chassis is generally truck-like, but can be adjusted to meet the particular utility vehicle use. This specific chassis design helps meet weight distribution and space utilization needs.[5] There are four utility trucks in the non-revenue support vehicle fleet for use by Fleet and Facilities.

## Vehicle Operational Profiles

**Table 24** provides an overview of the on-road vehicles that make up Mountain Line's paratransit and nonrevenue fleets.

*Table 24 - Vehicle Information for Paratransit and Non-Revenue Service Fleets*

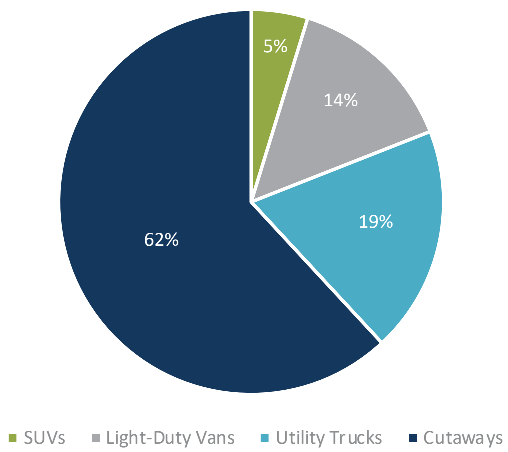
| Vehicle Type | Vehicle Number/ID | In-Service Date (Year) | Vehicle Use | Average Daily Mileage (mi) | Maximum Daily Mileage (mi) |
|---|---|---|---|---|---|
| **Arboc Cutaway** | 5561 | 2010 | Paratransit | 30 | 50 |
| **ElDorado Cutaway** | 5562 | 2013 | Paratransit | 37 | 60 |
| **ElDorado Cutaway** | 5563 | 2013 | Paratransit | 71 | 200 |
| **ElDorado Cutaway** | 5564 | 2013 | Paratransit | 97 | 175 |
| **ElDorado Cutaway** | 5565 | 2013 | Paratransit | 95 | 217 |
| **ElDorado Cutaway** | 5566 | 2013 | Paratransit | 78 | 200 |
| **ElDorado Cutaway** | 5567 | 2015 | Paratransit | 69 | 130 |
| **ElDorado Cutaway** | 5568 | 2015 | Paratransit | 93 | 222 |
| **Ford 4WD Escape SUV** | 5401 | 2007 | Administrative Purposes; In-town travel | <15 | 15 |
| **Ford 1 Ton 4x4 Truck** | 5402 | 2008 | Service Truck, snowplow | Non-Winter Months: <15 | Winter Months: 100 |
| **Ford 1 Ton 4x4 Truck** | 5405 | 2014 | Service Truck, snowplow | 38 | 38 |
| **Chevy Uplander Light-duty Van** | 5406 | 2007 | Field Supervisor | 21 | 21 |
| **Ford F450 Truck** | 5407 | 2016 | Service Truck, snowplow | Non-Winter Months: <60 | Winter Months: 100 |
| **Mobility Venture Light-Duty Van** | 5408 | 2016 | Field Supervisor | 55 | 55 |
| **Mobility Venture Light-Duty Van** | 5409 | 2017 | Field Supervisor | 39 | 39 |
| **Goshen Cutaway** | 5455 | 2002 | Driver Lunch Van | <15 | 15 |
| **Eldorado Cutaway** | 5456 | 2006 | Driver Lunch Van | <15 | 15 |
| **Eldorado Cutaway** | 5558 | 2007 | Driver Lunch Van | <15 | 15 |

[5] https://raymondhandling.com/dictionary/utility-vehicle/

| | | | | | |
|---|---|---|---|---|---|
| **Eldorado Cutaway** | 5559 | 2007 | Driver Lunch Van | <15 | 15 |
| **Eldorado Cutaway** | 5460 | 2007 | Driver Lunch Van | <15 | 15 |
| **Chevy 3/4 Ton Truck** | 5411 | 2003 | Service Truck, snowplow | Non-Winter Months: <60 | Winter Months: 100 |

**Figure 21** provides a breakdown of the on-road vehicle categories that comprise Mountain Line's paratransit fleet and support vehicle fleet. The majority (62%) of the vehicles are comprised of cutaways, including all of the paratransit vehicles.

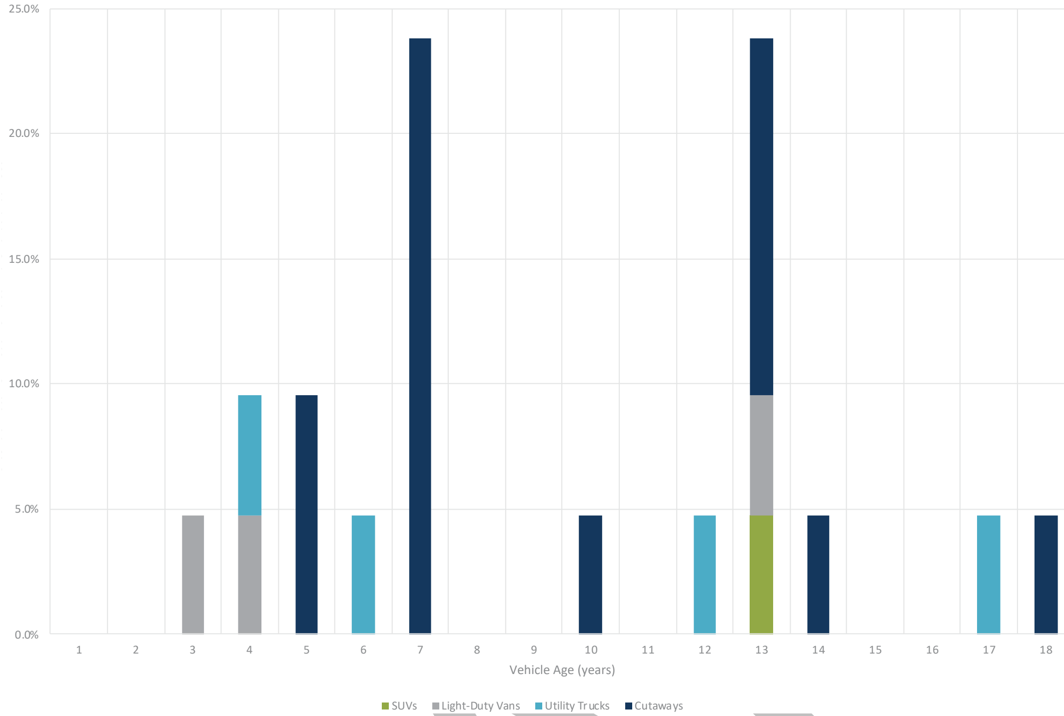
*Figure 21 - Paratransit and Non-Revenue Service Fleets by Vehicle Type*




Vehicle age varies from three (3) to eighteen (18) years old as shown in

Figure 22. Nearly two-fifths (38.1%) of the fleet has been in service for thirteen (13) years or longer. Mountain Line has intentionally retired cutaways from the paratransit fleet into lunch van duty, resulting in older cutaways in the support vehicle fleet.

*Figure 22 - Paratransit and Non-Revenue Service Vehicles by Age and Vehicle Type*




The utility trucks and cutaways that make up Mountain Line's paratransit fleet and support vehicle fleet have higher daily average miles driven compared to the SUV and light-duty vans as demonstrated in Error! Reference source not found.. The utility trucks average just over 62 miles a day, while cutaways average nearly 50 miles a day. The cutaways that operate in the paratransit fleet have the highest maximum daily mileage of up to 222 miles per day.

*Figure 23 - Average Daily Miles per Vehicle*

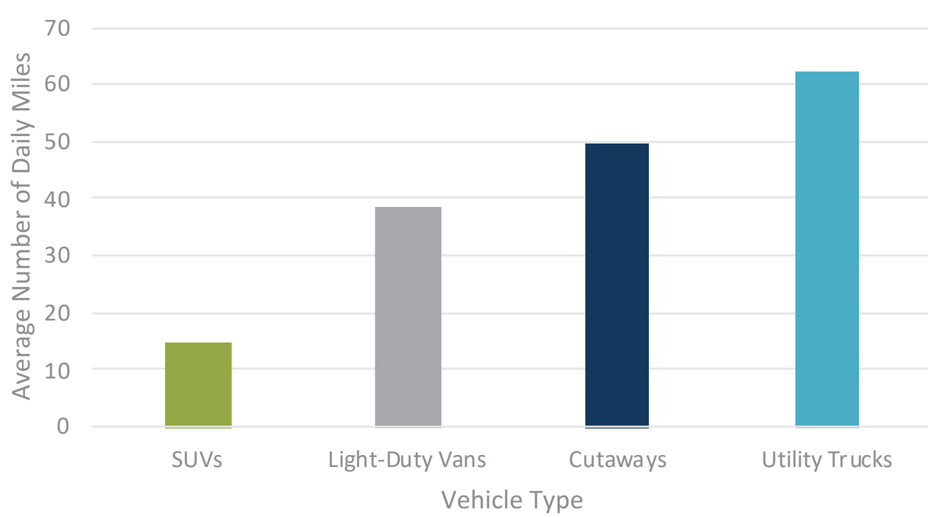
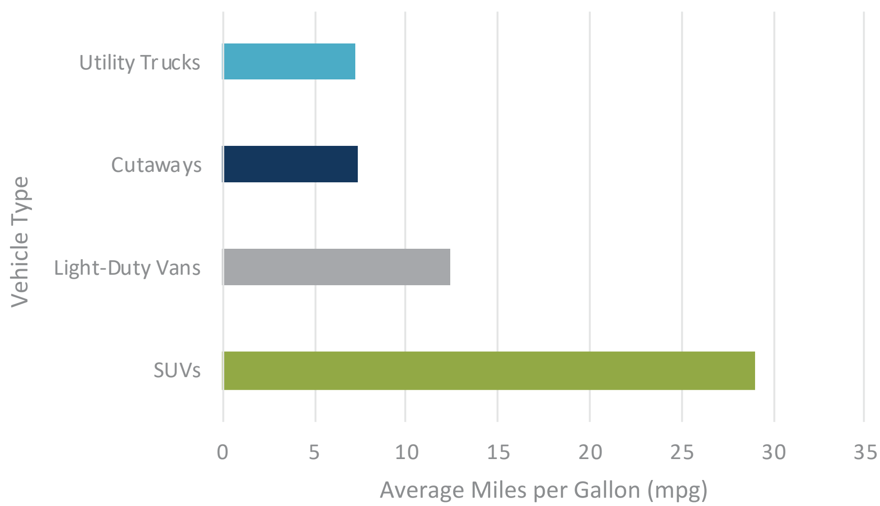


**Figure 24** shows that the SUV in the support vehicle fleet has the highest average fuel economy (29 mpg) compared to the other vehicle types. The utility trucks and cutaways have similar average fuel economies, at 7.3 mpg and 7.4 mpg, respectively, while the light-duty vans have a 12.3 mpg average fuel economy.

