Zero Emission Bus Roadmap

Submitted by:
Center for Transportation and the Environment

In partnership with:

SINGH + Associates, Inc. | Consulting Engineers

Issued: March 28, 2019

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1 Introduction

CyRide is the city bus system for Ames, Iowa. It is a collaboration between the City of Ames, Iowa State University (ISU), and the ISU's Student Government. CyRide operates 14 fixed routes, a Dial-A-Ride service for persons with a disability and a late-night service called Moonlight Express. CyRide engaged the Center for Transportation and the Environment (CTE) to prepare a Zero Emission Bus Roadmap to evaluate the costs, benefits, and strategies of acquiring and operating zero emission buses (ZEBs) in the CyRide fleet.

The study was conducted in four major parts to cover the various aspects central to supporting a ZEB fleet.

- **Operational Review**: Evaluation of what portions of CyRide's current 40' bus operations could be served with current battery-electric bus (BEB) technology. This analysis was based on a screening-level model of CyRide's bus service days being run with a generic electric bus, representative of the 40' BEB models available under the Federal Transit Administration (FTA) Buy America program in 2018. The outcomes of the Operational Review were an indication of what portion of CyRide's fleet could likely be replaced with BEBs, which would likely not be serviceable with a BEB, and which were within the margins of error of the model. The model also evaluated feasibility based on weather conditions and level of degradation of the buses' energy storage capacity, which naturally occurs with use of the batteries.

  Based on the operational review, CTE worked with CyRide to develop a strategically planned BEB fleet size that would result in increased utilization of the BEBs to capitalize on the operations cost and emissions savings that result while avoiding applications within CyRide's operations that would under-utilize the buses.

- **Facility/Equipment Review**: Based on the BEB planned fleet developed during the operational review, CTE worked with Singh and Associates, a transit industry electrical engineering firm, and Ames Municipal Electric to identify low-cost opportunities to support vehicle charging and develop a conceptual designs and cost estimates for equipment needed to charge the selected fleet. Singh and CTE also developed guidance for incorporating BEB charging infrastructure at a potential new CyRide garage facility.

- **Fleet/Maintenance**: CTE compiled information from BEB deployment and operations experience across the country to develop a list of requirements and best practices for BEB fleet maintenance.

- **Financial/Economic Analysis**: Based on the planned BEB fleet, conceptual charging design cost estimate, and projected energy and maintenance costs, CTE developed a lifecycle cost evaluation for procuring and operating the planned BEB fleet in place of diesel buses for an 18-year vehicle life cycle.

2 Operational Review

The goal of the operational review was to evaluate the capability of current 2018 40’ BEBs to perform meaningful service in CyRide operations as currently scheduled. To conduct the analysis, CTE applied their screening-level methodology that focuses on evaluating:

- Sensitivity to the energy requirements for heating and cooling the bus and battery, which vary significantly with temperature
- Range of uncertainty based on route-specific requirements (e.g. stop and go requirements, hills, high-speed requirements, loading, etc.)
- The effects of battery degradation over the life of a BEB battery pack.

Table 1 outlines the **planning range**[1] estimates for different operational scenarios foreseeable in the CyRide service area. These estimates are based on data from comparable BEB deployments CTE has managed, assuming a generic 40’ BEB model with 450 kilowatt-hours (kWh) of battery capacity. The generic bus model was developed by CTE to reflect the current state of practice in the BEB industry.

[1] **Planning Range** is intended to reflect mileage possible on the more challenging days for each scenario. There may be extremely cold or hot days on which the bus can’t complete the planning range. CyRide should have contingency options available for such occasions (e.g. deploying a diesel relief bus if the battery energy runs low). The interval presented indicates the variability between different routes based on route-specific requirements (e.g. stop and go requirements, hills, high-speed requirements, etc.). The influence of such route-specific requirements must be evaluated through modeling or testing before moving forward with a BEB deployment based on these estimates.

Table 1: Planning Range Estimates by Operational Scenario

Operational Scenario	8-hr. average temperature	Planning range in CyRide operations	
		New Battery	End of Warranty Life Battery (70% original capacity)[2]
Summer, Hot Day[3]	80°-95° F	90-170 miles	60-110 miles
Summer, Mild Day	60°-80° F	100-130 miles	70-90 miles
Academic Year, Mild Day	30°-60° F	140-240 miles	100-170 miles
Academic Year, Cold Day (with supplemental diesel heater)[4]	-10°F - 30° F	100-130 miles	70-90 miles
Academic Year Cold Day (with no supplemental heat--for comparison only)	-15°F – 50° F	50-70 miles	30-50 miles

CTE then applied the screening model to CyRide's current operations. This was done by evaluating all of CyRide's current **service blocks**[5] to estimate their feasibility with the generic BEB model. CyRide's current service consists of three categories of service blocks:

- **Academic Year Daily Blocks—** 261 days/yr.
  Academic year daily blocks are run all non-holiday days throughout the academic year, excluding University break periods (e.g. spring break). As the largest portion of CyRide's operation, the Academic Year daily blocks were evaluated first as they would constitute the majority of BEB operations and will serve as

[2] As batteries age, they lose energy storage capacity. **End of Warranty Life Battery Capacity** is defined as the lowest battery capacity possible within warranty conditions—i.e. the lowest energy storage capacity an owner could experience without triggering warranty coverage. Manufacturers typically warranty bus batteries to 70 or 80% of the original energy storage capacity for twelve or six years of operations.

[3] Due to the increased energy demand from the air conditioner, not evident in the winter due to ability of supplemental diesel heater to reduce heating electrical energy demand, the summer range is lower than the remainder of the year.

[4] CyRide requested planning to include a **diesel auxiliary heater** for this analysis. A diesel heater serves to extend the BEB's ability to operate in cold weather by avoiding the impact electric heat use has on range. Additionally, diesel heat is useful in maintaining a comfortable cabin temperature for riders and operators in northern climates. Diesel heaters use a minimal amount of fuel, consuming less than 1 gallon per hour per bus on the coldest days. As a result, there would be a net reduction of diesel use when a diesel-heater equipped BEB does not have to be swapped out standard diesel bus on a cold day, as can occur if an electric-only heated BEB can't make it's required mileage on a cold day. NOTE: the HVAC energy requirements for BEBs with supplemental diesels vary widely between manufacturers based on differences in heater control strategy and HVAC system design. The estimates used are for options that have been deployed in the market.

[5] **Service blocks** ('*blocks*') are the service that a bus does from leaving the depot to returning. Blocks can be distributed among buses as needed, with buses running any number of blocks on a given day as time allows.

the basis for the planning fleet size **(Figures 1 and 2)**.

- **Academic Year Extra Blocks—** 160 of the 261 academic year days
  Academic year extra blocks are deployed to provide additional capacity when demand exceeds standing load capacity on certain routes at specific times of day. Because they are shorter than the daily blocks, some extras can be paired with daily blocks to increase the mileage run by the BEBs **(Figure 2** and **Appendix 1)**. CTE evaluated the need to charge buses between their daily block and any extra blocks and determined that in all cases there was sufficient remaining energy on the buses to run the additional extra blocks without mid-day charging. The academic year blocks did include 60' articulated bus operations on Rt. 23, however, 60' operations were not deemed feasible with the current state of practice vehicles and were excluded from the remainder of the analysis and discussion.
- **Summer Blocks—**Annual Days of Operation: 98 days/yr.
  Finally, CTE evaluated the reduced service summer schedule to determine how CyRide could expect to run BEBs in the summer months **(Appendix 1)**.

The CTE screening model evaluates all bus service blocks, and categorizes them as likely to be feasible, unlikely to be infeasible, or potentially feasible in the different operational scenarios:

- **Likely to be feasible:** Blocks that are feasible regardless of the route-specific requirements and battery degradation that may influence range
- **Unlikely to be feasible:** Blocks that are not anticipated to be feasible under foreseeable route conditions
- **Possibly feasible:** Blocks that could be feasible, but are within the margin of error of the screening model –i.e. they may or may not be feasible depending on route-specific requirements

The results of the feasibility assessment indicate that 17 (42%) of CyRide's Academic Year Daily blocks are likely feasible under nearly all weather conditions, levels of battery degradation and route specific requirements. These 17 blocks comprise the base-level operations CyRide could expect from a BEB fleet during the academic year **(Figure 2)**. In practice, CyRide will likely be able to reliably run many of the 'Possibly Feasible' blocks in some or all conditions, however these blocks represent minimum feasibility of BEBs in CyRide operations.

Table 2: Number of buses in each feasibility category on Daily Academic Year Blocks

Route	*40' Buses on Route*	*Likely Feasible*	*Possibly Feasible*	*Unlikely to be Feasible*
#1 Red Route	*6*	-	4	2
#2 Green Route	*4*	1	1	2
#3 Blue Route	*4*	1	2	1
#5 Yellow Route	*1*	-	1	-
#6 Brown Route	*5*	2	3	-
#7 Purple Route	*2*	2	-	-
#9 Plum Route	*2*	1	1	-
#11 Cherry Route	*5*	5	-	-
#12 Lilac Route	*2*	2	-	-
#21 Cardinal Route	*3*	2	1	-
#23 Orange Route[6]	*1*	1	-	-
#25 Gold Route	*5*	-	3	2
Totals	**40**	**17/42%**	**16/40%**	**7/18%**

CTE suggests that this screening level modeling exercise should be refined with higher precision modeling to reduce the level of uncertainty (i.e. sort out the 'possibly feasible' blocks) as they apply to CyRide's exact route requirements. Higher precision modeling would require collecting data on the second-by-second speed and grade profile of the buses operating the target blocks, and running those speed and grade profiles with CTE's system-dynamics based model of the specific BEB model and configuration CyRide is targeting. This extra level of analysis would allow CTE to gauge the impacts of driver behavior, stop density, loading and terrain to reduce the uncertainty of the screening level model.

2.1 CyRide's BEB Planning Fleet

Based on the feasibility assessment of the academic year daily blocks, CTE and CyRide developed a planning fleet of up to 17 40' BEBs around the likely feasible number of academic year daily blocks that could be reliably accomplished with a BEB on all but the most extreme-weather days and battery degradation conditions.

2.2 Operations Planning

Due to the higher upfront costs of BEBs, the cost savings and the environmental benefits of

[6] The orange route is primarily served with 60' articulated buses and only one 40' bus.

BEBs depend on maximizing the utilization of the vehicles. To evaluate the utilization prospects for a CyRide BEB fleet, CTE evaluated the ‘Extra’ blocks to determine how they can be paired with the daily blocks to increase utilization (miles per day) on the BEB fleet, thus enhancing the operational savings of the BEBs vehicles compared with conventionally-fueled vehicles. Based on this analysis CTE proposed bus service days consisting of one regularly scheduled block, paired with scheduled extras where feasible. The average BEB distance without extras increased from 50 miles per day when running only the regularly scheduled blocks to 80 miles when adding the extras **(Figure 1)**.

On milder days, the number of feasible blocks increased from 17 to 27, with a corresponding mileage increase from a range of 55-99 miles on cold days to 56-148 miles per bus on the milder days **(Figure 2)**. CTE recommends that CyRide develop strategies to take advantage of the reduced HVAC energy demands on milder days to deploy buses on harder blocks to increase their utilization and associated operational savings and environmental benefits. This type of advanced dispatch practice will take experience to implement, however, the additional benefits would be significant.