*Figure 24 - Average Fuel Economy by Vehicle Type*




## Electric Vehicle Research

Potential battery-electric vehicle options (both on-road and off-road) for service in Mountain Line's paratransit fleet and support vehicle fleet are separated into five primary categories:

- Cutaways and Small Buses
- Vans
- Sedans and SUVs
- Utility Trucks
- Off-road Vehicles and Tools

Many of the cutaways, small buses, and vans listed below are based on Ford or other OEM chassis but include third-party electric drivetrains and passenger bodies. Some of the vehicles included below are built entirely by a single OEM. The listed vehicles are not a complete inventory of available makes and models but do represent promising battery-electric alternatives for Mountain Line's needs. Vehicles that are generally considered sports or luxury vehicles were excluded from this review, as they are not typically operated in public sector fleets.

Based on the current operational profile of Mountain Line's paratransit fleet and support vehicle fleet, it appears there are suitable replacements currently on the market for few Mountain Line vehicles. Key implications of this vehicle research are:

- Most available battery-electric alternative vehicles are built on factory cab/chassis platforms and involve third-party electrification repowers. These vehicles are typically Transit/Sprinter-type vans or cutaways and are not Altoona-tested, which precludes them from purchase with FTA funds.
- As of November 2020, the only Altoona-tested ADA-accessible battery-electric light-duty transit vehicle is the GreenPower EV Star, which may be a suitable alternative vehicle for several vehicles in Mountain Line's paratransit fleet.
- Battery-electric light-duty transit vehicles are typically significantly more costly than their fossil-fueled counterparts. Converting the paratransit fleet and support vehicle fleet to battery-electric alternatives will likely require more funding than fossil fuel capital replacement plans prescribe and/or creative financing.
- There are many battery-electric passenger vehicles on the market with advertised single-charge ranges of more than 150 miles. These vehicles may be suitable battery-electric alternatives for Mountain Line, specifically for SUV in the non-revenue support vehicle fleet.
- The battery-electric light-duty transit vehicle market is rapidly evolving. Vehicle classes that do not currently have battery-electric alternatives will likely see multiple new models brought to market in the next few years.

The information gathered for this assessment is from a combination of manufacturer and dealer marketing materials and press releases, test results, and direct correspondence.[6] Range figures, in particular, should be viewed skeptically and assumed to be optimistic. Average battery-electric vehicle costs and operational ranges published by the OEMs are included in **Table 25** and details are included in **Appendix H**.

*Table 25 - Battery-Electric Vehicle Availability Summary Table*

| Vehicle Type | Number of Models Assessed | Operational Range of EV Options (miles) | Maximum Daily Mileage of Current Vehicles | Cost Range |
|---|---|---|---|---|
| **Cutaways & Small Buses** | 6 | 80-170 | 15 - 222 | $200,000-$270,000 |
| **Vans** | 3 | 60-190 | 25 - 60 | $160,000-$200,000 |
| **Sedan & SUVs** | 5 | 149-259 | 15 | $33,045-$45,845 |
| **Utility Truck** | 1 | 160 | 15 - 110 | $205,000-$210,000 |

[6] Items listed as "TBD" in the tables below were still being researched and awaiting responses from OEMs when this report was finalized and will be revised in a future version of this document to the extent feasible.

## Paratransit Fleet Transition Recommendations

Mountain Line intends to operate the cutaways in paratransit service for between 7 and 10 years. **Table 26** provides details for the Mountain Line paratransit vehicles.

*Table 26 - Paratransit Fleet Vehicle Details*

| Vehicle ID | In-Service Date | Service Life (yr) | Anticipated Replacement Date | Average Daily Mileage (mi) | Maximum Daily Mileage (mi) |
|---|---|---|---|---|---|
| **5561** | 7/10/20 | 10 | 12/10/20 | 30 | 50 |
| **5562** | 1/13/13 | 8 | 12/10/21 | 37 | 60 |
| **5563** | 1/13/13 | 7 | 1/13/20 | 71 | 200 |
| **5564** | 1/13/13 | 8 | 1/13/21 | 97 | 175 |
| **5565** | 1/13/13 | 8 | 1/13/21 | 95 | 217 |
| **5566** | 1/13/13 | 9 | 1/13/22 | 78 | 200 |
| **5567** | 3/15/15 | 8 | 3/15/23 | 69 | 130 |
| **5568** | 3/15/15 | 8 | 3/15/23 | 93 | 222 |

Mountain Line plans to retire vehicles 5561 and 5563 in 2020 and replace them with gasoline powered service vans. The remainder of the vehicles in the paratransit fleet are due for replacement between 2021 and 2023. As discussed previously, currently the only Altoona-tested ADA-accessible battery-electric light-duty transit vehicle is the GreenPower EV Star with a reported maximum range of 150 miles (see **Appendix H**). A review of the operational data for the paratransit fleet indicates that, although all of the vehicles average less than 100 miles per day of operation, five (5) of the eight (8) complete daily service at times greater than 150 miles per day, up to approximately 220 miles a day. Further, discussion with Mountain Line staff revealed that any of the vehicles could be required to complete the estimated maximum service length in a day. As a result, currently a one-to-one replacement of vehicles in paratransit service is not feasible with a battery-electric option. It is recommended that Mountain Line reevaluate replacement of the paratransit vehicles with battery-electric alternatives during the next replacement cycle which is expected to begin in approximately 2028, as there are anticipated to be additional alternatives available with increased range that would meet service needs. The expected cost to replace the eight (8) vehicles in the paratransit fleet today with battery-electric is approximately $1.6 million, compared to approximately $680,000 to replace the vehicles with gasoline powered vehicles (estimated $85,000 each). These costs do not consider that additional battery-electric vehicles would be required in order to complete the maximum daily service.

## Non-Revenue Support Vehicle Transition Recommendations

Mountain Line does not have an established replacement schedule for support vehicles. The vehicles remain in operation until Mountain Line determines that they have reached their useful life, either as a result of repair costs, safety concerns, or other evaluation factors. As discussed previously, there are currently few EVs that meet Mountain Line service needs; however, details regarding potential replacements are provided as follows:

- The SUV (#5401) currently operating to provide administrative support could be replaced today with a suitable battery-electric sedan or SUV at a similar cost to a gasoline powered alternative. Examples are provided in **Appendix H**.
- According to Mountain Line, driver lunch vans are typically vehicles that have been retired from paratransit service, though it is unclear if this will continue to occur in the future. If this approach continues, it is unlikely that the driver lunch vans would be transitioned to battery-electric until approximately 2035 or later; however, there are currently multi-passenger vans available that meet the service needs to serve as driver lunch vehicles or provide passenger service. As provided in **Table 25**, these vehicles currently cost between $160,000 and $200,000 and have an estimated operating range up to 60 miles.
- There are currently few alternatives for service trucks, particularly those that are equipped to operate as a snow plow in winter. Estimated range on the vehicles surveyed is limited to an estimated 110 miles.

The battery-electric vehicle market continues to evolve and improve with more offerings introduced each year, including additional options for transit and service vehicles. CTE recommends continuing to monitor the market, and as vehicles are deemed to be necessary for replacement, determine individually if there is a suitable battery-electric replacement vehicle. As noted previously, Mountain Line could replace the existing SUV today with a suitable, cost-effective battery-electric alternative. Transit vans are also available for replacement; however, purchase costs are considerably higher, up to three times as expensive, than a traditional gasoline powered vehicle.

## Charging Infrastructure Options

Electric Vehicle Supply Equipment (EVSE) is the equipment used to deliver electrical energy from an electricity source to an EV. ESVE communicates with the EV to ensure that an appropriate and safe flow of electricity is supplied. EVSE for EV is classified into several categories by the rate at which the batteries are charged. The types of EVSE applicable to Mountain Line's paratransit fleet and the support vehicle fleet include Level 2 chargers and DC fast chargers (as discussed **Infrastructure Requirements and Recommendations** section of this *Implementation Plan*). Level 2 provides AC electricity to the vehicle, with the vehicle's onboard equipment convert AC to the DC needed to charge the batteries. DC fast charging provides DC electricity directly to the vehicle. Charging times range from 20 hours or more to less than 30 minutes, depending on the type of EVSE, the battery's capacity, state of charge, and the vehicle's acceptance rate or charging speed. Details of the charging options and considerations for the paratransit fleet and other service vehicles is included in **Appendix I.**

## Charging Recommendations for Mountain Line's Paratransit and Support Vehicles

CTE recommends a shared charger strategy using a combination of DC fast charging and Level II charging to support the paratransit fleet and support vehicle fleet in the future. A total of two (2) 150-kW DC plug-in style fast chargers could be equipped with multiple dispensers to support all eight (8) paratransit cutaway vehicles. It is possible that future cutaways will have the ability to charge using the on-route charging equipment that is proposed for the heavy-duty transit fleet, and therefore could share charging resources. Alternately individual Level II chargers could be utilized to support each paratransit vehicle.

A shared charging strategy with load management using networked Level II chargers are recommended for the support vehicle fleet as these chargers can be installed inexpensively and can be shared between multiple vehicles; however, CTE recommends that Mountain Line allow vehicle technology to further develop in order to meet service needs before purchasing support vehicles (other than the SUV previously discussed). As with heavy-duty bus charging, electrical switchboard and transformers would be required to support charging of the paratransit fleet and the support vehicle fleet.

## Emissions

Estimates for annual emissions reductions that would result from a full transition to battery-electric vehicles for the paratransit fleet and support vehicle fleet are provided by vehicle type in **Table 27**. Expected well-to-wheel emissions reductions range from 60% to nearly 80% compared to operating gasoline powered vehicles. Fuel cost savings were not estimated at this time as there are a limited number of vehicles that could be replaced on a one-to-one basis. Multiple vehicles would be required to operate the same level of service that Mountain Line currently provides today.

*Table 27 – Estimated Emissions Reductions by Vehicle Type when Fully Transitioned to Electric Vehicles*

| Vehicle Type | Anticipated Emissions Reductions at Full Transition[7] | Estimated Annual GHG Reductions (tons) |
|---|---|---|
| **Cutaways & Small Buses (Paratransit)** | 79% | |
| **Cutaways & Small Buses (Driver Lunch Vehicles)** | | |
| **Vans** | 77% | |
| **Sedan & SUVs** | 73% | |
| **Utility Truck** | 60% | |

[7] Emissions estimates were calculated using the agency's vehicle usage data input into Argonne National Labs' AFLEET tool. The AFLEET tool calculates GHGs based on outputs from ANL's GREET model and calculates state-based criteria emissions using the EPA's MOVES model 2014a. The GREET model calculates GHG production for upstream emissions using the regional energy mix as defined by the EIA for the agency's local region.

## Project Schedule

A draft project schedule is included in **Attachment J**. The project schedule assumes revenue service deployment in June 2023 for the first two (2) BEBs to coincide with completion of the DCC.

# APPENDIX A

## Available Battery Configurations

**Table A1** and **Table A2** outline the available battery configurations for 35' and 60' BEBs, respectively, for several OEMS. The usable battery capacity noted in the following tables are based on 80% of the nameplate battery capacities.

*Table A1 - 35' BEB Battery Configurations*

| Bus Model | Nameplate Battery Capacity (kWh) | Usable Battery Capacity (kWh) |
|---|---|---|
| **New Flyer XE35 Rapid Charge** | 160 | 128 |
| | 213 | 170 |
| **New Flyer XE35 Long Range Charge** | 311 | 249 |
| | 388 | 310 |
| **Proterra ZX5** | 220 | 176 |
| **Proterra ZX5+** | 440 | 352 |
| **Gillig** | 444 | 355 |
| **BYD** | 266 | 213 |

*Table A2 - 60' BEB Battery Configurations*

| Bus Model | Nameplate Battery Capacity (kWh) | Usable Battery Capacity (kWh) |
|---|---|---|
| **New Flyer XE60 Rapid Charge** | 213 | 170 |
| | 267 | 214 |
| | 320 | 256 |
| **New Flyer XE60 Long Range Charge** | 466 | 373 |
| **BYD** | 446 | 357 |

# APPENDIX B

## Charging Equipment Specifications

# APPENDIX C

## APS Supplied-Equipment Clearance Requirements

# APPENDIX D

# Heliox Portable Chargers for Depot Applications

# APPENDIX E

## DC Automatic Plug-In Charging Details for Fixed-Route Heavy Duty Buses

Although Mountain Line has selected an approach using 450-kW high-capacity overhead chargers for top off charging at the depots at the end of each service day, details of DC Automatic Plug-In charging systems and associated infrastructure have been included below. Mountain Line selected the approach using high capacity charging at the depot due to service considerations and because of concerns over the weight associated with infrastructure (pantographs, etc.) that would be required to be installed in the roof structure as the roof system was not designed to carry the additional load. The details are provided in the event that there are changes to the Mountain Line plan in the future for depot charging based on improvements in bus technology (range and efficiency) that would allow for one-to-one replacement of current hybrid diesel buses with depot charged BEBs or in the case that plug-in charging is determined to be the best choice for the NAU or other separate facility.

**DC AUTOMATIC PLUG-IN CHARGING SYSTEM**

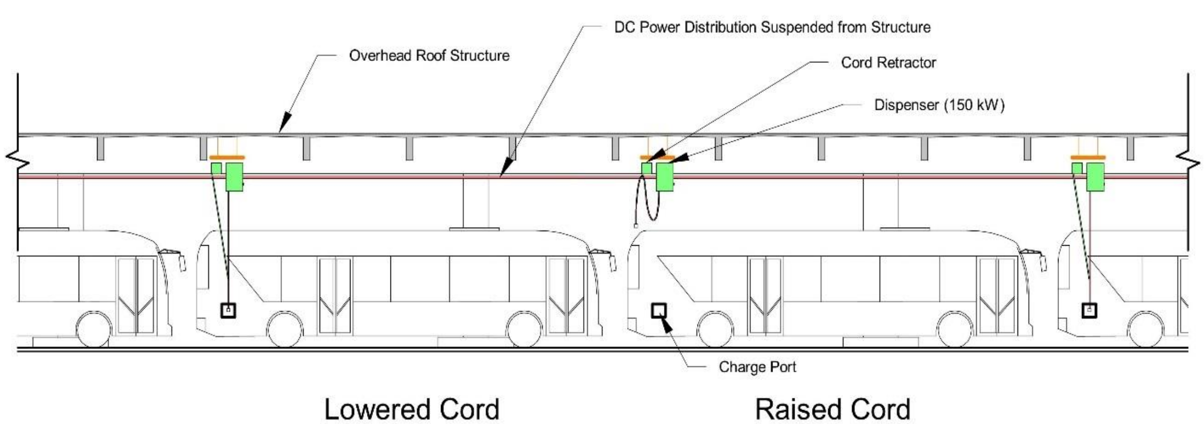
This charging technology combines multiple available technologies (DC charging cabinets with dispensers outfitted with plug-in cords) and equipment hardware (remote controlled cable retractors or overhead pantograph), as described in the name.

**DC** – Direct current is distributed by the flexible cord that terminates in the charging gun, which is manually plugged into the charging port of the battery electric bus.  Alternately, an overhead pantograph can also be used to supply energy to the bus at a lower rate (150 kW).

**Automatic** – The charger automatically starts and stops charging the BEB once the charging cord is manually plugged into the bus charging port. The automatic charger controls determine when to start the charging process and when to stop (at charge completion or manual interruption by the user or charge management software), without any operator interaction required.

**Overhead** – The dispenser, charging cord and gun are located overhead. Since there are no user controls on the automatic dispenser, all of the equipment – the dispenser, charging cord with plug-in gun, and cord retractor – can be located above the bus. Locating this equipment above the roof of the bus in the space between parked buses reduces the risk of bus damage (either the bus body or the extended side mirrors) to the dispenser body or charging cord. The charging cord and plug-in gun are stored in a raised position using a motorized cord retractor. The cord retractor lowers the cord and charging gun to the operator when needed, as shown in the figure below.

*Figure E-1 - Overhead Location for DC Power Distribution*




Automatic DC plug-in depot charging systems are currently available from multiple vendors, including several BEB OEMs (GreenPower, Proterra), as well as third-party vendors (ABB, Heliox, Chargepoint, Siemens).  A charger consists of a charging cabinet that contains an integrated rectifier, and a dispenser.

Some vendors supply an integrated dispenser while others separate the dispenser from the charging cabinet. Separating the dispenser from the charging cabinet and remotely locating the charging cabinet away from the bus reduces floor space requirements and provides additional spatial flexibility. In addition, an automatic plug-in dispenser can be located overhead, which eliminates the need for allocation of scarce floor space in the bus parking area. However, if the dispenser is located overhead, additional cord management features, such as a cord retractor with retractor power and controls, are required to raise and lower the cord. At least one charger OEM manufacturers an overhead pantograph system for depot installation that can be used with lower charging rates.

Third-party charging systems with SAE J1172 DC compliant charging cords and guns are compatible with multiple battery electric buses produced by various OEMs as long as they are specified with SAE J1772 compliant charging plug-in ports. This includes BEB OEMs who do not produce their own plug-in charging equipment such as Gillig and New Flyer. Following this standard will allow initial BEB charging equipment and infrastructure installed to be compatible to multiple BEB OEMs for future vehicle procurement.

Due to DC power distribution constraints, there is a limit to how far the charging cabinets can be from the dispenser – between 350 and 500 feet maximum from the DC charging cabinet to a remote dispenser. This distance would include any vertical drops or rises.

With most manufacturers, this charging system allows for both 1:1 dedicated charging and shared charging using multiple dispensers and a single charger that can be managed through charge management software.

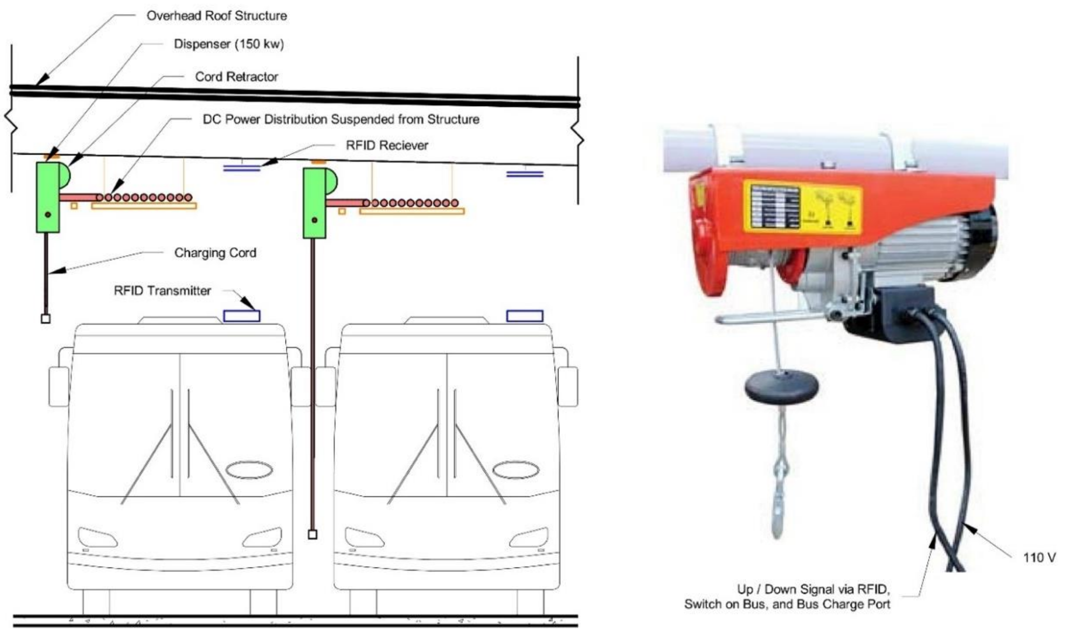
The only operator interaction required with a DC charging system is that an operator needs to plug and unplug the bus. Once the bus is plugged in, charge management software dictates when the bus begins charging and stops charging, monitors energy usage and battery state of charge, and provides status reports. Currently multiple vendors, including charger OEMs and third-party software companies, are developing charge management software to provide further operational flexibility.