Figure 1: Screening-Level Analysis Results and Planning Service Days (Academic Year)

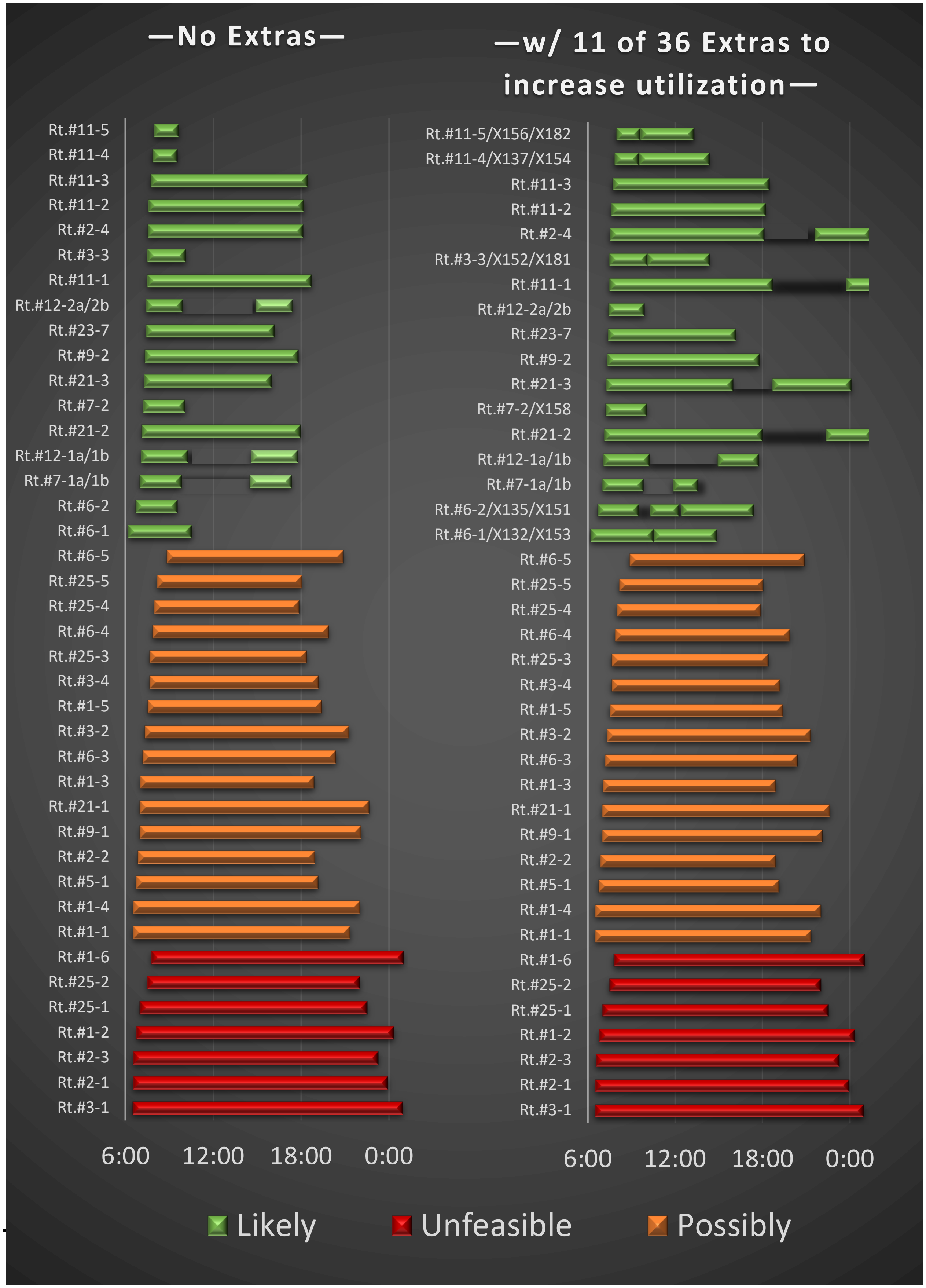
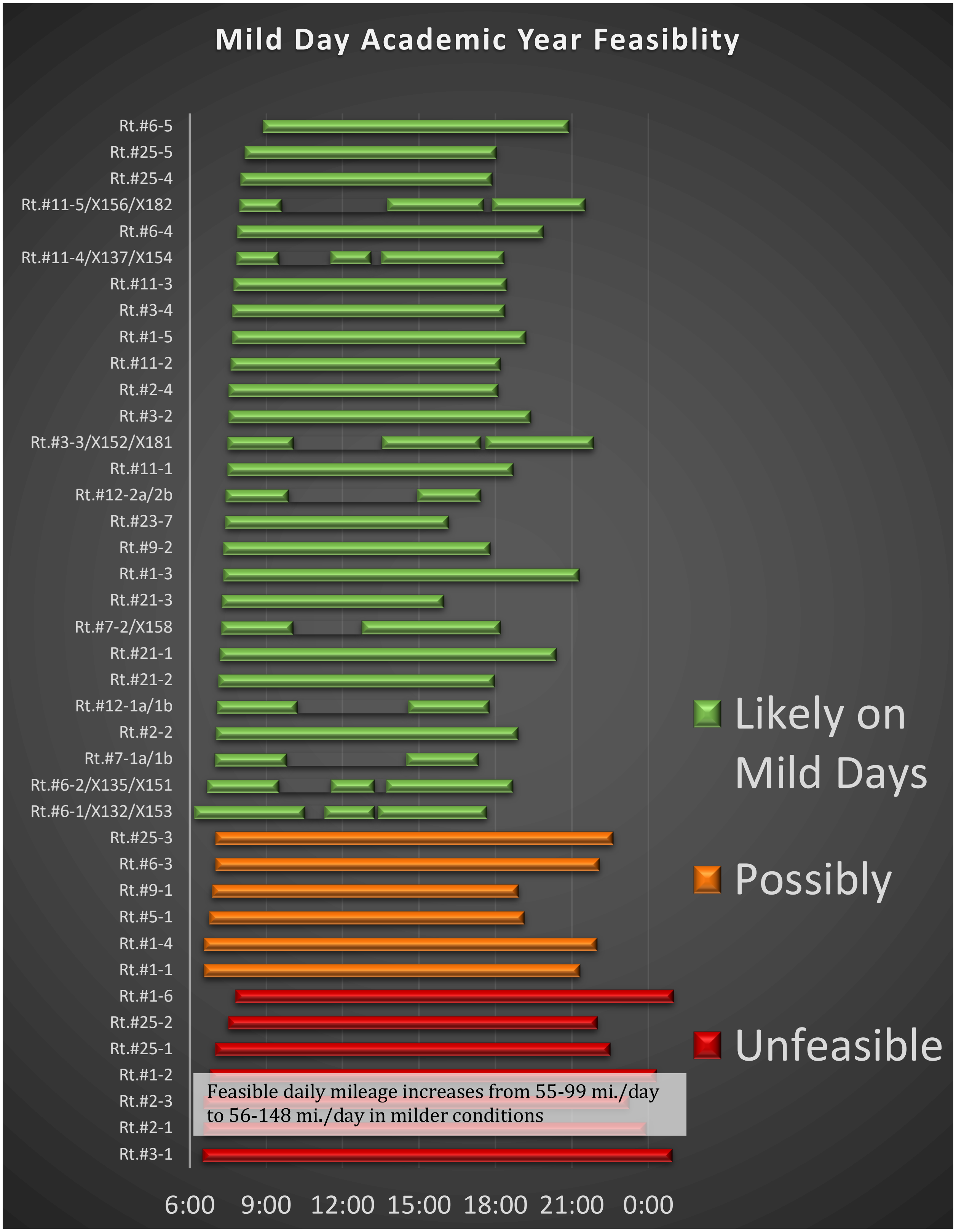


Figure 2: Screening-Level Analysis of BEB Feasibility on Mild Academic Year Days



Similar screening level analysis was conducted on the summer blocks to determine the feasibility of summer operations. Due to the increased energy demand from the air conditioner, not evident in the winter due to ability of the supplemental diesel heater to reduce heating electrical energy demand, the summer range is lower than the remainder of the year. Additionally, the summer blocks are generally longer than the academic year blocks exacerbating the range limitations of BEBs. As such, CTE determined 7 blocks would likely be feasible with the BEBs on the hottest days with the highest air conditioning accessory load. On milder days (estimated below 80°F) CTE estimates that 15 blocks would be feasible. The overall feasibility of operations under different times of year and different conditions is shown in **Table 3**. A complete table of feasibility by block is included in **Appendix 1**.

To increase utilization of all 17 buses in the summer months, CTE recommends CyRide consider splitting the long summer blocks at driver reliefs, and bringing in a new bus with a relief driver to reduce the effective length of the block for the BEB.

Table 3: Planning Fleet Operations and Estimated Service Days per Scenario

Operations	Avg. hours /bus/day	Avg. miles /bus/day	Estimated Days/year
Academic Year –Cold Day –No Extras	7 hrs.	50 mi.	12
Academic Year –Cold Day –w/Extras	9 hrs.	88 mi.	18
Academic Year –Mild Day	11.5 hrs.	126 mi.	231
Summer –Hot Day	3 hrs.	25 mi.	20
Summer –Mild Day	8 hrs.	82 mi.	78
No Service Holidays	–	–	6
Total/Year/bus	**3,460 hrs.**	**37,000 mi.**	**365**

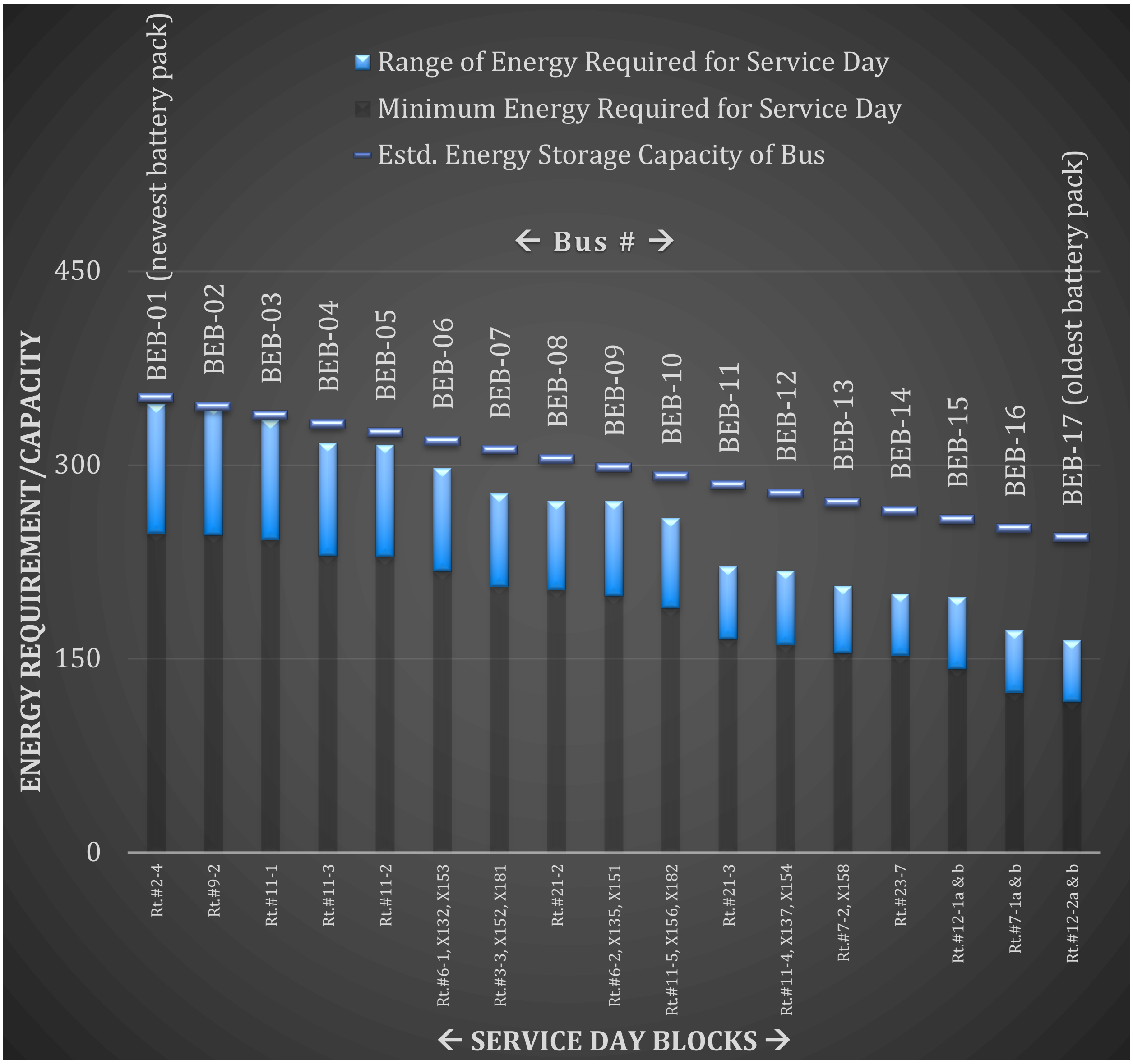
CTE's analysis indicates a potential for CyRide to operate electric buses for an average of 37,000 miles per year. CyRide currently runs their buses an average of 30,000 miles per year. As such CTE assumed 30,000 miles per bus for the annual operations estimate in subsequent environmental and economic analyses. That said, CTE recommends all zero emissions vehicle operators maximize operations of their zero emissions vehicles in the interest of maximizing the environmental and cost savings of these vehicles.

2.3 Battery Degradation Analysis

Over the service life of BEB batteries, their energy storage capacity will decrease with wear and tear on the batteries. The result is that the range per-charge of the buses will steadily decrease. CyRide will likely have to replace the BEB battery packs at some point in the life of each bus, however, it is important to confirm that there will be meaningful service for the bus to perform throughout the life of the battery pack.

To evaluate the service prospects for older batteries, CTE evaluated the distribution of energy requirements for the identified routes as compared to the estimated distribution of energy storage capacity across the BEB Fleet **(Figure 3)**.