At the 150 kW range, the conduit size for a single power connection between a charger and a dispenser is approximately 3 to 4 inches. Additionally, a low voltage signal wire and data control wiring are also installed between each charger and dispenser in parallel and in a separate conduit from the DC power conduits. These multiple conduits to each dispenser can create a sizeable quantity of conduits to route and organize either underground or overhead. The distribution path of DC connected power and control wiring must be carefully coordinated with any existing structure.

Chargers are typically ground mounted and dispensers may be suspended from the underside of the roof structure or from a pedestal mounted location. A cord retractor, mounted adjacent to the dispenser in the roof structure, allows the charging cord to be lowered within reach of the operator or technician and raise the cord when the bus leaves in order to avoid damage to cords and buses from dangling cords. A light duty motorized exterior rated hoist can be used to serve as a cord retractor. Buy America compliant cord reels that will handle the complex cross section (power, controls and data) and multi-voltages of wire within a SAE J1772 charging cord are currently being developed and, if available, can be used in place of the more simple cord retractor.

The retractor would be suspended adjacent to the dispenser with its cable end attached to the lower third of the charging cord. The motorized retractor would raise and lower the charging cord and gun as shown in example illustration. When a bus pulls into a parking position, the cord must be in a raised position to keep the bus from hitting or damaging the cord and gun. The bus operator would stop under a dispenser by aligning the bus with painted “stop stripes” on the pavement, potentially aided by an audible alarm or indicator light in the bus. When the bus is properly positioned, an RFID transmitter on the bus would send a signal to an RFID receiver mounted near the dispenser. By activating an up/down button either in the bus driver's cockpit or near / inside the charging port on the bus, a service technician could lower the charging cord and plug the bus in for charging. After charging is complete or when the bus needs to vacate the parking space, the plug-in cord would be removed from the charging port and the same up/down controls would be activated to retract the cord above the bus roof.

*Figure E2 -Overhead Cable Management Infrastructure*




Raised Cord Lowered Cord Motorized Retractor

**BUS INTERFACE AND CHARGING CONTROL SYSTEM**

The dispenser and the motorized cord retractor are installed at each charging position. Once a bus pulls into the charging position, the cord retractor lowers the charging cord and gun such that the service technician can plug the gun into the bus. Once the gun is plugged into the bus, the rest of the charging sequence is completed by charge management software.

The charging cord and gun should be compliant with SAE J1772 standards. In addition to the DC power connection for the bus, the charging gun will also have a data connection and a low-voltage connection for controls. Referred to as Electric Vehicle Supply Equipment (EVSE) controls, the EVSE protocol controls when the charging process begins and terminates. The low-voltage conductors in the charging gun contact the low-voltage wires in the charging port on the bus. This connection signals the charging system that it is safe to begin the automatic charging process. If the connection is broken, either by being bumped out of the socket or by being purposefully removed, the system recognizes the disconnect and immediately stops the automatic charging process. To begin the automatic charging process again, the charging gun need only be fully re-inserted.

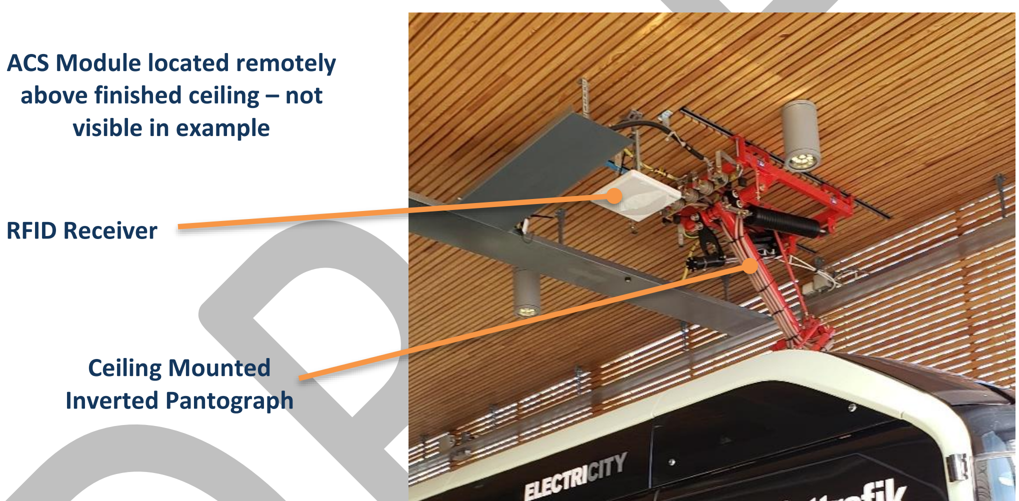
The EVSE protocol controls not only the automatic charging process, but also whether the bus can begin moving or not. When the cord is fully plugged in, the battery electric bus's traction motors are disabled, making the bus immobile. The other bus systems function as normal, including air conditioning, heat, interior and exterior lights, radio, exterior head display signage, etc. The bus cannot move again until the charging gun is unplugged.

The EVSE protocol also collects data about the operation and interaction of the dispenser, charger, and the bus. This data – which includes charging sequence, timing, and status of the plugged-in bus (e.g. the state of charge, battery health, and charging curves) – is transmitted to any charge management system or vehicle data collection reporting software for processing.

**OVERHEAD PANTOGRAPH CHARGER**

Similar to the on-route charging system planned for the DCC, Kaspar Drive, and NAU or other separate facility, the overhead pantograph charger utilizes an inverted pantograph suspended from the garage roof structure / framing to connect to charging bars on the roof for battery charging. The primary difference between the on-route charger and a depot pantograph charger is the mast. With a depot pantograph charging system the mast is not needed to support the pantograph. An example of the ceiling mounted pantograph is shown below. The overhead pantograph charger is available for coupling with 150-kW DC depot charging cabinets and may be considered as an alternative to plug-in charging discussed in the previous section. Currently, a 150-kW DC depot charging cabinet can only be coupled with a single overhead pantograph, although multiple manufacturers are developing alternative solutions that allow charging from a single charger with multiple pantographs.

*Figure E3 - Ceiling Mounted Overhead Pantograph*




**DC CHARGING CABINET**

The overhead pantograph charging systems (suspended ACS module & inverted pantograph) utilize DC power. As discussed previously, the DC charging cabinet takes the utility provided AC power and converts it to DC by using a rectifier located within a DC charging cabinet. This DC power, along with control and signal power, and low voltage wiring, is then brought through a series of surface mounted conduits routed up the wall and across the underside of the roof structure to the ACS module and through to the pantograph.

# APPENDIX F

## Infrastructure ROM Cost Estimates

# APPENDIX G

## Training Requirements

# APPENDIX H
# EV Vehicles and Tools

## Cutaways and Small Buses

**Phoenix Motorcars Zeus 400 Shuttle Bus**

The Phoenix Motorcars Zeus 400 is an electric cutaway that incorporates a Ford E-series chassis and Starcraft passenger body. Phoenix Motorcars is a California-based company. These vehicles are typically built with a wheelchair lift installed behind the rear axle. Although advertised by Phoenix Motorcars as seating a maximum of two wheelchairs, the seating area can likely be customized to accommodate more. The range of prices below takes into account different seating configurations.

| Specification | Specification Value(s) |
|---|---|
| Passenger capacity | Up to two wheelchair or 23 ambulatory passengers |
| Lift-capable? | Yes |
| Battery size | Up to 150kWh |
| Approx. nameplate single-charge range | Up to 160 miles |
| Length | variable |
| Approx. cost | $225,000 - $245,000 |
| Availability | Available |
| Altoona Tested? | No |

*Sources: <http://www.phoenixmotorcars.com/products/>, <https://www.latest.facebook.com/PhoenixMotorcarsZEUS/LightningElectric Ford E-450 Shuttle Bus>, <http://www.phoenixmotorcars.com/city-of-redlands-receives-1st-electric-shuttle-bus/>, Correspondence with Dealer: Thomas Allen*

*Image source: <http://www.phoenixmotorcars.com/wp-content/uploads/2017/08/vehicle-01.jpg>*



**Lightning Electric Ford E-450 Shuttle Bus**

The Lightning Electric Ford E-450 shuttle bus is an electric cutaway built on a Ford E-450 chassis. Lightning Electric is headquartered in Loveland, CO.

| Specification | Specification Value(s) |
|---|---|
| Passenger capacity | Typically two wheelchair and 12 ambulatory passengers |
| Lift-capable? | Yes |
| Battery size | 86kWh or 129kWh |
| Approx. nameplate single-charge range | 80 or 120 miles |
| Length | 25’ |
| Approx. cost | $230,000 |
| Availability | Available |
| Altoona Tested? | No |

*Sources: <https://lightningsystems.com//lightningelectric-e450-shuttle/>, <https://petaluma.granicus.com/MetaViewer.php?view_id=31&clip_id=2728&meta_id=424736 >, Correspondence with Lightning Systems*

*Image source : <https ://lightningsystems.com/wp-content/uploads/2019/11/E450_shuttle_600px.png>*

**Lightning Electric Ford F-550 Shuttle Bus**

The Lightning Electric Ford F-550 shuttle bus is a larger version of the Lightning Electric E-450 high-floor electric cutaway. The vehicle is built on a Ford F-550 chassis, allowing for more passenger capacity than an E-450, in a similar vehicle. Lightning Electric is headquartered in Loveland, CO.

| Specification | Specification Value(s) |
|---|---|
| Passenger capacity | Typically two wheelchair and 20-30 ambulatory passengers |
| Lift-capable? | Yes |
| Battery size | 160kWh or 192kWh |
| Approx. nameplate single-charge range | 120 miles |
| Length | 32' |
| Approx. cost | $270,000 |
| Availability | Available |
| Altoona Tested? | No |