Figure 3: Energy Required vs. Energy Capacity Range of Buses Over Battery Pack Life



This analysis indicates that the same 17 bus service days used for the planning operations would be feasible throughout the life of the bus batteries, indicating CyRide would see no impact on their ability to get this same level of service out of the buses for their entire service lives.

2.4 Charging Requirements for Planned BEB Service

CTE evaluated the charging required to support the planned operations. All service days were feasible without midday charging, so all charging can be accommodated upon final return to the depot for the evening. To inform the cost implications of the charging schedule, CTE coordinated with Ames Municipal Electric, the electrical utility for the city, to determine the electricity rates CyRide would be subject to for the BEB fleet.

Ames Municipal Electric indicated that CyRide would be subject to a special municipal rate outlined below with the approval of City Council —*with notes included to clarify the different terms.*

- **Use Rate = $0.0644/kWh**–*kWh use is based on how much total energy the buses use*
    - One Bus uses a maximum of 390 kWh/day of grid energy[7] which results in **a maximum of $753/ month in use charges per bus**
- **Demand Rate = $8.91/kW** – *kW demand is based on how fast energy is pulled from the grid to charge buses*
    - Based on the special municipal rate CyRide would receive, demand charges would be based on the highest demand observed between 4:00 PM and 8:00 PM within each month.

Based on this electric rate structure, the primary constraint was to charge outside the hours of 4:00 PM-8:00 PM to control demand costs. Additional manageable costs related to charging accrue from the cost of the infrastructure and power supply required to power the chargers. Because a BEB can be charged in less than four hours, CyRide has sufficient time to charge multiple buses with a single charger. This strategy can reduce equipment costs by charging multiple buses with each charger, rather than buying a charger for every bus, and correspondingly reduce infrastructure costs by reducing the number of chargers that must be connected to electrical distribution infrastructure.

Many heavy-duty fleet charging manufacturers are addressing this strategy by developing chargers that can share power between cables simultaneously connected to multiple vehicles. This setup allows power to be routed to different vehicles without the need to plug and unplug vehicles, or move vehicles between chargers. Based on this approach, CTE created a charging schedule whereby buses would begin charging 10 minutes after returning to the depot, after cleaning and minor service is completed. Charging would then be cycled between buses, while avoiding charging between 4:00 PM and 8:00 PM. CTE assumed each 100 kW-rated charger can serve three buses resulting in a total of six chargers to serve the 17-bus fleet. The ratio of chargers to plugs in charging systems on the market varies above and below the one to three ratio used.

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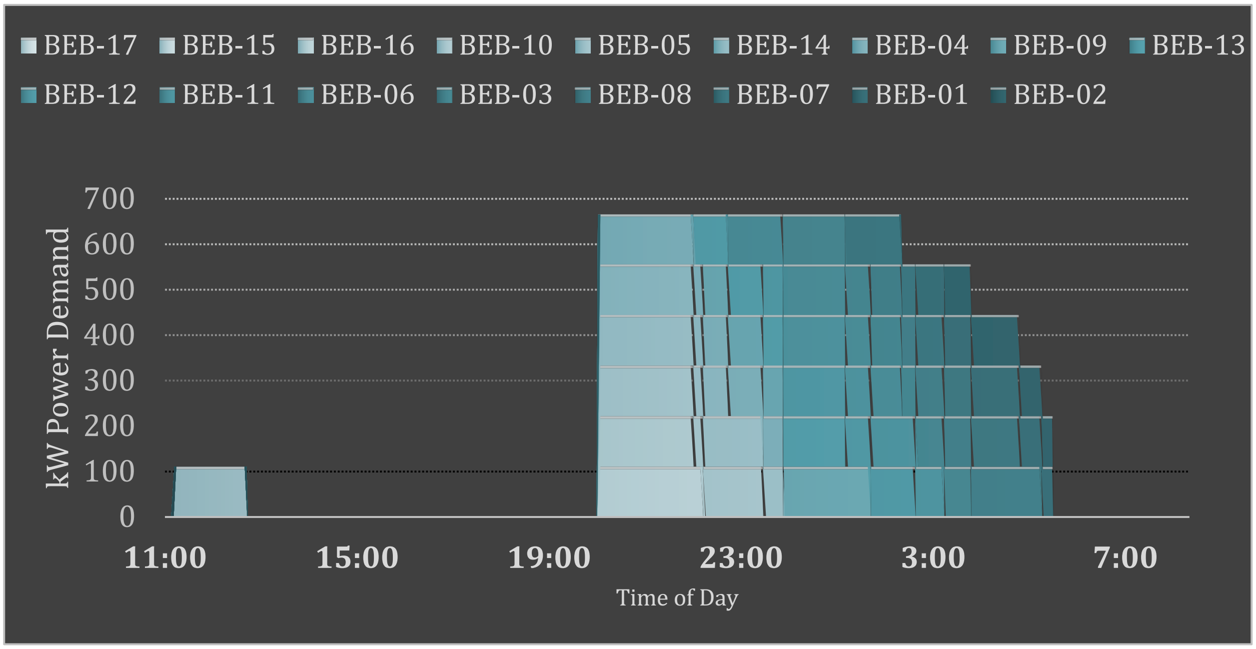
[7] **Grid energy** consumption is greater than the energy used by the bus due to energy losses in the charger hardware.

Figure 4: CyRide Charging Schedule—Hard Academic Year Day



NOTE: One of the planning service days returns mid-day. This bus would be charged upon return.

Based on this schedule analysis, CyRide can serve the planning fleet operations with six 100 kW chargers, each serving three buses, and a peak power demand of 670 kW. These estimates were used for the infrastructure and financial analysis.

3 Fleet Transition Schedule

CyRide provided CTE with a current fleet inventory, bus procurement, and bus disposal schedule for the next two years (2019 and 2020). The current fleet inventory is included in **Appendix 2**. The existing revenue fleet is composed of 100 vehicles that use a variety of fuels, including gasoline, diesel, and electricity (diesel hybrid). Twelve (12) of the vehicles have diesel fueled hybrid electric powertrains. In addition to the different fuel types, the fleet is a mix of vehicle service types, including 47 high-floor 40-foot transit buses, 39 low-floor 40-foot transit buses, 6 60-foot articulated transit buses, and 9 cutaways. The oldest vehicles are model year 1993 and the newest vehicles are model year 2018. A total of 13 of the high-floor transit buses are planned for disposal in 2019 (9) and 2020 (4) and are planned for replacement with five (5) low-floor transit buses in 2019 (4) and 2020 (1) reducing the total revenue fleet to 92 vehicles by 2020, with 84 vehicles supporting fixed-route services.

Currently CyRide does not have a regulatory mandate to transition to zero emissions vehicles and has not established specific zero-emission fleet goals to replace traditional buses with BEBs. However, based on completion of the operational review, it was determined that CyRide could feasibly replace up to 17 conventional diesel buses in daily service during the academic year based on the current state of BEB technology. As a result, this was determined to be the maximum number of BEBs to consider for transition into the CyRide fleet. CTE relied on CyRide's existing vehicle procurement and retirement plans as well as discussions with CyRide staff to forecast future procurements. Based on input from CyRide staff, an average of approximately two (2) conventional buses were replaced with BEBs per year over the transition period.

CyRide is not a direct recipient of federal funding; procurement of vehicles is completed through the State of Iowa. For vehicles that do not already have an expected retirement date, CTE assumed the lifespan of each fixed-route transit bus to be 18 years. Cutaway vehicles were not considered in the evaluation. Articulated buses were also not considered in the transition as operational screening indicated that the current blocks are not suitable for replacement on a 1:1 basis with current technology. CTE assumed that the fleet will not grow over the transition period based on discussions with CyRide staff because ridership is currently declining and expected to continue to do so in the future. These assumptions were used to develop a BEB procurement schedule. **Table 4** and **Figure 5** show how the fleet composition changes over the transition period. The BEB fleet completion milestone is:

- 2030 – the year that CyRide purchases 17th and final BEB to build out the fleet based on the operational review

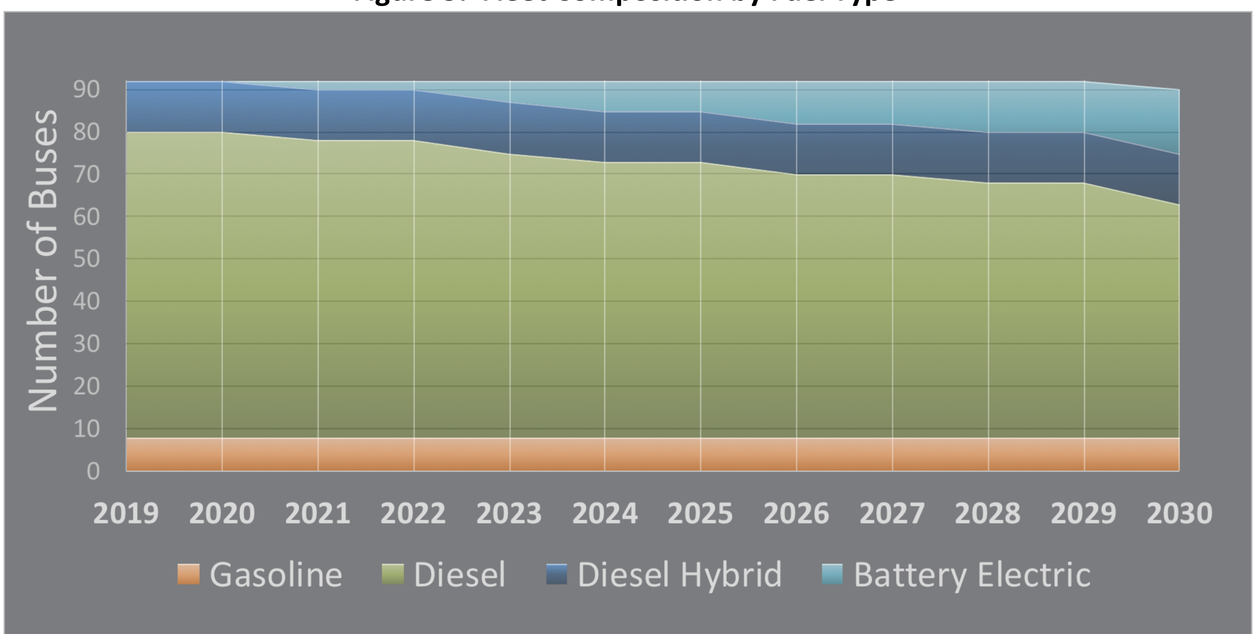
If technology improves and more daily service blocks become feasible assuming a 1:1 replacement of diesel with BEBs, then additional BEBs may be purchased and the transition period extended.

Table 4: Fixed-Route Fleet Composition by Fuel Type

	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Diesel	75	72	70	70	67	65	63	61	59	57	55	55
Hybrid	12	12	12	12	12	12	12	12	12	12	12	12
Electric	0	0	2	2	4	6	8	10	12	14	16	17
Total	**87**	**84**	**84**	**84**	**84**	**84**	**84**	**84**	**84**	**84**	**84**	**84**
% Fleet BEB	0%	0%	2%	2%	5%	7%	10%	12%	14%	17%	19%	20%

Figure 5 illustrates how the fleet fuel type will change over time. At the beginning of 2019, the fleet is a mix of gasoline, diesel, and diesel hybrid buses. By 2030, 17 new BEBs will be incorporated into the CyRide fleet comprising approximately 18% of the total fleet and 20% of the total fixed-route fleet.

Figure 5: Fleet Composition by Fuel Type



4 Facility/Equipment Assessment

The Facilities/Equipment Assessment uses results from the Operational Review and Transition Schedule to define the requirements for charging infrastructure necessary to support transition to a BEB fleet.

In initial BEB deployments, charging requirements are met relatively easily with a handful of plug-in pedestal chargers and minimal infrastructure investment. Supporting a larger, long term, BEB fleet requires a significantly different approach to charging and substantial infrastructure upgrade. Plug-in charging may no longer be practical as charger dispensers installed in the facility or yard create a hazard. Instead, the preferred approach is to use overhead pantograph or reel dispensers attached to the roof structure or gantry.

CTE and Singh and Associates developed estimates for components of each project to build up a total cost estimate for infrastructure deployment projects. Key Assumptions of this approach include:

- Overhead gantry or roof structure to support pantograph or overhead reel
- One (1) plug-in reel or overhead pantograph per bus
- Three (3) buses per 100 kW charger
- Off-peak charging based on the adjusted Commercial Rate provided by Ames Municipal Electric during meeting on December 18, 2019 (and confirmed via email)
- Charge management software to sequence charging between buses
- No movement of buses overnight

CyRide stores fleet vehicles at a bus depot located at 601 North University Boulevard, Ames, Iowa **(Figure 6)**.

Figure 6: CyRide Bus Depot (601 North University Boulevard, Ames, IA)

Infrastructure projects must occur at the depot before CyRide can adopt large numbers of BEBs. Charging equipment must be installed onsite, power distribution infrastructure must be in place to connect the chargers to the local utility service, and the property must have the capacity to draw the required power from the grid.

To help forecast the general scope and timeline of the necessary infrastructure projects at the existing depot, two separate scenarios for deployment were evaluated:

- Initial deployment of two (2) buses in 2021
- Full-scale build out to accommodate up to seventeen (17) buses at CyRide's existing depot

In addition, a high level assessment of projects and costs was also completed for an as yet to be determined future depot to accommodate full fleet transition.

To help forecast the general scope and timeline of the necessary infrastructure projects at the current depot, CTE and Singh and Associates used the following assumptions in conjunction with the above scenarios:

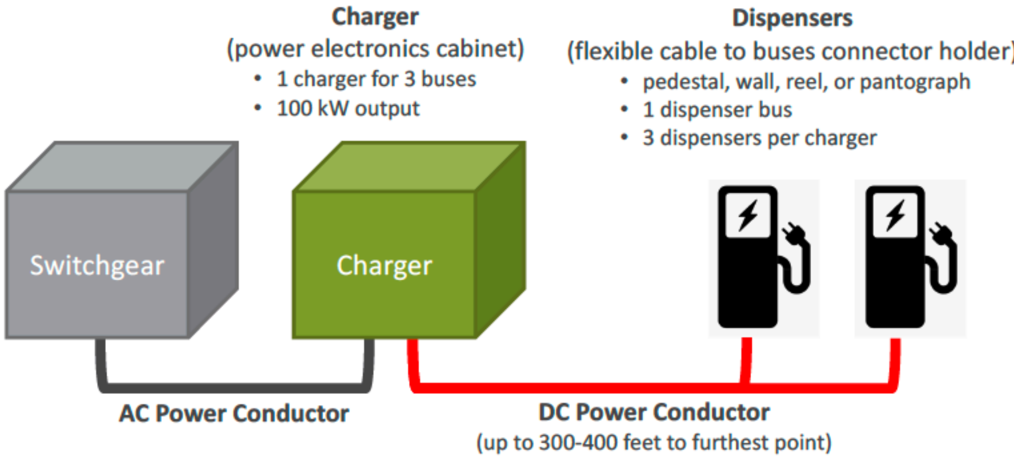
- Charging occurs based on the schedule developed in the operational summary. This includes during off-peak hours (weekdays from 12 am – 4 pm, 8 pm – 12 am, all day weekends) when the buses are parked at the depot. Charging is conducted using charge management functions which ensure only six chargers are operating at a time.
- Off-peak charging based on the adjusted Commercial Rate provided by Ames Municipal Electric during a meeting on December 18, 2019 (and confirmed via

email from email from Donald E. Kom, Director of Electrical Services for the City of Ames to Joel Donham with CTE on February 15, 2019)

- Three (3) buses per 100 kW charger
- Overhead roof structure to support pantograph or overhead reel
- One (1) plug-in reel or overhead pantograph per bus
- Programmable charge management software automatically controls the charging schedule
- No movement of buses overnight

Figure 7 provides an illustration of the charging system including power distribution (switchgear), charger, and dispensers.

Figure 7: Illustration of charger and dispenser configuration downstream of utility meter



4.1 Current Facility Assessment

The existing as-built drawings indicate that the facility has as 2000 amp (A), 120/208Y, 3 phase switchgear which has been confirmed in the field. The switchgear currently has an 80% rated 2000 amp main breaker. The incoming power from Ames Municipal Electric is provided from a 500 Kilovolt-amp (KVA) pad-mounted transformer located outside the building near the location of the switchgear (inside). Four (4) sets of 500 thousand circular mil (Kcmil) secondary conductors are fed underground in 4-inch conduits from the transformer into the bottom of the switchgear providing a maximum of 1520 amp capacity. Four (4) sets of 80% rated 500 Kcmil conductors allows for a connected full load of 1216 amps.

A review of the twelve-month record of the peak demand provided by Ames Municipal Electric indicated the highest peak demand reported was 264 KW, which equates to 780 amps peak. Based the available information from the utility and the NEC demand calculations, CyRide currently utilizes approximately 975 amps of its connected load capacity, leaving a surplus of 241 amps at 120/208V. The current service arrangement offers limited availability to accommodate the required 480-volt bus charging equipment without modifications to increase capacity.

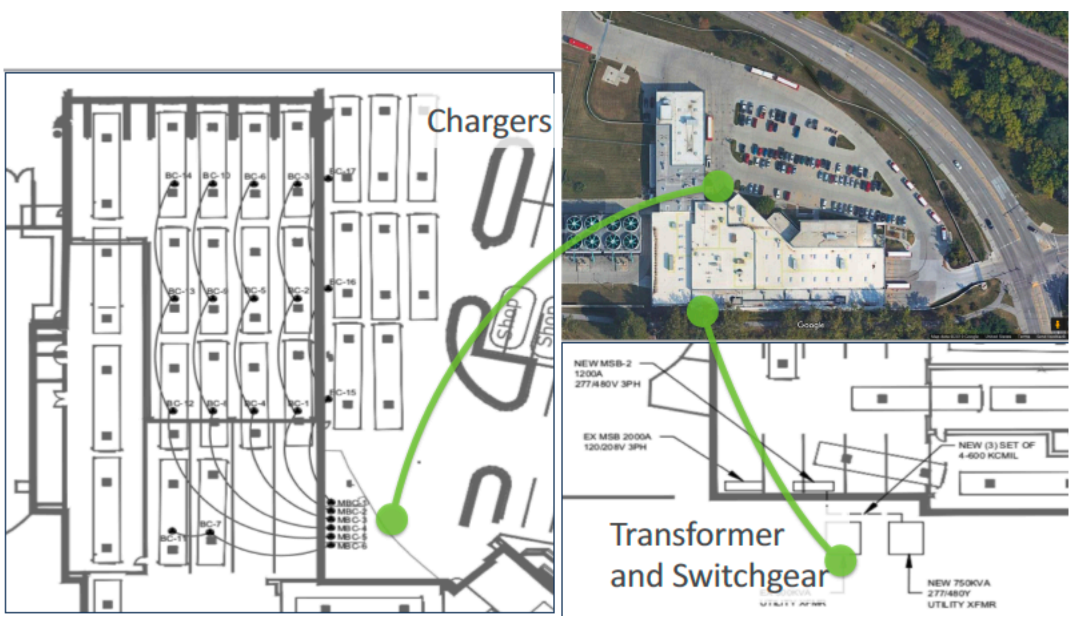
4.2 Infrastructure Upgrades

It is not economical or necessary to upgrade the power capacity and distribution of the depot all at once. Instead, CTE and Singh and Associates recommend a phased approach to increase the facility's power capacity and support the BEB fleet. Singh and Associates developed order of magnitude scope and cost estimates for each power project. Details of the power upgrade projects are discussed below:

4.2.1 Power Project 1: 2-Bus Initial Deployment Project

To accommodate the new 480-volt charging system and allow for future growth, an additional new 1,200 amp, 277/480Y, 3 phase service would be installed adjacent to the existing service. The existing 500 kVA utility provided transformer would remain in service and no modifications would be made to the current switchgear that currently serves the facility. The new service that feeds bus charging only would include a new, utility provided 750 kVA transformer and associated underground secondary feeders from the utility transformer to the new 1,200 amp switchgear. The new electrical service (transformer and switchgear) would be sized to accommodate the full (17) bus deployment scenario; however, initially only one (1) 175 amp breaker would be required to feed (1) 100 KW charger that would serve (2) remote charging stations for the initial bus deployment. The location of the new service (transformer and associated switchgear and the charger locations are depicted on **Figure 8**.

Figure 8: Location of New Utility Service and BEB Chargers



The charger would either be installed on a concrete pad or on an elevated steel pedestal to protect from potential flooding. The dispensers would be installed either on the wall of the building or in the ceiling above each BEB parking stall for the initial deployment. All the conduit, wiring and data cabling associated with the charging equipment would be installed and run overhead. A figure depicting the bus layout and charger and infrastructure locations is included in **Appendix 3**.

4.2.2 Power Project 2: 17-Bus Full-Scale Deployment Project

The new 277V/480Y service provided in the 2-bus initial deployment project would be sized to accommodate the remaining 15 buses. Five (5) additional 175 amp breakers would be required to be installed in the 1,200 amp switchgear. Five (5) additional 100 KW depot chargers that would provide connections to three (3) dispenser each for a total of (15) remote dispensers would also be installed. The chargers would be installed adjacent to the charger installed for the initial deployment project, either on a concrete pad or elevated steel pedestal. The additional dispensers, either reel type or pantograph style, would be installed on roof support structure. An example of an overhead outdoor gantry system and overhead pantograph style chargers is depicted in **Figure 9**. The dispenser (pantograph) are connected to a ground mounted charger.

Figure 9: BEBs charging using pantograph style charger at Amsterdam Airport

Although the gantry system would not be required at the facility, potential structural upgrades to roof structure to support pantograph or roof reels may be required. As discussed previously, wall or pedestal mounted dispensers are not practical for the 17-bus full-scale deployment. All the conduit, wiring and data cabling associated with the charging equipment would be installed and run overhead. The installation of the additional chargers, dispensers, and associated wiring and data cable would be split over two separate projects in 2023 and 2026 based on the projected bus deployment. Two (2) additional 100-kW chargers and six (6) remote dispensers and associated conductors and data cabling would be installed in 2023 to support deployment of six additional BEBs (two per year from 2023 to 2025). Three (3) additional 100-kW chargers and nine (9) remote dispensers and associated conductors and data cabling would be installed in 2026 to support deployment of nine (9) additional BEBs (two per year from 2026 to 2029 and one in 2030).

4.2.3 Future BEB Deployment at New Facility

Future considerations for construction of a new facility include providing adequate electrical capacity to support charging of vehicles and designing the roof structure for the new facility to support pantograph or overhead reels. The size of the BEB fleet housed at the new facility is unknown as further detailed evaluation of routes could indicate that more blocks are feasible, if technology improves such that additional existing blocks are feasible, or if the blocking schedule is changed to further accommodate BEB deployment.

The infrastructure to support BEBs at a new facility, at a to be determined location was developed incrementally based on adding (15) electric buses at a time at the facility up to 120 BEBs. The incremental needs for every additional 15 buses added to the depot includes one (1) additional section of switchboard with five (5) 175A breakers and five (5) 100 KW chargers that would serve fifteen (15) remote dispensers. The chargers would be installed outside and adjacent to the locations of each group of fifteen (15) buses. The chargers would be installed on a concrete pad or elevated on a steel pedestals to avoid water damage. The dispensers would be overhead pantograph style or overhead cable reel. All the conduit, wiring and data cabling associated with the charging equipment would be installed and run overhead. A figure depicted a conceptual charging layout for 120 buses at a future facility is included in **Appendix 3**.

5 Fleet/Maintenance Review

5.1 Fleet Maintenance Data

One of the anticipated benefits of moving to a BEB fleet is reduced maintenance costs. Anecdotal evidence suggest that a transit agency may attain 30% to 50% in maintenance cost savings. This is due to the fact that there are fewer fluids to replace (no engine oil or transmission fluid), fewer brake changes due to regenerative braking, and far fewer moving parts than on a diesel bus.

Whether or not that anecdotal evidence is proven true remains to be seen. There is limited data available on early deployments and many early deployments are from new manufacturers where production quality issues manifest as additional maintenance requirements. The largest data set to evaluate maintenance issues to date is a comparison study of BEB and compressed natural gas (CNG) buses conducted by the United Stated Department of Energy National Renewable Energy Laboratory (NREL) at Foothill Transit. Data collected by NREL during the study period (April 2014 through July 2015) indicates the following results:

- BEBs recorded an average of 9,331 miles between road calls (MBRC) while CNG buses recorded an average of 45,547 MBRC.
- Propulsion system related failures occurred a frequency of 25,078 MBRC for the BEBs and 91,093 MBRC for the CNG buses.
- Overall fleet availability was 90% for the BEBs and 94% for the CNG buses
- Maintenance Costs average $0.16 / mile for BEBs and $0.18 / mile for the CNG buses
- Although there were more road calls, the BEBs spent less time in maintenance than the CNG buses (178 hours vs. 233 hours)
- The BEBs averaged 17.48 miles per gallon diesel equivalent (MPGDE) while the CNG buses averaged 4.51 MPGDE

Full results from the study are available in the *Foothill Transit Battery Electric Bus Demonstration Results* prepared by Leslie Eudy, Robert Prohaska, Kenneth Kelly, and Matthew Post. Results from NREL research indicate an approximately 37% reduction in maintenance costs for BEBs relative to diesel.