*Sources: <https://lightningsystems.com/lightningelectric-f-550-bus/>, Correspondence with Lightning Systems*

*Image source : <https ://lightningsystems.com/wp-content/uploads/2019/11/F550_bus2.png>*

**Micro Bird DS-Series Paratransit**

The Micro Bird DS-Series electric shuttle bus is a lift-equipped cutaway built on a Ford or GM chassis. The wheelchair lift on this vehicle is typically installed behind the rear axle. Micro Bird Bus is a joint venture between U.S. school bus manufacturer Blue Bird and Canadian bus maker Girardin. These vehicles are primarily manufactured in Canada.

| Specification | Specification Value(s) |
|---|---|
| Passenger capacity | Up to two wheelchair or 28 ambulatory passengers |
| Lift-capable? | Yes |
| Battery size | TBD |
| Approx. nameplate single-charge range | TBD |
| Length | 24'-29' |
| Approx. cost | TBD |
| Availability | Available |
| Altoona Tested? | No |

*Source : <https ://mbcbus.com/product/d-series/>*

*Image source : <https ://mbcbus.com/wordpress/wp-content/uploads/2014/09/Microbird-G5-with-Lift-Door-streamer_with-stripes-1140x676.jpg>*

### Motiv Power EPIC E-450 Shuttle Bus

The Motiv Power Electric Powered Intelligent Chassis (EPIC) E-450 shuttle bus is built on the Ford E-450 platform with a Champion passenger body. The wheelchair lift on this vehicle is typically installed behind the rear axle. Motiv Power is based in Foster City, California.

| Specification | Specification Value(s) |
|---|---|
| Passenger capacity | TBD |
| Lift-capable? | Yes |
| Battery size | 106kWh |
| Approx. nameplate single-charge range | 85 miles |
| Length | TBD |
| Approx. cost | TBD |
| Availability | Available |
| Altoona Tested? | No |

*Sources : <https ://www.motivps.com/motivps/portfolio-items/epice450-allelectric-shuttlebus/>, <https ://www.trucks.com/2018/05/30/motiv-profits-demand-electric-trucks-buses/>*

*Image source : <http ://www.motivps.com/motivps/wp-content/uploads/2019/06/E450-Champion-shuttle-right-edited-NEW-1000x700.png>*

### SEA E450 Shuttle Bus

The SEA Electric E450 shuttle bus is built on a Ford E-450 chassis with the SEA-Drive 100 electric drivetrain. Although SEA Electric is an Australian company, this vehicle is primarily manufactured in the U.S.

| Specification | Specification Value(s) |
|---|---|
| Passenger capacity | Typically two wheelchair and 12 ambulatory passengers |
| Lift-capable? | Yes |
| Battery size | 100kWh |
| Approx. nameplate single-charge range | 130-170 miles |
| Length | TBD |
| Approx. cost | $200,000 |
| Availability | Available |
| Altoona Tested? | No |

*Sources: <https://www.sea-electric.com/wp-content/uploads/2019/10/E4B-Commuter-Bus-ebrochure-AU.pdf>, <https://www.carsales.com.au/editorial/details/aussie-ev-maker-plans-new-production-facility-in-latrobe-valley-115381/>, Correspondence with manufacturer*

*Image source : <https ://www.sea-electric.com/wp-content/uploads/2019/10/SEA-E4B-FRONTFWY.jpg>*

## Large Vans

**Lightning Electric Ford Transit Passenger Van**

The Lightning Electric Ford Transit is a large passenger van built on the Ford Transit platform. Lightning Electric is headquartered in Loveland, CO. This vehicle includes double rear-wheel assemblies to accommodate battery weight.

| Specification | Specification Value(s) |
|---|---|
| Passenger capacity | One wheelchair or four ambulatory passengers |
| Lift-capable? | Yes |
| Battery size | 43kWh or 86kWh |
| Approx. nameplate single-charge range | 60 or 120 miles |
| Length | 18’-22’ |
| Approx. cost | $173,000 |
| Availability | Available |
| Altoona Tested? | No |

*Sources: <https://lightningsystems.com/lightningelectric-ford-transit-shuttle/>, <https://www.californiahvip.org/vehicles/lightning-systems-lightningelectric-drivetrain-on-ford-transit-350hd-passenger-bus-60-mile-range/>, <https://www.ford.com/commercial-trucks/transit-cargo-van/models/transit-van/>, Correspondence with Lightning Systems*

*Image source : <https ://lightningsystems.com/wp-content/uploads/2019/11/transit_passenger_01_cropped-1.png>*

**GreenPower EV Star ADA**

The EV Star ADA vehicle is a large passenger van built entirely by GreenPower. This vehicle recently passed Altoona testing, which provides some demonstrated range figures.[8] During the testing process, this vehicle was tested under Manhattan, Orange County, and EPA Heavy-Duty Urban Dynamometer Driving Schedule (HD-UDDS) testing conditions, achieving ranges of 96, 120, and 153 miles, respectively. The Manhattan test cycle simulates a low average speed urban driving context, while the Orange County test cycle simulates a combination of highway and urban driving conditions. The EPA HD-UDDS test simulates longer periods of higher-speed driving.


| Specification | Specification Value(s) |
|---|---|
| Passenger capacity | Up to two wheelchair or 12 ambulatory passengers |
| Lift-capable? | Yes |
| Battery size | 118kWh |
| Approx. nameplate single-charge range | 150 miles |
| Length | 25’ |
| Approx. cost | $200,000 |
| Availability | Available |
| Altoona Tested? | Yes |

*Sources: <https://www.greenpowerbus.com/product-line/>, Correspondence with distributor.*

*Image source : <https ://www.greenpowerbus.com/wp-content/uploads/2019/01/shuttle-buses.jpg>*



[8] Federal Transit Administration. April 2020. *Federal Transit Bus Test Report Number LTI-BT-R19113*. <http://apps.altoonabustest.psu.edu/buses/reports/515.pdf?1586273484>

## Vehicles Available in the Future

A select set of electric vehicles that are reported to be available soon and may be suitable for Mountain Line's paratransit and non-revenue service are included in the table below. Plans to offer these vehicles for sale, which are primarily shared by manufacturers, typically state projected specifications, capabilities, and costs. These projections are not always accurate, however, and may change.

| Vehicle | Passenger Capacity | ADA-Accessible? | Range | Projected Cost | Expected Availability |
|---|---|---|---|---|---|
| Ford Transit Electric | Likely one wheelchair and four ambulatory | Likely | Unavailable | Unavailable | 2021 |
| Lion Electric LionM | Up to 6 wheelchair or 22 ambulatory | Yes | 75 or 150 miles | Up to $350,000 (160kWh model) | Currently available for pre-order |
| Nissan Ariya SUV | Up to 4 ambulatory passengers | No | Up to 300 miles | $40,000 - $45,000 | 2021 |

*Sources: <https://media.ford.com/content/fordmedia/fna/us/en/news/2020/03/03/ford-to-offer-all-electric-transit.html>, <https://thelionelectric.com/documents/en/BrochureANGLionM.pdf>, <https://www.forbes.com/sites/sebastianblanco/2018/05/30/lion-electric-bus/#117ced372827>, <https://www.caranddriver.com/photos/g33311834/2022-nissan-ariya-revealed/>*

## Sedans and SUVs

**Chevy Bolt**

The Chevy Bolt is a four-door hatchback that is widely available in the U.S. and is manufactured in South Korea and Michigan.

| Specification | Specification Value(s) |
|---|---|
| Passenger capacity | Up to four ambulatory passengers |
| Lift-capable? | No |
| Battery size | 66kWh |
| Approx. nameplate single-charge range | 259 miles |
| Length | ~14’ |
| Approx. cost | $36,620-$41,020 |
| Availability | Available |

*Sources : <https ://media.chevrolet.com/media/us/en/chevrolet/vehicles/bolt-ev/2020.tab1.html>, <https ://media.chevrolet.com/content/media/us/en/chevrolet/vehicles/bolt-ev/2020/_jcr_content/iconrow/textfile/file.res/2020%20Chevrolet%20Bolt%20EV%20Product%20Guide.pdf>*

*< https://www.terrymarxen.com/models/chevrolet-bolt+ev>*

*Image source : <https ://www.chevrolet.com/content/dam/chevrolet/na/us/english/index/vehicles/2020/cars/bolt-ev/colorizer/01-images/2020-bolt-2lz-gpj-colorizer.jpg?imwidth=600>*

**Hyundai Ioniq SE**

The Hyundai Ioniq is four-door, battery-electric sedan manufactured in South Korea.

| Specification | Specification Value(s) |
|---|---|
| Passenger capacity | Up to four ambulatory passengers |
| Lift-capable? | No |
| Battery size | 38.3kWh |
| Approx. nameplate single-charge range | 170 miles |
| Length | 15’ |
| Approx. cost | $33,045 |
| Availability | Currently only available in California, Washington, & Oregon |

*Sources : <https ://www.hyundaiusa.com/us/en/vehicles/ioniq-electric>, <https ://www.hyundaiusa.com/us/en/vehicles/ioniq-electric/compare-specs>, Correspondance with Hyundai*

*Image source : <https ://www.hyundaiusa.com/us/en/build/summary/#/379H1N3O1M0>*

**Hyundai Kona Electric SEL**

The Hyundai Kona is a crossover SUV manufactured in South Korea.

| Specification | Specification Value(s) |
|---|---|
| Passenger capacity | Up to four ambulatory passengers |
| Lift-capable? | No |
| Battery size | 64kWh |
| Approx. nameplate single-charge range | 258 miles |
| Length | ~14’ |
| Approx. cost | $37,190 |
| Availability | Currently only available in California, Washington, & Oregon |

*Sources : <https ://www.hyundaiusa.com/us/en/vehicles/kona-electric>, <https ://www.hyundaiusa.com/us/en/vehicles/kona-electric/compare-specs>, Correspondance with Hyundai*

*Image source : <https ://www.hyundaiusa.com/us/en/build/summary/#/368A1N1F1Q0>*

**Kia Niro EV**

The Kia Niro is a subcompact crossover vehicle manufactured in South Korea.