5.2 Available BEB Models

Table 5 provides information about currently available or planned 40’ bus models in the United States. The data including battery capacity, nominal range, and curb weight were provided in published information from the bus original equipment manufacturers (OEMs) and have not been independently verified by CTE.

Table 5: Currently Available or Planned 40' Bus Model Details

OEM	Model	Battery Capacity (kWh)	Nominal Range (miles)	Altoona Tested	Curb Weight (lbs.)
BYD	K9M	348	156	Yes	31,702
	K9MC	496	250	No	33,510
Complete Coach Works (CCW)	ZEPS	280, 373, 465 & 558	NA	No	NA
El Dorado	Access BE (planned)	440	130	No	NA
GILLIG	TBD	TBD	TBD	No	NA
Green Power Bus	EV 350	320	>185	No	NA
New Flyer	Xcelsior CHARGE	267, 454, 545	114, 215, 260	Yes	30,500
Proterra	FC	94	67-72	Yes	29,365
	FC+	126	72-87	Yes	31,000
	XR	220	136-164	Yes	27,730
	XR+	330	193-238	Yes	29,365
	E2	440	251-302	Yes	31,000
	E2+	550	303-367	No	31,426
	E2 Max	660	350-426	No	33,061

6 Financial/Economic Assessment

Based on discussions with CyRide, the lifecycle cost evaluation was prepared based on the local cost share to CyRide after contributions from external funding sources, rather than the full cost born by all funding partners. The financial assessment uses cost inputs below to complete a full lifecycle evaluation for deployment of BEBs:

- Bus capital costs
- Bus maintenance and major component replacement costs
- Fueling operating costs
- Infrastructure and facility upgrade capital costs

In addition to the lifecycle costs analysis, CTE also generated a lifecycle emission analysis by estimating greenhouse gas emissions.

6.1 Bus Capital Costs

CTE and CyRide created cost assumptions for this analysis for 40’ low-floor transit buses for comparison of diesel and BEBs. Key assumptions are:

- Bus costs are based on recent CyRide procurements and industry quotes
- Bus costs are inclusive of taxes and configurable options
- Cost projections in future years are based on 2019 bus costs since there was no basis for either cost increases or decreases over time
- Local cost to CyRide is based on 80% federal cost share of the bus purchase price
- Costs for spare parts and diagnostic tools are not included in the bus purchase price

Conventional wisdom dictates that the cost of BEBs will decrease over time due to higher production volume and competition from new vendors entering the market. While this was true in the initial development of BEBs, costs appear to have leveled out. However, vendors have added more battery storage over the same timeframe, increasing range capabilities without increasing base costs. **Table 6** provides bus cost estimates used in this analysis.

Table 6: Price for a 40’ Low-Floor Transit Bus by Fuel Type

Cost	Diesel	Battery-Electric
Total Vehicle Cost	$ 450,000	$ 800,000
Local Cost to CyRide	$ 90,000	$ 160,000

These costs were utilized to develop the total cost to purchase vehicles for the two (2) bus initial deployment project as well as the 17 bus full-scale deployment at the current CyRide facility and compare to the cost of diesel buses as provided in **Table 7.**

Table 7: Cost Comparison for Vehicle Deployment

Cost	2-Bus Initial Project		17-Bus Full-Scale	
	Diesel	BEB	Diesel	BEB
Total Vehicle Cost	$ 900,000	$ 1,600,000	$ 7,650,000	$ 13,600,000
Local Cost to CyRide	$ 180,000	$ 320,000	$ 1,530,000	$ 2,720,000

Results from this analysis will be used in the total lifecycle cost evaluation to develop the total lifecycle cost to CyRide for operating BEBs.

6.2 Bus Maintenance Costs

As discussed in **Section 5**, maintenance cost savings are expected to be significant for BEBs relative to diesel buses due to the fact that there are fewer fluids to replace (no engine oil or transmission fluid), fewer brake changes due to regenerative braking, and far fewer moving parts than on a diesel bus.

CTE utilized labor and maintenance costs provided by CyRide to prepare a weighted average cost per mile for their 40’ bus fleet as the basis for the maintenance cost evaluation. A 37%

cost reduction was applied to the labor and maintenance cost per mile for a diesel bus to estimate costs for a BEB bus based on NREL research. **Table** 8 provides the assumptions to support the maintenance cost evaluation.

Table 8: Labor and Maintenance Cost Per Mile by Vehicle Type

Vehicle Type	Estimate	Source
Diesel	$0.57/mile	CyRide-weighted average cost for 40' fleet
BEB	37% less than diesel	U.S. DOE NREL

In addition to labor and maintenance, CTE estimated the cost impact of the mid-life overhauls for major components for each vehicle type. Mid-life overhaul estimates for the diesel bus were provided by CyRide while the cost for a mid-life battery replacement was based on vendor quotes.

Table 9: Mid-Life Overhaul Cost Estimate

Vehicle Type	Overhaul Scope	Estimate	Source
Diesel	Engine and Transmission Rebuild	$ 35,000 per bus	CyRide estimate
BEB	Battery Replacement	$ 200,000 per bus	Bus Manufacturer

Based on the estimated annual mileage of 30,000 miles per vehicle, the average annual maintenance cost for a diesel bus is approximately $17,100 while a BEB is approximately $10,800; however, one-time mid-life overhaul costs are approximately $200,000 on a BEB if the battery requires replacement during the life of the vehicle while a diesel bus is only estimated at $35,000. Based on the typical 18 year life for CyRide vehicles, a battery replacement is expected to be required, though current batteries have not been in service long enough to understand the rate of degradation when the batteries are in transit service.

Current battery warranties range from approximately 3 years to 12 years at anywhere from 70% to 80% state of health based on the original battery capacity. Bus OEMs offer extended warranty programs or battery leasing options to mitigate the effects of battery degradation by guaranteeing a minimum state of health of the battery throughout the duration of the extended warranty or lease period. A capital purchase for an extended warranty may be worthwhile for CyRide considering the 18-year vehicle life, though CTE is not aware of any bus OEMs that currently offer an extended warranty of this duration.

6.3 Fueling Operating Costs

As discussed on the Operational Review, CTE utilized a screening level assessment of the routes and blocks to assess energy requirements for deployment of BEBs at CyRide.

Fuel cost estimates are based on assumptions included in **Table 10**:

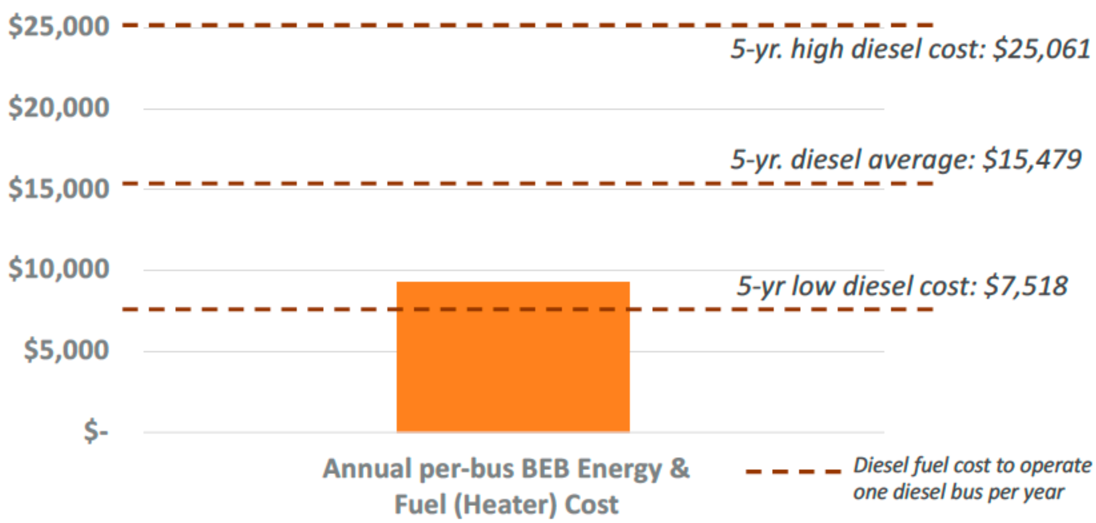
Table 10: Fuel Cost Assumptions

Fuel	Estimate	Source
Diesel	$2.10/gallon	CyRide
Electricity	$0.0644/kWh	Ames Municipal Electric, adjusted commercial rate

- Diesel cost used for the evaluation was based on a 5-year average of diesel fuel cost provided by CyRide.
- The average electricity rate is based on the adjusted commercial rate provided by Ames Municipal Electric as discussed in the Operational Review; billing of demand charges is based on billed demand only between 4 PM and 8 PM on weekdays.
- The average fuel efficiency of the current CyRide fleet is $4.07 per gallon. The fuel efficiency was calculated based on a review of bus efficiency data provided by CyRide.
- Assume that all BEBs are equipped with a diesel fired auxiliary heater that operates for 3-months per year at 10 hours per day; typical diesel fired auxiliary heater utilizes less than 1 gallon of diesel fuel per hour.
- The average CyRide 40' diesel bus operates for 30,000 miles per year.

A comparison of the fuel costs associated with operating a diesel bus and BEB for one year are provided in **Figure 10**.

Figure 10: Annual Fuel Cost Comparison Between Diesel and BEB



Results indicate that a typical BEB in service at CyRide is expected to cost approximately $9,200 in electric and fuel costs (for diesel fired auxiliary heat) while a diesel bus is expected to cost approximately $15,500 to operate based on the 5-year-average diesel fuel costs. Based on the analysis, operation of a BEB in CyRide service is expected to reduce fuel costs by approximately

$6,300 per year per bus. Individual costs will vary depending on the route/blocks that the BEBs are deployed to service; however, fuel cost savings will increase with increased operation. Results from the fuel cost evaluation will be utilized to prepare the lifecycle cost evaluation.

6.4 Infrastructure and Facility Upgrade Costs

Cost estimates were developed by Singh and Associates for the 2-Bus Initial Project and 17-Bus Full-Scale deployment project. Costs are based on current year construction and equipment costs and do not include escalation factors for future years. The estimates were developed at a +/- 20% level of accuracy to support project planning and include contingency. Total costs as well as local costs to CyRide are considered in the cost evaluation. Estimated costs to CyRide for the 2-Bus Initial Project assumes that approximately 85% of the costs are covered by FTA Low or No Emission Vehicle grant or Volkswagen Settlement Funding (estimated at $360,000 for the project). The costs to CyRide for the 17-Bus Full-Scale deployment assume that 80% of the costs are covered through Bus and Bus Facilities Grant funding. Please note that the costs for infrastructure upgrades do not include any potential costs required to complete structural upgrades to the existing facility to support overhead pantograph or overhead reels as this was not part of the scope of the evaluation, though an engineering evaluation should be completed during the design. Additional discussion regarding funding opportunities to support BEB deployment are included in Section 6.7 of this report. A summary of the infrastructure costs associated with BEB deployment developed by CTE and Singh and Associates is included in **Table 11**.

Table 11: Infrastructure Cost Evaluation

Unit	2-Bus Initial Project	17-Bus Full-Scale
Transformer Upgrade	$ 22,000	$0
Switchgear and Feeders	$ 73,050	$ 13,750
Conduit, Wiring, Terminations	$ 19,550	$ 109,500
Equipment Connections	$ 19,900	$ 75,150
Chargers	$ 100,000	$ 650,000
Contractor General Conditions, Bonding, Fees	$ 18,300	$ 29,800
Contingency	$ 21,400	$ 34,800
Engineering Design/Construction	$ 48,000	$ 140,000
Total	**$ 322,200**	**$ 1,053,000**
-20% Total	$ 257,760	$ 842,400
+20% Total	$ 386,640	$ 1,263,600
Local Cost to CyRide	**$ 35,030**	**$ 210,600**

Please note that the transformer provided by Ames Municipal Electric for the 2-Bus Initial Project is of sufficient size to support the 17-Bus Full-Scale deployment at the existing facility. As a result, no additional cost is required for transformer upgrade. Although the cost for the transformer upgrade is captured in the total infrastructure upgrade cost for the 2-Bus Initial Project, the transformer will be provided to CyRide as an in-kind donation by Ames Municipal Electric. Results from the infrastructure cost evaluation will be used to support development of the lifecycle cost evaluation.

6.5 Lifecycle Cost Evaluation

CTE prepared lifecycle cost evaluations for the 2-Bus Initial Project and 17-Bus Full-Scale Project based on an 18-year vehicle life. The lifecycle evaluations utilized the bus capital costs, infrastructure upgrade cost estimates, fueling costs, and maintenance costs to evaluate the total cost of ownership. The costs are based on 2019 costs with no escalation factor for future years. Based on discussions with CyRide, the lifecycle evaluation was completed specifically to assess the total local cost of ownership to CyRide. As a result, capital costs that are expected to be covered by federal funding as discussed in **Section 6.1** and **6.4** (e.g. portions of the bus purchase and infrastructure upgrades) are not included in the evaluation. A summary of the total local cost of ownership is included in **Table 12**, **Figure 11** and **Figure 12**.

Table 12: Total Local Cost of Ownership

Unit	2-Bus Initial Project		17-Bus Full-Scale	
	Diesel	BEB	Diesel	BEB
Bus Capital	$ 180,000	$ 59,000[1]	$1,530,000	$ 2,420,000
Maintenance	$ 685,600	$ 790,990[2]	$ 5,827,600	$ 6,696,500
Fuel	$ 557,200	$ 298,700	$ 4,736,600	$ 2,356,600
Infrastructure	$ 0	$ 35,030	$ 0	$ 210,600
Total Local Cost of Ownership	**$ 1,422,800**	**$ 1,183,720**	**$ 12,094,000**	**$ 11,684,000**

Please note that for the total local cost of ownership evaluation for the 2-Bus Initial Project, bus capital costs include $20,000 for the local share of the bus purchase, $10,000 for spare parts purchase, and $29,000 for consultant support in vehicle design and deployment. Maintenance costs include an additional $1,590 in local training costs.

Figure 11: Total Local Cost of Ownership for 2-Bus Initial Project

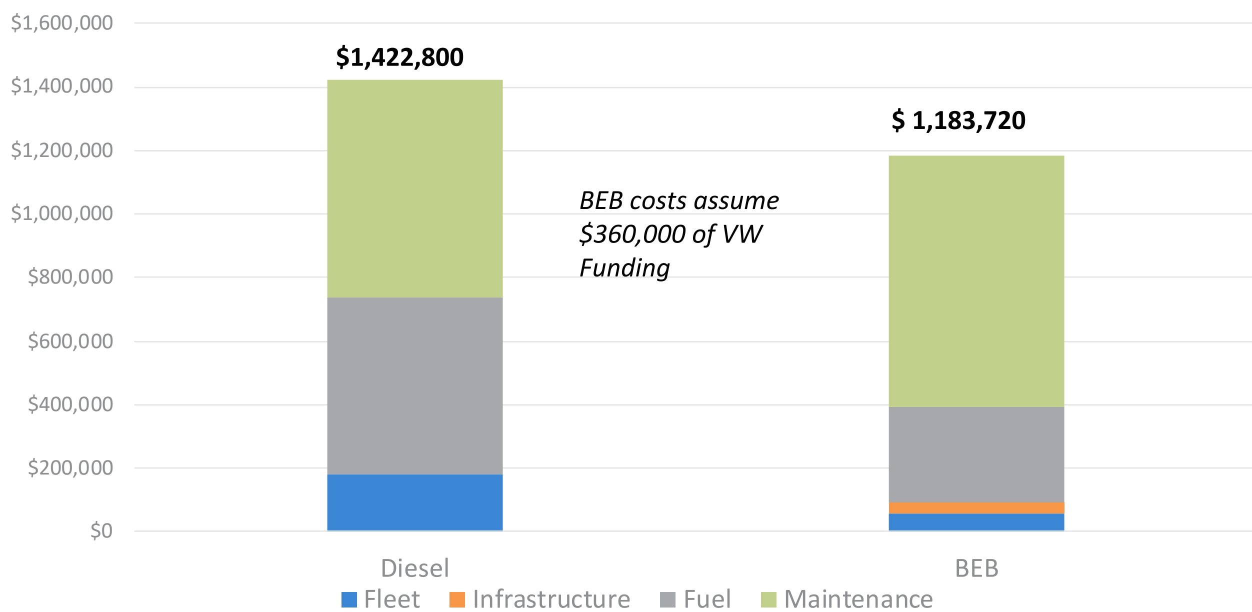
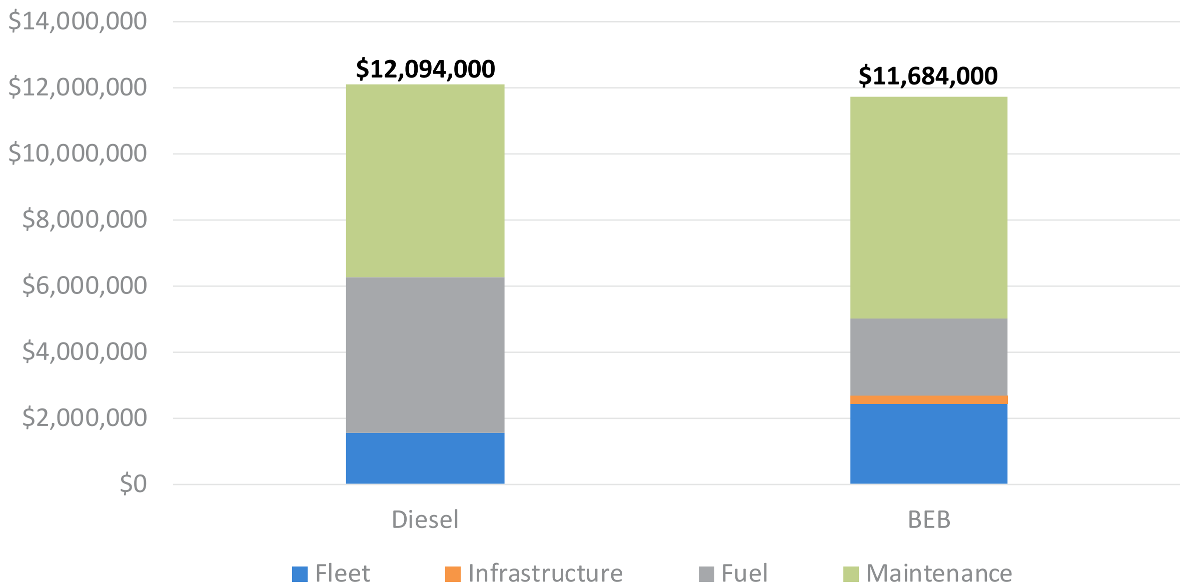


Figure 12: Total Local Cost of Ownership for 17-Bus Full-Scale



A review of the results indicate that, assuming federal funding is available and maximized to support BEB deployment, the total local cost of ownership to CyRide is reduced by deploying BEBs for fixed-route service in place of diesel buses.

6.6 Environmental Benefits of BEBs

In addition to reduced total local cost of ownership, there are environmental benefits for deploying BEBs at CyRide. The primary environmental benefits of BEBs are reduced local air pollution and reduced emissions of greenhouse gases. Based on a 17 BEB fleet, and a current fleet average 30,000 miles of operations, the CyRide BEB fleet could prevent the emission of approximately 1 million pounds of carbon dioxide and 2.5 million pounds of greenhouse gas emissions per year, which is equivalent to the carbon removed from the air by approximately 1,372 acres of trees.

A table detailing net annual carbon dioxide emissions reductions associated with operating BEBs is included in **Table 13.** Powerplant emissions were calculated based on Energy Information Administration (EIA) Iowa electric power industry emissions for natural gas generation.

Table 13: Annual Carbon Dioxide Emissions Reductions

Vehicles	Tailpipe Emissions Reductions (lbs. CO2)	Powerplant Emissions (lbs. CO2)	Net Emissions Reductions (lbs. CO2)
2	295,013	172,452	122,561
17	2,507,615	1,465,844	1,041,770

6.7 BEB Funding Opportunities

CyRide can seek funding for BEBs through several state and federal programs intended to support both zero emission and conventional vehicles. The major sources of funding are:

- FTA Low or No Emission Vehicle Program (Low-No Program)
- FTA Bus and Bus Facilities Program
- The Iowa Allocation of the Volkswagen Diesel Emissions Settlement
- EPA Diesel Emissions Reduction Act (DERA) Grant

6.7.1 FTA Low or No Emission Vehicle Program

The FTA offers competitive funding through the Low or No Emission Vehicle Program (Low-No). The Fixing America's Surface Transportation (FAST) Act makes funding available from the Mass Transit Account of the Highway Trust Fund to support the program. The statutory reference for the program is 49 U.S. Code §5339 – Grants for buses and bus facilities. The Low or No Emission Grants are included in §5339 (c). Under the FAST Act, $55 million per year is authorized until fiscal year 2020. Additional funds may be appropriated to the fiscal year funding (this occurred in FY 2018). In both 2018 and 2019, $30 million dollars in additional funding has been allocated to the Low-No program.

Funding is awarded competitively under the Low-No program in response to a Notice of Funding Opportunity (NOFO) issued by FTA. The NOFO is typically issued in the spring (FY16 - 3/29/16; FY17: 4/27/17; FY18 – 4/23/18; FY19– 3/18/19). Applications are due approximately 60 days after release of the NOFO.

As stated in the FY18 NOFO, "The Low or No Emission Bus Program (Low-No Program) provides funding to State and local governmental authorities for the purchase or lease of zero-emission and low-emission transit buses, including acquisition, construction, and leasing of required supporting facilities such as recharging, refueling, and maintenance facilities. FTA recognizes that a significant transformation is occurring in the transit bus industry, with the increasing availability of low and zero emission bus vehicles for transit revenue operations." Eligible applicants include direct recipients of FTA grants under the Section 5307 Urbanized Area Formula program, states, and Indian Tribes. Projects in rural (non-urbanized) areas must be submitted as part of a consolidated state proposal. States and other eligible applicants also may submit consolidated proposals for projects in urbanized areas.

The maximum federal share for vehicles under the Low-No Program is 85% and 90% for the cost of equipment or facilities. Applicants may request up to 0.5% of requested grant funding for workforce development and an additional 0.5% for costs associated with training at the National Training Institute.

One of the most unique characteristics of the Low-No Program is that applicants are allowed to name project partners. Project partners may include, but are not limited to, specific vehicle manufacturers, equipment vendors, owners or operators of related facilities, or project consultants. If an application that involves such a partnership is selected for funding, the competitive selection process will be deemed to satisfy the requirement for a competitive procurement under 49 U.S.C. 5325(a) for the named entities.

To date, FTA has completed three of the five rounds of Low-No funding authorized in the FAST ACT. The table below summarizes the award history for FY 16, FY17, and FY18.

Table 14: Low-No program applications and awards history

Fiscal Year	Applications Received/ $Requested	Awards	Average Award	Minimum Award	Maximum Award
FY16	101/$446M	20	$2,750,000	$683,400	$3,905,378
FY17	128/$515M	51	$1,078,275	$408,130	$1,750,000
FY18	149/$557M	52	$1,624,019	$403,266	$2,290,000

6.7.2 FTA Bus and Bus Facilities Program

The FTA offers competitive funding through the Bus and Bus Facilities Program. The statutory reference for the program is 49 U.S. Code §5339 – Grants for buses and bus facilities. The Buses and Bus Facilities Competitive Grants are included in §5339 (b). Under the FAST Act, between $213 million and $289 million per year is authorized until fiscal year 2020. Additional funds may be appropriated each fiscal year funding (this occurred in FY 2018).

Funding is awarded competitively under the Bus and Bus Facilities program in response to a NOFO issued by FTA. For the past three fiscal years, the NOFO was released in either the spring or summer (FY16 - 3/29/16 in conjunction with the Low-No Program; FY17: 7/18/17; FY18 – 6/21/18). Applications are due approximately 45 days after release of the NOFO.

As stated in the FY18 NOFO, the Grants for the Bus and Bus Facilities Program authorizes FTA to award funds for capital projects to replace, rehabilitate, purchase or lease buses and related equipment and to rehabilitate, purchase, construct or lease bus-related facilities. Eligible applicants include designated recipients of FTA funding that allocate funds to fixed route bus operators, states or local governmental entities that operate fixed route bus service, and Indian tribes. Eligible subrecipients include all otherwise eligible applicants and also private nonprofit organizations engaged in public transportation.

The maximum federal share for projects selected under the program is 80% of the net project cost, with the exception of projects that acquire vehicles that are compliant with the Clean Air Act and/or the Americans with Disabilities Act. Projects meeting these criteria are eligible for a maximum federal share of 85% of net project cost.

An emerging trend associated with this funding is the increasing number of awarded projects that reference the purchase of BEBs and supporting infrastructure. In FY 2016, awarded projects referenced CNG, hybrid-electric, and biodiesel bus purchases. In FY 2017, about 5.5%

of the funding went to projects referencing BEBs and the percentage almost doubled in the FY 2018 awards, with almost 10% of the funding being awarded to BEB projects.