| Specification | Specification Value(s) |
|---|---|
| Passenger capacity | Up to four ambulatory passengers |
| Lift-capable? | No |
| Battery size | 64kWh |
| Approx. nameplate single-charge range | 239 miles |
| Length | ~14’ |
| Approx. cost | $40,440-$45,845 |
| Availability | Available |

*Sources : <https ://www.kia.com/us/en/niro-ev>, <https ://www.kia.com/us/en/niro-ev/specs><https://www.kia.com/us/en/inventory/result?year=2020&seriesId=V&zipCode=86001 >*

*Image source : <https ://www.kia.com/us/en/niro-ev/build>*

**Nissan Leaf S, SV, S Plus, and SV Plus**

The Nissan Leaf is a four-door hatchback in widespread use throughout the U.S. This vehicle is available in four models with varying cost, range, and features, and is manufactured in Tennessee.

| Specification | Specification Value(s) |
|---|---|
| Passenger capacity | Up to four ambulatory passengers |
| Lift-capable? | No |
| Battery size | 40kWh-62kWh |
| Approx. nameplate single-charge range | 149-226 miles |
| Length | ~15’ |
| Approx. cost | $34,610 - $46,010 |
| Availability | Available |

*Source: <https://www.nissanusa.com/vehicles/electric-cars/leaf.html>,*

*< https://www.pinnaclenissan.com/all-inventory/index.htm?search=LEAF&compositeType=new&trim=S&trim=SL+PLUS&trim=SV&trim=SV+PLUS&payment-selection=payment-panel-paymentLease&cityFuelEconomy=&dl.formElapsedTime=1402&dl.pageName=INDEX&payment-selection=payment-panel-paymentLease&dl.formTrackingId=INVENTORY_SEARCH&saveFacetState=true&dl.element=BUTTON+Search&lastFacetInteracted=inventory-listing1-facet-anchor-internetPrice-0*

*Image source : <https ://www.nissanusa.com/vehicles/electric-cars/leaf/build-price.html#configure/Apcpq/version>*

## Utility Trucks

**Phoenix Motors Zeus 500 Truck**

The Phoenix Motorcars Zeus 500 Truck is an electric cutaway that incorporates a Ford E-450 Superduty chassis. There are a variety of truck options for this chassis including: flatbed, utility, service, animal-control, and refrigerated trucks.

| Specification | Specification Value(s) |
|---|---|
| Passenger capacity | One ambulatory passengers |
| Lift-capable? | No |
| Battery size | Up to 150kWh |
| Approx. nameplate single-charge range | Up to 160 miles |
| Length | variable |
| Approx. cost | $205,000 - $210,000 |
| Availability | Available |

*Sources:* http://www.phoenixmotorcars.com/products/#trucks, *Correspondence with Dealer: Thomas Allen*

**Pickup Trucks**

The three electric pickup trucks listed below are all currently only available for preorder. Although they aren't specifically utility trucks, they could potentially still serve as replacements for the multiple gasoline fueled trucks in Mountain Line's non-revenue fleet.

**Lordstown: Endurance**

| Specification | Specification Value(s) |
|---|---|
| Passenger Capacity | Up to 5 |
| Battery Size | TBD |
| Approx. Nameplate Single-Charge Range | 250+ miles |
| Length | TBD |
| Approx. Cost | $52,500 |
| Availability | Preorder is available today, with vehicle shipping planned to begin by the end of 2020. |

*Source:<https://insideevs.com/news/389264/lordstown-endurance-at-least-200-miles-epa/>*
*<https://lordstownmotors.com/pages/endurance>*

**Tesla: Cybertruck**

| Specification | Specification Value(s) |
| --- | --- |
| Passenger Capacity | Up to 6 |
| Battery Size | Est. 200 kWh |
| Approx. Nameplate Single-Charge Range | 250 – 500+ miles (EPA Est.) |
| Length | 231.7" |
| Approx. Cost | $69,900 |
| Availability | Preorder is available today, with the single motor rear-wheel drive production planned to begin in late 2022, and the dual and tri motor production in late 2021. |

*Source:* <*https://www.tesla.com/cybertruck*>
<*https://www.cars.com/articles/tesla-cybertruck-impressive-specs-killer-price-polarizing-looks-413819/*>

**Rivian R1T Truck**

| Specification | Specification Value(s) |
| --- | --- |
| Passenger Capacity | Up to 5 |
| Battery Size | 105 – 180 kWh |
| Approx. Nameplate Single-Charge Range | 400+ miles |
| Length | 217.1" |
| Approx. Cost | $69,000 |
| Availability | Preorder is available today, with production scheduled to begin in the second half of 2020. |

*Source:* https://rivian.com/r1t/ <*https://www.caranddriver.com/rivian/r1t*>

## Off-Road Vehicles and Tools

Mountain Line has a variety of tools (snowblowers, pressure washers) and off-road vehicles (forklifts, tractors, lawn mowers) in its non-revenue fleet that have electric alternatives on the market currently, some of which are listed in the sections below. However, these off-road vehicles and tools will not be considered in the transition analysis.

***Mini- Excavators***

**Bobcat**

| Specifications | E10E |
|---|---|
| Horsepower | 10 HP |
| Battery Size | 12.7 kWh |
| Traveling Speeds | 1.3 – 1.9 mph |
| Battery Runtime | Up to 8 hours |
| Approx. Cost | TBD |
| Availability | Available |

Source :<https://www.bobcat.com/eu/company-info/news-media/e10-electric>

***Tractors***

**Solectrac**

| Specifications | Compact Electric Tractor (CET) | eUtility Electric Tractor | eFarmer Electric Tractor |
|---|---|---|---|
| Horsepower | 30 HP | 40 HP Continuous, 50 HP Peak | 30 HP |
| Battery Size | 22 kWh | 28 kWh | 28 kWh |
| Battery Runtime | 3-6 hrs. depending on load. | 4-8 hrs. depending on loads | 4-8 hrs. depending on loads |
| Approx. Cost | $25,800 - $33,000 | $45,000 - $75,000 | $45,000 - $56,175 |
| Availability | Initial sales will be limited to California and Canada, and expanded as interest in other states grows. | Available now on a first to deposit basis. | Will be available in late 2020 |

Source :<*https://www.solectrac.com/*>

***Forklifts***

**Komatsu America Corporation**



| Specifications | AE50 Series | AM50 Series | BBX50 Series |
|---|---|---|---|
| Capacity | 3,000 – 4,000 lbs. | 3,000 – 4,000 lbs. | 4,000 – 6,500 lbs. |
| Battery Voltage/Capacity | 48 V | 48 V | 36/48 V |
| Maximum Travel Speed (loaded) | 9 - 10 mph | 9 – 10 mph | 7.5 – 10.9 mph |
| Maximum Fork Height | 129.9” | 129.9” | 128” |
| Approx. Cost | TBD | TBD | TBD |
| Availability | Available | Available | Available |

*Source: <u><</u>https://www.komatsuamerica.com/equipment/forklift/electric-riders#page=0&sortby=sortorder&sortdir=Asc>*

**Linde Material Handling**






| Specifications | E12 – E20 EVO | E16 – E20 EVO | E20 – E35 | E20 – E35 R | E35 – E50 | E60 – E80 |
|---|---|---|---|---|---|---|
| Capacity | 2400 – 4,000 lbs. | 3,200 – 4,000 lbs. | 4,000 – 7,000 lbs. | 4,000 – 7,000 lbs. | 6,400 – 9,980 lbs. | 12,000 – 16,000 lbs. |
| Voltage | 24/48 V | 48 V | 80 V | 80 V | 80 V | 80 V |
| Maximum Travel Speed (loaded) | 7.7 – 9.9 mph | 12.4 mph | 12.4 mph | 12.4 mph | 11.1 mph | 9.9 mph |
| Maximum Fork Height | 110” – 124” | 110” – 124” | 123” – 161.2” | 123” - 137” | 114” – 166” | 120” – 151” |
| Approx. Cost | TBD | TBD | TBD | TBD | TBD | TBD |
| Availability | Available | Available | Available | Available | Available | Available |

*Source: <u><</u>https://www.linde-mh.com/en/Product-Finder/?offerType=new&sorting[field]=productType&sorting[direction]=ASC&productTypes[]=2377>*

**Mitsubishi Forklift Trucks**




| Specifications | FB16PNT-FB20PNT | FBC15N-FBC18LN | FBC23N-FBC30LN | FBCS14N-FBCS18N |
|---|---|---|---|---|
| Capacity | 3,000 – 4,000 lbs. | 3,000 – 4,000 lbs. | 4,500 – 6,500 lbs. | 3,000 – 4,000 lbs. |
| Battery Voltage/Capacity | 36/48 V | 36/48 V | 36/48 V | 36 V |
| Maximum Travel Speed (loaded) | 10 mph | 9.3 – 11.3 mph | 9.3 – 11.3 mph | 8 mph |
| Maximum Fork Height | 258.5” | 217” | 131.5” | 188” |
| Approx. Cost | TBD | TBD | TBD | TBD |
| Availability | Available | Available | Available | Available |

*Source:* <https://www.mcfa.com/en/mit/all-forklifts#>

**Raymond Corporation**

*Specification document only listed unloaded travel speed.


| Specifications | 4000 Series Counter-Balanced Trucks Stand-Up | 4000 Series Counter-Balanced Trucks Sit-Down |
|---|---|---|
| Capacity | 3,000 – 5,000 lbs. | 3,000 – 6,500 lbs. |
| Battery Voltage/Capacity | 36 V | 36 V and 48 V |
| Maximum Travel Speed (loaded) | 7.2 – 8.0 mph | 9.6 – 12 mph* |
| Maximum Fork Height | 227” – 270” | 227” – 278” |
| Approx. Cost | TBD | TBD |
| Availability | Available | Available |