6.7.3 Volkswagen Settlement

A complaint was filed against Volkswagen alleging Clean Air Act violations related to Volkswagen's 2.0 and 3.0 liter diesel engines in MY 2009-2016 vehicles. Settlements were reached in October 2016 (2.0 liter engines) and in February 2017 (3.0 liter engines). The settlement has three components:

- Vehicle Buyback and Modification for Volkswagen Owners ($10.8B)
- Zero Emission Vehicle Investment (national program and California program ~$2B)
- Environmental Mitigation Trust (for the states to reduce NOx emissions ~$2.9B)

Each state is eligible to become a beneficiary under the trust and the allocations are based on the number of affected vehicles registered in the state. Iowa's allocation is $20,179,540. The national settlement decree outlines eligible mitigation activities. It is then up to states to draft a Beneficiary Mitigation Plan (BMP) that outlines how the state plans to use the funds allocated under the Environmental Mitigation Trust. The Iowa Department of Transportation was designated as the state's official beneficiary. The state's BMP was submitted to the Trustee on August 8, 2018. It is important to note the BMP is not binding and can be revised. According to the state's BMP, the Iowa DOT expects to have at least three application cycles with awards totaling approximately $6 million in each cycle. The Iowa BMP includes the five categories of projects and a targeted percentage of overall funding:

- Class 4-8 School Bus, Shuttle Bus, or Transit Bus (45%)
- Freight Trucks and Port Drayage Trucks (15%)
- Non-Road Transport and Equipment (10%)
- Zero Emission Vehicle Supply Equipment (15%)
- Diesel Emissions Reduction Act (DERA) Grant Program (15%)

Category 1 includes repowering or replacing a 2009 engine model year or older diesel bus with a new diesel, alternate fueled, or all-electric engine or bus. Replaced engines and buses must be scrapped.

The state opened the application period for the first funding cycle in late November 2018 and applications were due **January 18, 2019**. Two more years of VW funding are likely in 2020 and 2021. This first cycle includes three of the five categories identified in BMP: Class 4-8 School Bus, Shuttle Bus, or Transit Bus; Freight Trucks and Port Drayage Trucks; and Non-Road Transport and Equipment. The funding available in the first cycle for the bus category is $3,150,000 (total targeted funding included in the Beneficiary Mitigation Plan is $9,450,000). Funding limits vary by fuel type, with an all-electric replacement being eligible for up to a maximum of $300,000 or 45% of total costs per vehicle, whichever is less. Applicants may also request up to $10,000 per vehicle for charging infrastructure. The project must be completed within two years of award, which can be a short timeframe for a bus and/or infrastructure procurement.

The current Beneficiary Mitigation Plan is available on Iowa DOT's VW Settlement website:

https://www.iowadot.gov/vwsettlement/beneficiary.aspx

The Volkswagen Settlement Environmental Mitigation Trust Funding Cycle 1 – Implementation Guidelines are available at: https://www.iowadot.gov/vwsettlement/

Links to required application materials are also available on this page

Iowa DOT is accepting questions and posting responses at:

https://www.iowadot.gov/vwsettlement/faq.aspx

6.7.4 DERA Program

The DERA program was authorized through the Energy Policy Act of 2005. The program was established to provide grants, loans and rebates to support reductions in diesel emissions through advanced engine configurations and emissions controls. A base level of Federal funding is provided with an additional bonus allotment available to match state-provided program funding. In 2018 Iowa received a base allotment of $275,123, and added $300,000 of voluntary state funding to receive bonus additional federal allotment of $137,562. The resulting program total was $712,685. Iowa has elected to contribute a portion of their total VW settlement allotment to increase future funding levels for the DERA program.

Eligible projects include the purchase of new low emissions transit buses (including BEBs) being used to replace existing diesel buses. BEBs are funded at 45% with a mandatory fleet owner contribution of 55%.—federal funds cannot be used for the cost share. Likewise, electrified parking spaces can be funded at 30% with a 70% local contribution.

The Iowa DERA program has previously been used to fund battery electric transit buses. The Des Moines Area Regional Transit Authority (DART) was awarded $378,000 from the 2017-2018 program to replace a diesel transit bus with a BEB.

Application information can be found at the Iowa DOT webpage: https://iowadot.gov/dera/. The 2019 Application is not yet available; however, applications are anticipated to be due in the fall as they were for the 2018 program (11/9/18).

7 BEB Best Practices

CTE has compiled a list of best practices for BEB deployment based on literature review as well as experience with over $300 Million in BEB deployment projects. Best practices are categorized as follows:

- Planning
- Stakeholder Engagement
- Design
- Procurement
- Bus Build
- Bus Acceptance
- Training
- Operations
- Maintenance

A table describing the BEB best practices is included in **Appendix 4**.

8 Training

The BEB Training Plan should include the following:

- 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

CyRide should identify operations and maintenance staff that require training and will work with the OEM to develop the internal training requirements and program materials. Training is recommended for all staff at CyRide to familiarize them with BEB operations.

Operator training is typically provided by the OEM to agency trainers. CyRide may wish to identify specific operators to complete training based on routes/blocks identified for the initial project BEB operations of the. 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 is typically completed by a combination of the bus OEM and individual component manufacturers. Maintenance training is typically provided to agency Maintenance Trainers, as well as specifically identified key maintenance staff that are expected to work on the BEBs.

Maintenance training will 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
- High Voltage Systems
- Depot Charger
- HVAC

Final operation and maintenance manuals, in hard copy and electronic version, will be provided by the bus OEM upon delivery of the first BEB. CyRide should coordinate training for local first responders with the bus OEM and their subcontractors, as required.

The following table provides an estimate of the number of training hours that are typically provided by the equipment OEM as part of the bus purchase. Please note that specific high voltage training is not typically provided by the bus OEM; however, familiarization with the high voltage systems of the BEBs are included in the typical Operator and Maintenance Training. As CyRide currently operates diesel hybrid buses, specific high voltage training may not be required.

Table 15: Typical Training Hours and Topics Provided by Bus OEM

Description	Quantity (Hours)
BEB Orientation	4 - 8
Operator Training	8 - 16
Maintenance Training	32 - 48
Depot Charger Maintenance Training	16 – 32

Bus OEMs may also work with manufacturers of specific components (e.g. propulsion system, HVAC, doors, ramp, etc.) to provide further specific training as necessary.

Appendices

1. CyRide Block Feasibility Estimates Based on Generic Bus
2. Current Fleet Inventory
3. Conceptual Depot Design
4. BEB Best Practices
5. CTE Qualifications

Appendix 1: CyRide Block Feasibility Estimates Based on Generic Bus

Screening Model Assumes
- 450 kWh battery storage, 80% of which available for routine operations
- End of Life Condition: 70% of Original Energy Storage Capacity

Academic Year Daily Blocks (p. 1 of 2)

						Feasibility vs. Scenario		
					Total	Hard Conditions		Mild Conditions
Block	**Bus Type**	**Out**	**In**	**Duration**	**Mileage**	**New Batteries**	**End of Life Batteries**	**New Battery**
Rt.#1-1	40' Bus	6:32	21:19	14:47	156	Possibly	Possibly	Unlikely
Rt.#1-2	40' Bus	6:47	0:19	17:32	186	Unlikely	Unlikely	Unlikely
Rt.#1-3	40' Bus	7:02	18:53	11:51	126	Possibly	Possibly	Likely
Rt.#1-4	40' Bus	6:32	21:59	15:27	163	Possibly	Possibly	Unlikely
Rt.#1-5	40' Bus	7:32	19:23	11:51	126	Possibly	Possibly	Likely
Rt.#1-6	40' Bus	7:47	0:59	17:12	186	Unlikely	Unlikely	Unlikely
Rt.#2-1	40' Bus	6:32	23:55	17:23	199	Unlikely	Unlikely	Unlikely
Rt.#2-2	40' Bus	6:52	18:54	12:02	139	Possibly	Possibly	Likely
Rt.#2-3	40' Bus	6:33	23:15	16:42	192	Unlikely	Unlikely	Unlikely
Rt.#2-4	40' Bus	7:32	18:06	10:34	124	Likely	Possibly	Likely
Rt.#3-1	40' Bus	6:30	0:56	18:26	200	Unlikely	Unlikely	Unlikely
Rt.#3-2	40' Bus	7:20	21:16	13:56	148	Possibly	Possibly	Likely
Rt.#3-3	40' Bus	7:30	10:06	2:36	35	Likely	Likely	Likely
Rt.#3-4	40' Bus	7:40	19:11	11:31	125	Possibly	Possibly	Likely
Rt.#5-1	40' Bus	6:45	19:08	12:23	155	Possibly	Possibly	Unlikely
Rt.#6-1	40' Bus	6:12	10:32	4:20	56	Likely	Likely	Likely
Rt.#6-2	40' Bus	6:42	9:32	2:50	39	Likely	Likely	Likely
Rt.#6-3	40' Bus	7:12	20:22	13:10	157	Possibly	Possibly	Unlikely
Rt.#6-4	40' Bus	7:52	19:52	12:00	140	Possibly	Possibly	Likely
Rt.#6-5	40' Bus	8:52	20:52	12:00	140	Possibly	Possibly	Likely
Rt.#7-1a	40' Bus	7:00	9:50	2:50	30	Likely	Likely	Likely
Rt.#7-1b	40' Bus	14:30	17:20	2:50	30	Likely	Likely	Likely
Rt.#7-2	40' Bus	7:15	10:05	2:50	30	Likely	Likely	Likely
Rt.#9-1	40' Bus	7:00	22:05	15:05	176	Possibly	Possibly	Unlikely
Rt.#9-2	40' Bus	7:20	17:47	10:27	124	Likely	Possibly	Likely

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Block	Bus Type	Out	In	Duration	Total Mileage	Feasibility vs. Scenario: Hard Conditions – New Batteries	Hard Conditions – End of Life Batteries	Mild Conditions – New Battery
Rt.#11-1	40' Bus	7:30	18:41	11:11	115	Likely	Possibly	Likely
Rt.#11-2	40' Bus	7:37	18:11	10:34	109	Likely	Possibly	Likely
Rt.#11-3	40' Bus	7:44	18:26	10:42	109	Likely	Possibly	Likely
Rt.#11-4	40' Bus	7:51	9:31	1:40	30	Likely	Likely	Likely
Rt.#11-5	40' Bus	7:58	9:38	1:40	30	Likely	Likely	Likely
Rt.#12-1a	40' Bus	7:05	10:15	3:10	35	Likely	Likely	Likely
Rt.#12-1b	40' Bus	14:35	17:45	3:10	35	Likely	Likely	Likely
Rt.#12-2a	40' Bus	7:25	9:55	2:30	29	Likely	Likely	Likely
Rt.#12-2b	40' Bus	14:55	17:25	2:30	29	Likely	Likely	Likely
Rt.#14-1	Cut Away Bus	6:43	19:06	12:23	140	-	-	-
Rt.#21-1	40' Bus	7:00	22:37	15:37	129	Possibly	Possibly	Likely
Rt.#21-2	40' Bus	7:08	17:58	10:50	86	Likely	Possibly	Likely
Rt.#21-3	40' Bus	7:16	15:58	8:42	70	Likely	Likely	Likely
Rt.#23-1	60' Articulated Bus	6:30	22:34	16:04	116	Unlikely	Unlikely	Unlikely
Rt.#23-2	60' Articulated Bus	6:45	18:11	11:26	77	Unlikely	Unlikely	Unlikely
Rt.#23-3	60' Articulated Bus	7:08	18:18	11:10	74	Unlikely	Unlikely	Unlikely
Rt.#23-4	60' Articulated Bus	7:12	17:57	10:45	71	Unlikely	Unlikely	Unlikely
Rt.#23-5	60' Articulated Bus	7:16	17:29	10:13	68	Unlikely	Unlikely	Unlikely
Rt.#23-6	60' Articulated Bus	7:20	16:37	9:17	62	Unlikely	Unlikely	Unlikely
Rt.#23-7	40' Bus	7:24	16:10	8:46	59	Likely	Likely	Likely
Rt.#25-1	40' Bus	7:00	22:30	15:30	220	Unlikely	Unlikely	Unlikely
Rt.#25-2	40' Bus	7:30	22:00	14:30	208	Unlikely	Unlikely	Unlikely
Rt.#25-3	40' Bus	7:40	18:22	10:42	160	Possibly	Possibly	Unlikely
Rt.#25-4	40' Bus	8:00	17:52	9:52	148	Possibly	Possibly	Likely
Rt.#25-5	40' Bus	8:10	18:02	9:52	148	Possibly	Possibly	Likely