*Source:* <https://www.raymondcorp.com/lift-trucks/reach-fork-trucks>

**Toyota**

| Specifications | 3-Wheel Electric | Core Electric | Large Electric | Stand-Up Rider | Electric Pneumatic | High-Capacity Electric Cushion |
|---|---|---|---|---|---|---|
| Capacity | 3,000 – 4,000 lbs. | 3,000 – 6,500 lbs. | 8,000 – 12,000 lbs. | 3,000 – 4,000 lbs. | 4,000 – 7,000 lbs. | 15,000 – 40,000 lbs. |
| Voltage | 36/48 V | 36/48 V | 36/48 V | 36 V | 80 V | 72/80 V |
| Maximum Travel Speed (loaded) | 9.5 – 9.9 mph | 11.3 – 11.5 mph | 7.5 – 10.5 mph | 7.5 mph | 11.8 mph | 4.6 – 5.2 mph |
| Maximum Fork Height | 100” – 277.5” | 80” – 278” | 120” – 239” | 128” - 277” | 118” – 258” | 69” – 327” |
| Approx. Cost | TBD | TBD | TBD | TBD | TBD | TBD |
| Availability | Available on WA State Contract | Available on WA State Contract | Available | Available on WA State Contract | Available on WA State Contract | Available |

*Source: <https://www.toyotaforklift.com/lifts/electric-motor-rider-forklifts>*

***Riding Lawn Mowers***

**Ryobi**

| Specifications | Electric Series |
|---|---|
| Battery Capacity | 2,400 - 3,600 watts |
| Charge Time | 6-10 hours* |
| Run Time on a Single Charge | 1-2 hours or 1-3 acres |
| Forward Speed | 5 - 8 mph |
| Approx. Cost | $2,399 - $4,199 |
| Availability | Available |
| *Charge rate stated as “overnight”. 6-10 hours given as an estimated range. | |

*Source:*<https://www.ryobitools.com/outdoor/products/mowers?page=1>

**Cub Cadet**

| Specifications | Electric Series |
|---|---|
| Battery Capacity | 1,500 – 3,000 watts |
| Charge Time | 4 hours |
| Run Time on a Single Charge | 1-1.5 hours or 1-2 acres |
| Forward Speed | 4 - 5.5 mph |
| Approx. Cost | $2,799 - $3,999 |
| Availability | Available |

*Source:*<https://www.cubcadet.com/en_US/riding-lawn-mowers/electric-riding-mowers?scroll=1>

**Turf One**

| Specifications | Electric Series |
|---|---|
| Battery Capacity | 1,440 – 3,600 watts |
| Charge Time | 8 - 12 hours |
| Run Time on a Single Charge | 2-2.5 hours or 2 acres |
| Forward Speed | 3.7 - 4 mph |
| Approx. Cost | $2,199 - $3,499 |
| Availability | Available |

*Source:*< https://www.turfonemfg.com/electric-riding-mower>

***Pressure Washers***

**Annovi Reverberi (AR)**

| Specifications | Electric Series |
|---|---|
| Max PSI | 1,350 - 2,050 |
| Motor Amperage | 11 - 19 Amps |
| Max GPM | 1.4 – 2.2 |
| Approx. Cost | $119-779 |
| Availability | Available |

*Source: <https://www.arnorthamerica.com/pages/ar-blue-clean-power-washers/#section3>*

**Snow Joe**

| Specifications | Electric Series |
|---|---|
| Max Pressure | 50 – 3,000 PSI |
| Motor Amperage | 11 – 14.5 amps |
| Max Flow Rate | 0.6 – 2 GPM |
| Approx. Cost | $84 - $549 |
| Availability | Available |

*Source:<https://www.snowjoe.com/collections/pressure-washers>*

**Ryobi**

| Specifications | Electric Series |
|---|---|
| Max Pressure | 1,600 – 2,300 PSI |
| Motor Amperage | 13 amps |
| Max Flow Rate | 1.2 GPM |
| Approx. Cost | $99 - $299 |
| Availability | Available |

*Source:<https://www.ryobitools.com/outdoor/products/pressure-washers>*

**Karcher**

| Specifications | Electric Series |
|---|---|
| Max Pressure | 1,600 - 2,000 PSI |
| Motor Amperage | 13 amp |
| Max Flow Rate | 1.25 - 1.4 GPM |
| Approx. Cost | $129 - $459 |
| Availability | Available |

*Source:<https://www.kaercher.com/us/online-shop-en/general-result-page/~20035386-electric-pressure-washers.html>*

**Greenworks**

| Specifications | Electric Series |
|---|---|
| Max Pressure | 1,500 - 2,700 PSI |
| Motor Amperage | 13 – 15 amp |
| Max Flow Rate | 1.1 – 2.3 GPM |
| Approx. Cost | $90 - $350 |
| Availability | Available |

*Source:<https://www.greenworkstools.com/shop-by-tool/pressure-washers>*

**Briggs and Stratton**

| Specifications | Electric Series |
|---|---|
| Max Pressure | 1,700 – 2,200 PSI |
| Motor Amperage | TBD |
| Max Flow Rate | 1.2 – 3.5 GPM |
| Approx. Cost | $199 - $399 |
| Availability | Available |

*Source:<https://www.briggsandstratton.com/na/en_us/products/pressure-washers.html>*

**Yard Force**

| Specifications | Electric Series |
|---|---|
| Max Pressure | 1,600 – 2,200 PSI |
| Motor Amperage | 13 amp |
| Max Flow Rate | 1.2 – 1.25 GPM |
| Approx. Cost | $95 - $349 |
| Availability | Available |

*Source:<https://www.yardforceusa.com/pressure-washers>*

***Snowblowers***

**Ryobi**

| Specifications | Electric Series |
|---|---|
| Motor Amperage | 13 amps |
| Clearing Width | 20 – 21 in |
| Clearing Distance | 25 – 35 ft |
| Approx. Cost | $299 - $499 |
| Availability | Available |

*Source:<https://www.ryobitools.com/outdoor/products/snow-blowers>*

**Snow Joe**

| Specifications | Electric Series |
|---|---|
| Motor Amperage | 11 - 15 amps |
| Clearing Width | 15 – 22 in |
| Clearing Distance | 20 - 25 ft |
| Approx. Cost | $129 - $249 |
| Availability | Available |

*Source:*<https://www.snowjoe.com/collections/snow-blowers-power-shovels >

**Toro**

| Specifications | Electric Series |
|---|---|
| Motor Amperage | 7.5 - 15 amps |
| Clearing Width | 12 – 18 in |
| Clearing Distance | 20 - 30 ft |
| Approx. Cost | $279 |
| Availability | Available |

*Source:*<https://www.toro.com/en/homeowner/snow-blowers>

# APPENDIX I

## Charging Equipment for Paratransit and Other Service Vehicles

Electric Vehicle Supply Equipment (EVSE) is the equipment used to deliver electrical energy from an electricity source to an EV. ESVE communicates with the EV to ensure that an appropriate and safe flow of electricity is supplied. EVSE for EV is classified into several categories by the rate at which the batteries are charged. The types of EVSE applicable to Mountain Line's paratransit fleet and the support vehicle fleet include Level 2 chargers and DC fast chargers (as discussed **Infrastructure Requirements and Recommendations** section of this *Implementation Plan*). Level 2 provides AC electricity to the vehicle, with the vehicle's onboard equipment convert AC to the DC needed to charge the batteries. DC fast charging provides DC electricity directly to the vehicle. Charging times range from 20 hours or more to less than 30 minutes, depending on the type of EVSE, the battery's capacity, state of charge, and the vehicle's acceptance rate or charging speed. Details of the charging options and considerations for the paratransit fleet and other service vehicles is included in this Appendix**.**

## Level 2 Charging

Level 2 EVSE offers charging through a 240V (typical in residential application) or a 208V (typical in commercial application) AC plug and requires installation of charging equipment and a dedicated electrical circuit. Depending on the battery type, charger configuration, and circuit capacity, Level 2 charging adds about 10 to 25 miles of range per hour of charge time. Error! Reference source not found. below lists a range of charging times for common electric vehicles and Level 2 chargers.

*Table I-1 - AC Charging Time by Vehicle Battery Size*

| Vehicle | Battery Capacity (kWh) | Time Required for Full Battery Charged Based on Charger Loads (h) | | | |
|---|---|---|---|---|---|
| | | 3.8 kW | 7.2 kW | 12 kW | 19.2 kW |
| **Kia Niro** | 64 | 16.8 h | 8.9 h | 5.3 h | 3.3 h |
| **GreenPower EV Star ADA** | 118 | 31.1 h | 16.4 h | 9.8 h | 6.1 h |
| **Phoenix Motors Zeus 500 Truck** | 150 | 39.5 h | 20.8 h | 12.5 h | 7.8 h |

Level 2 EVSE is available at a range of price points based on ability to be networked and power. Prices starting with low cost, portable relatively low speed (3.8-7.7kW) "dumb" chargers (non-networked) such as Clipper Creek's entry level AmazingE charging cordsets all the way up to relatively fast (19.2 kW) full feature hard-wired smart chargers that use WiFi or cellular connection to transmit and track charging and financial data such as Blink's IQ 200. The installed cost is typically 2x to 5x the cost of the hardware itself as explained below. The advantage of dumb chargers are their low cost and simplicity. The benefits of higher cost chargers include faster charging speeds, ability to manage and share power loads, ability to schedule charging to take advantage of time of use charging rates and the ability to monitor charging data using on-line dashboards, smart phone apps and perhaps most importantly an effective mechanism for vanpool and other EV users to pay for their charging.

### DC Fast/High Powered Charging

DC fast charging EVSE (480V input to the EVSE) enables rapid charging. A 50kW DC Fast Charger, the most common public fast charger (other than Tesla's superchargers) adds 60 to 80 miles of range to a light duty vehicle in as little 20 minutes. High powered DC fast chargers (150 to 450 kW) are the fastest and most expensive type of ESVE. For comparison, DC fast charging is what is proposed for the Mountain Line heavy duty transit BEB fleet that provide fixed route service.

*Table I-2 - DC Fast Charge Time by Vehicle Type and Charger Size*

| EV/ZEB Vehicles | Battery Capacity (kWh) | Time Required for Full Battery Charged Based on Charger Loads (h) | | |
|---|---|---|---|---|
| | | 50 kW | 150 kW | 350 kW |
| **Kia Niro** | 64 | 1.3 h | 0.43 h | 0.18 h |
| **GreenPower EV Star ADA** | 118 | 2.4 h | 0.79 h | 0.34 h |
| **Phoenix Motors Zeus 500 Truck** | 150 | 3 h | 1 h | 0.43 h |

DC fast chargers require more space and are considerably more expensive to purchase and install, including relatively large investments for electrical service upgrades, and would therefore not be cost effective or appropriate as a primary charging technology for the light duty vehicles that Mountain Line will be charging. DC fast charging would be an option for the paratransit vehicles in that multiple vehicles could share a single plug-in charger. Installation of dispensers with drop down cords would have similar challenges as previously discussed for the heavy duty buses at the Kaspar Drive Maintenance Facility.

### Current Charging Options

Currently available charging technologies appropriate to Mountain Line's paratransit fleet and support vehicle fleet needs include the strategies discussed below and summarized in Error! Reference source not found..

### Dedicated Chargers

The simplest way to charge a fleet is with individual chargers dedicated to each vehicle in the fleet. This approach to charging typically requires each fleet vehicle be assigned a parking stall and that each parking stall be equipped with its own charger. Cutaway fleets can use Level 2 chargers to provide adequate range and deploy smart chargers to track electrical use by vehicle or department, similar to tracking gasoline consumption.

Vehicle operators pick up the vehicle at the assigned stall, manually disconnect the charger before using the vehicle, and later return the vehicle to the assigned stall and reconnect the charging cord. For fleet facilities with on-site staff or an automated parking management system, vehicles could be rotated between stalls because all stalls would be comparably equipped with EVSE. This method isn't recommended for cutaways as the battery packs tend to be bigger and need most of a night to fully charge.

**Benefits**: The primary benefit of this approach is its simplicity and predictability for fleet operators and drivers. It also provides flexibility due to the relative abundance of chargers, allowing for future expansion via implementation of load management systems or other options.

**Disadvantages**: A ratio of one charger per parking stall or per EV requires numerous charger installations, which is generally inefficient and can potentially be a more-costly approach due to the expense of procuring and installing[9] each charger. In addition to the cost, the parking facility is more heavily impacted during the charging infrastructure construction period.

With a one EV to one charger ratio, the capacity to charge other vehicles is wasted for two reasons: 1) the charger sits idle while the dedicated vehicle is in use, and 2) a fully charged EV in the assigned parking space blocks other vehicles from using the charger. Operational costs of dedicated chargers can be higher as well. Simultaneously charging multiple EVs at fleet facilities, without managed charging or energy storage incorporated into the system, could result in costly demand charges.

Network and data costs can also add up over time when smart chargers or third-party load management systems are deployed, and ongoing charger maintenance costs are usually proportionate to the quantity of chargers installed. Generally, data management networks can cost $75-$200 per year per vehicle.

**General Recommendations**: Dedicated chargers generally make the most sense in the following circumstances:

- Locations that are currently equipped with significant quantities of chargers that could be dedicated to a unique parking space/fleet EV. These chargers, however, would not be available to the public when in use by Mountain Line's paratransit revenue fleet.
- Facilities at which a limited number of EVs are domiciled and ample electrical capacity is available.

### Dedicated Chargers with Load Management

One way to reduce the maximum power load to avoid or reduce needed electrical service upgrades or utility demand charges is through load splitting, balancing or management systems. These systems allow fleet operators to control when and how each fleet EV is charged by distributing power between chargers. With the extra capacity available in buildings, and by utilizing a load management system, most fleet facilities would not need electrical service upgrades.

**Benefits**: The primary benefit of load management is reduction of peak electrical load to reduce or avoid costly electrical service upgrades and utility demand charges.

**Disadvantages**: Load management requires networked smart chargers, which may have higher capital and/or operating costs and depends on the individual system and quantity of chargers. Third-party load splitting or management systems can operate with non-networked dumb chargers, but the equipment and service require additional capital and data costs.

[9] Installation costs typically include design, permitting, and electrical service upgrades.

**General Recommendations**: Adding load management to dedicated chargers generally makes the most sense in parking facilities with limited power supply where large numbers of heavily utilized EVs with long dwell times are domiciled.

### Shared Chargers

At facilities with shared chargers, a minimum number of Level 2 chargers are installed to serve all the fleet EVs domiciled by rotating charger use. Mountain Line vehicles travel anywhere from 15 miles to 200 miles per day. Therefore, charging for the vehicles will range from 4 hours to 8 hours. It is unlikely that all Mountain Line vehicles will require an 8 hour charge at the same time, but to mitigate risk, it would be safer to consider a 1:1.5 or 1:1.25 charger to vehicle ratio. Additionally, a shared direct current fast charger (DCFC) could supplement shared Level 2 chargers at larger fleet facilities. In cases where dwell times are limited to only four hours, the anticipated duration of charging would still be sufficient to charge multiple vehicles.

**Benefits**: The primary benefit of sharing EV chargers is cost reduction, not just from reduced purchases but by reduced installation and needed electrical system upgrades. Mountain Line could purchase and install a minimum number of chargers and avoid the need to increase facility electrical capacity. An additional benefit is reduced construction related disruption at facilities during charger installation.

**Disadvantages**: Sharing chargers requires careful management of fleet EVs to ensure that all vehicles maintain a sufficient state of charge for their intended daily use. As more EVs are added to the fleet, it is likely that Mountain Lion would need to procure and install additional chargers.

**General Recommendations**: Sharing chargers makes the most sense under the following circumstances:

- Facilities that serve fleet EVs that typically have dwell times longer than eight hours.
- Facilities with limited available electrical capacity to avoid the expense of electrical service upgrades.

### Shared Chargers with Load Management

This is a variation on shared chargers that incorporates load management to provides flexibility. This could be achieved by networked smart chargers with integral load management or by a third-party add-on system.

**Benefits**: The primary benefit is to reduce peak demand charges, potential electric service upgrades costs, and initial investment costs associated with the procurement and installation of chargers generally (e.g., reduced number of individual units required). This approach is also useful to leverage the constrained electrical capacity of certain sites to install more chargers that would share available electrical load.

**Disadvantages**: It requires active parking/charging management by staff and poses a potential risk that fleet EVs may not be sufficiently charged if not managed properly.

**General Recommendations**: Adding load management to shared chargers makes the most sense at locations at which a load management system can serve multiple chargers needed in the future allowing the charging capacity of the fleet facility to expand over time.

### Mobile Charging

An alternative or possible complement to fixed EV chargers is mobile or semi-mobile charging. These consist of energy storage systems that draw power from the grid then dispense the electricity to EVs when needed. Two examples are Freewire Technologies, which has two mobile charging units, Mobi and Boost; and Danner, which has the Mobile Power Station (MPS). The MPS and Mobi units are literally mobile, equipped with wheels and operator controls, while the Boost is stationary and hard-wired but can be easily disconnected for re-location to another facility.

Each Mobi can charge up to eight light-duty EVs per shift and can be equipped with an optional Hydra unit that simultaneously charges seven vehicles (charging is at Level 1 speed). Boost is a larger unit that has 160 kWh of battery capacity and 120 kW output capable of charging 25 light-duty EVs per shift at 100kW.

*Figure I-1 - Portable Charger Examples*


Dannar's MPS can charge multiple types of batteries and replicate the function of a mobile generator. The DANNAR 4.00 base configuration comes standard with three 42 kWh Li-Ion battery packs (126 kWh total) and can be easily upgraded with up to nine additional packs for a total of 504 kWh of on-board electricity.


Another example of mobile charging includes portable battery-powered rescue chargers like SparkCharge and portable generators like Blink's mobile charger. SparkCharge produces a highly portable, modular DC fast charger. Its battery-powered chargers snap together like Lego blocks, and provide up to 20 miles of range per battery module. Blink's mobile EV charger is also designed for emergency battery augmentation, allowing otherwise stranded EVs to drive back to a charger in situations where battery range proves insufficient by supplying 9.6 kW of continuous power, enough for between 0.5 and 1 miles of range per minute plugged. Fleets can use either of these to augment short-range EVs or rescue EVs that run out of charge, which avoids the need to be towed to a charger or facilitating occasional longer distance trips.

**Benefits**: By being able to accept power from the grid at low voltage and/or during times when electrical demand is low or during the day when grid renewables and/or onsite solar (depending on the fleet's vehicle charging facility) generation is high, mobile energy storage platforms can help to avoid demand charges. Other benefits include the ability to:

- Charge additional fleet EVs than the facility's existing power capacity may support.
- Provide backup energy to fleet vehicles during power outages.
- Charge multiple EVs at the same site by moving the charger, rather than moving the vehicles.
- Relocating the charger from one facility to another to address changing needs.

The Danner Mobile Power Stations can also be outfitted with auxiliary equipment such as lifts or loaders, allowing these units to function as fully electric off-road equipment. Both the Danner and Mobi can also perform the function of a generator by powering electrical equipment where no power outlets are available.

**Disadvantages**: The main disadvantage of this option is the large upfront costs. Using mobile charging units also requires active parking/charging management by Mountain Line staff who will need to move the charger to individual fleet EVs and manually connect them. Mobile chargers take up space in the parking lot and staff may not be able to get the unit close enough to the EV in a crowded parking facility.

**General Recommendations**: Using mobile charging units makes sense:

- Where large numbers of fleet EVs could otherwise result in significant costs associated with electric service power upgrades that may be needed for Level 2 chargers.
- At facilities where fixed charging infrastructure near term is needed but may not be fiscally responsible because of site redevelopment plans in the future or that will be redeveloped.

*Table I-3 - Charging Strategy Summary*

| | Dedicated chargers | Dedicated chargers with load management | Shared chargers | Shared chargers with load management | Mobile charging |
|---|---|---|---|---|---|
| **Strengths:** | | | | | |
| **Convenience and simplicity** | Yes | Yes | No | No | Yes |
| **Capacity for future fleet expansion** | Yes | Yes | No | No | Yes |
| **Reduces peak demand and resulting service upgrades** | No | Yes | Yes | Yes | Yes |
| **Reduces CAPEX from fewer chargers purchased and installed.** | No | No | Yes | Yes | Depends on facility scale |
| **Challenges:** | | | | | |
| **Costs for hardware purchase, installation and load upgrades.** | Yes | Yes | No | No | More cost effective for larger facilities |
| **Initial cost of system plus data charges** | No | Yes | No | Depends on provider | Yes |
| **Requires active parking/charging management by agency staff** | No | No | Yes | Yes | Yes |
| **Risk of vehicles not being charged** | No | No | Yes | Yes | Yes |

# APPENDIX J
## Draft Project Schedule