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Block	Bus Type	Out	In	Duration	Total Mileage	Feasibility vs. Scenario: Hard Conditions: New Batteries	Hard Conditions: End of Life Batteries	Mild Conditions: New Battery
X101	40' Bus	7:10	11:01	3:51	22	Likely	Likely	Likely
X102	40' Bus	7:08	12:12	5:04	31	Likely	Likely	Likely
X103	40' Bus	7:15	12:05	4:50	35	Likely	Likely	Likely
X104	40' Bus	7:22	11:24	4:02	18	Likely	Likely	Likely
X105	40' Bus	6:58	10:57	3:59	22	Likely	Likely	Likely
X106	40' Bus	7:12	11:13	4:01	14	Likely	Likely	Likely
X107	40' Bus	7:16	11:17	4:01	14	Likely	Likely	Likely
X108	40' Bus	7:20	11:21	4:01	14	Likely	Likely	Likely
X109	40' Bus	7:03	9:55	2:52	19	Likely	Likely	Likely
X110	40' Bus	7:10	9:05	1:55	13	Likely	Likely	Likely
X111	40' Bus	7:13	11:09	3:56	24	Likely	Likely	Likely
X112	40' Bus	7:13	9:12	1:59	11	Likely	Likely	Likely
X113	40' Bus	8:10	10:24	2:14	16	Likely	Likely	Likely
X114	40' Bus	7:08	9:15	2:07	10	Likely	Likely	Likely
X115	40' Bus	7:22	11:06	3:44	14	Likely	Likely	Likely
X119	40' Bus	7:18	9:06	1:48	9	Likely	Likely	Likely
X120	40' Bus	8:10	10:06	1:56	10	Likely	Likely	Likely
X121	40' Bus	8:22	10:05	1:43	11	Likely	Likely	Likely
X122	40' Bus	7:20	9:19	1:59	8	Likely	Likely	Likely
X131	40' Bus	11:14	14:10	2:56	16	Likely	Likely	Likely
X132	40' Bus	11:18	13:17	1:59	8	Likely	Likely	Likely
X133	40' Bus	11:22	13:21	1:59	8	Likely	Likely	Likely
X134	40' Bus	11:26	13:29	2:03	8	Likely	Likely	Likely
X135	40' Bus	11:33	13:16	1:43	15	Likely	Likely	Likely
X136	40' Bus	11:22	13:26	2:04	12	Likely	Likely	Likely
X137	40' Bus	11:32	13:09	1:37	11	Likely	Likely	Likely

Academic Year Extra Blocks (p. 2 of 2)

						Feasibility vs. Scenario		
					Total	Hard Conditions		Mild Conditions
Block	**Bus Type**	**Out**	**In**	**Duration**	**Mileage**	**New Batteries**	**End of Life Batteries**	**New Battery**
X151	40' Bus	13:43	18:41	4:58	38	Likely	Likely	Likely
X152	40' Bus	13:33	17:25	3:52	12	Likely	Likely	Likely
X153	40' Bus	13:23	17:41	4:18	36	Likely	Likely	Likely
X154	40' Bus	13:31	18:21	4:50	31	Likely	Likely	Likely
X155	40' Bus	13:45	17:37	3:52	12	Likely	Likely	Likely
X156	40' Bus	13:45	17:33	3:48	21	Likely	Likely	Likely
X157	40' Bus	13:37	18:26	4:49	15	Likely	Likely	Likely
X158	40' Bus	12:45	18:11	5:26	35	Likely	Likely	Likely
X181	40' Bus	17:36	21:51	4:15	42	Likely	Likely	Likely
X182	40' Bus	17:51	21:31	3:40	36	Likely	Likely	Likely

Summer Blocks (p. 1 of 1)

						Feasibility vs. Scenario		
					Total	Hard Conditions		Mild Conditions
Block	Bus Type	Out	In	Duration	Mileage	New Batteries	End of Life Batteries	New Battery
Rt.#1-1_Summer	40' Bus	6:25	23:01	16:36	193	Unlikely	Unlikely	Unlikely
Rt.#1-2_Summer	40' Bus	6:21	21:18	14:57	191	Unlikely	Unlikely	Unlikely
Rt.#1-3_Summer	40' Bus	7:31	18:04	10:33	124	Possibly	Possibly	Likely
Rt.#1-4_Summer	40' Bus	7:30	18:05	10:35	126	Possibly	Possibly	Likely
Rt.#2-1_Summer	40' Bus	6:25	21:29	15:04	183	Unlikely	Unlikely	Unlikely
Rt.#2-2_Summer	40' Bus	6:21	18:03	11:42	110	Possibly	Possibly	Likely
Rt.#2-3_Summer	40' Bus	8:11	18:04	9:53	118	Possibly	Possibly	Likely
Rt.#2-4_Summer	40' Bus	8:51	18:01	9:10	125	Possibly	Possibly	Likely
Rt.#3-1_Summer	40' Bus	6:30	17:05	10:35	109	Possibly	Possibly	Likely
Rt.#3-2_Summer	40' Bus	7:30	17:47	10:17	124	Possibly	Possibly	Likely
Rt.#5-1_Summer	40' Bus	6:45	19:06	12:21	140	Possibly	Possibly	Likely
Rt.#6-1_Summer	40' Bus	6:25	16:45	10:20	102	Likely	Possibly	Likely
Rt.#6-2_Summer	40' Bus	6:45	19:09	12:24	155	Unlikely	Unlikely	Unlikely
Rt.#6-3_Summer	40' Bus	6:25	18:22	11:57	74	Likely	Possibly	Likely
Rt.#6-4_Summer	40' Bus	7:25	11:19	3:54	56	Likely	Likely	Likely
Rt.#7-1_Summer	40' Bus	7:00	9:50	2:50	30	Likely	Likely	Likely
Rt.#7-2_Summer	40' Bus	14:30	17:20	2:50	30	Likely	Likely	Likely
Rt.#9-1_Summer	40' Bus	7:20	20:59	13:39	175	Unlikely	Unlikely	Unlikely
Rt.#11-1_Summer	40' Bus	7:20	23:04	15:44	192	Unlikely	Unlikely	Unlikely
Rt.#11-2_Summer	40' Bus	7:40	23:05	15:25	192	Unlikely	Unlikely	Unlikely
Rt.#14-1_Summer	Cut Away Bus	6:43	23:03	16:20	192	-	-	-
Rt.#23-1_Summer	40' Bus (assumed)	6:30	23:04	16:34	192	Unlikely	Unlikely	Unlikely
Rt.#23-2_Summer	40' Bus (assumed)	6:45	17:02	10:17	65	Likely	Possibly	Likely
Rt.#23-3_Summer	40' Bus (assumed)	7:20	18:37	11:17	68	Likely	Possibly	Likely

Appendix 2: Current Fleet Inventory

Current #	Manf.	Model	Type	Year	Length (Feet)
105	GILILG	Lowfloor	Lowfloor	2012	40
106	GILILG	Lowfloor	Lowfloor	2012	40
107	GILILG	Lowfloor	Lowfloor	2012	40
108	GILILG	Lowfloor	Lowfloor	2012	40
109	GILILG	Lowfloor	Lowfloor	2012	40
110	GILILG	Lowfloor	Lowfloor	2012	40
126	GILLIG	Lowfloor	Lowfloor	2010	40
127	GILLIG	Lowfloor	Lowfloor	2010	40
128	GILLIG	Lowfloor	Lowfloor	2010	40
1111	GILLIG	Lowfloor	Lowfloor	2015	40
1112	GILLIG	Lowfloor	Lowfloor	2015	40
1113	GILLIG	Lowfloor	Lowfloor	2015	40
1114	GILLIG	Lowfloor	Lowfloor	2015	40
1115	GILLIG	Lowfloor	Lowfloor	2015	40
1116	GILLIG	Lowfloor	Lowfloor	2015	40
1136	GILLIG	Lowfloor	Lowfloor	2018	40
1137	GILLIG	Lowfloor	Lowfloor	2018	40
1138	GILLIG	Lowfloor	Lowfloor	2018	40
180	Gillig	Lowfloor	Lowfloor	2012	40
181	Gillig	Lowfloor	Lowfloor	2012	40
182	Gillig	Lowfloor	Lowfloor	2012	40
183	Gillig	Lowfloor	Lowfloor	2012	40
184	Gillig	Lowfloor	Lowfloor	2012	40
186	GILLIG	Lowfloor	Lowfloor	2008	40
187	GILLIG	Lowfloor	Lowfloor	2008	40
188	GILLIG	Lowfloor	Lowfloor	2008	40
189	GILLIG	Lowfloor	Lowfloor	2008	40
294	GMC	Terrain	Support	2013	NA
297	FORD	ESCAPE	Support	2011	NA
2122	GMC	Terrain	Support	2015	NA
2134	Ford	Fusion Hyb	Support	2016	NA
333	FORD	ElDorado	Cut-Away	2010	25
334	FORD	ElDorado	Cut-Away	2010	25
335	FORD	ElDorado	Cut-Away	2010	25
336	FORD	ElDorado	Cut-Away	2010	25
337	FORD	ElDorado	Cut-Away	2010	22
338	FORD	ElDorado	Cut-Away	2010	22
390	Glaval	Titan 2	Cut-Away	2012	25
391	Glaval	Titan 2	Cut-Away	2012	25
418	GILLIG	Lowfloor	Lowfloor / Hybrid	2010	40
419	GILLIG	Lowfloor	Lowfloor / Hybrid	2010	40
420	GILLIG	Lowfloor	Lowfloor / Hybrid	2010	40
421	GILLIG	Lowfloor	Lowfloor / Hybrid	2010	40
422	GILLIG	Lowfloor	Lowfloor / Hybrid	2010	40
423	GILLIG	Lowfloor	Lowfloor / Hybrid	2010	40
424	GILLIG	Lowfloor	Lowfloor / Hybrid	2010	40
425	GILLIG	Lowfloor	Lowfloor / Hybrid	2010	40
429	GILLIG	Lowfloor	Lowfloor / Hybrid	2010	40
430	GILLIG	Lowfloor	Lowfloor / Hybrid	2010	40
431	GILLIG	Lowfloor	Lowfloor / Hybrid	2010	40
432	GILLIG	Lowfloor	Lowfloor / Hybrid	2010	40
501	ORION	VII	Lowfloor	2006	40
502	ORION	VII	Lowfloor	2006	40
503	ORION	VII	Lowfloor	2006	40
504	ORION	VII	Lowfloor	2006	40
660	Nova	Artic	Articulating	2012	60
661	Nova	Artic	Articulating	2012	60
6101	Nova	Artic	Articulating	2016	60
6102	Nova	Artic	Articulating	2016	60
6103	Nova	Artic	Articulating	2016	60
6104	Nova	Artic	Articulating	2016	60

7117	Gillig	Phantom	Highfloor	2002	40
7118	Gillig	Phantom	Highfloor	2002	40
7119	Gillig	Phantom	Highfloor	2002	40
7120	Gillig	Phantom	Highfloor	2002	40
7121	Gillig	Phantom	Highfloor	2002	40
7123	GILLIG	Phantom	Highfloor	2002	40
7124	GILLIG	Phantom	Highfloor	2002	40
7125	GILLIG	Phantom	Highfloor	2002	40
7129	GILLIG	Phantom	Highfloor	2002	40
7130	GILLIG	Phantom	Highfloor	2002	40
7131	GILLIG	Phantom	Highfloor	2002	40
7132	GILLIG	Phantom	Highfloor	2002	40
7133	GILLIG	Phantom	Highfloor	2002	40
700	GILLIG	Phantom	Highfloor	2001	40
711	GILLIG	Phantom	Highfloor	1993	40
712	GILLIG	Phantom	Highfloor	1993	40
716	GILLIG	Phantom	Highfloor	1993	40
762	GILLIG	Phantom	Highfloor	2001	40
763	GILLIG	Phantom	Highfloor	2001	40
778	GILLIG	Phantom	Highfloor	2001	40
779	GILLIG	Phantom	Highfloor	2001	40
785	GILLIG	Phantom	Highfloor	2001	40
792	GILLIG	Phantom	Highfloor	2001	40
793	GILLIG	Phantom	Highfloor	2001	40
898	FORD	F-250	Support	2008	NA
899	FORD	F-450	Support	2006	NA
948	ORION	V	Highfloor	2003	40
949	ORION	V	Highfloor	2005	40
950	ORION	V	Highfloor	2005	40
951	ORION	V	Highfloor	2005	40
952	ORION	V	Highfloor	2005	40
953	ORION	V	Highfloor	2000	40
954	ORION	V	Highfloor	2000	40
955	ORION	V	Highfloor	2000	40
956	ORION	V	Highfloor	2000	40
957	ORION	V	Highfloor	2000	40
958	ORION	V	Highfloor	2000	40
970	ORION	V	Highfloor	2002	40
971	ORION	V	Highfloor	2002	40
972	ORION	V	Highfloor	2002	40
973	ORION	V	Highfloor	2002	40
974	ORION	V	Highfloor	2002	40
975	ORION	V	Highfloor	2002	40
9076	ORION	V	Highfloor	2002	40
977	ORION	V	Highfloor	2002	40

Appendix 3: Conceptual Depot Design

Figure A3-1: Site Overview of Current CyRide Depot

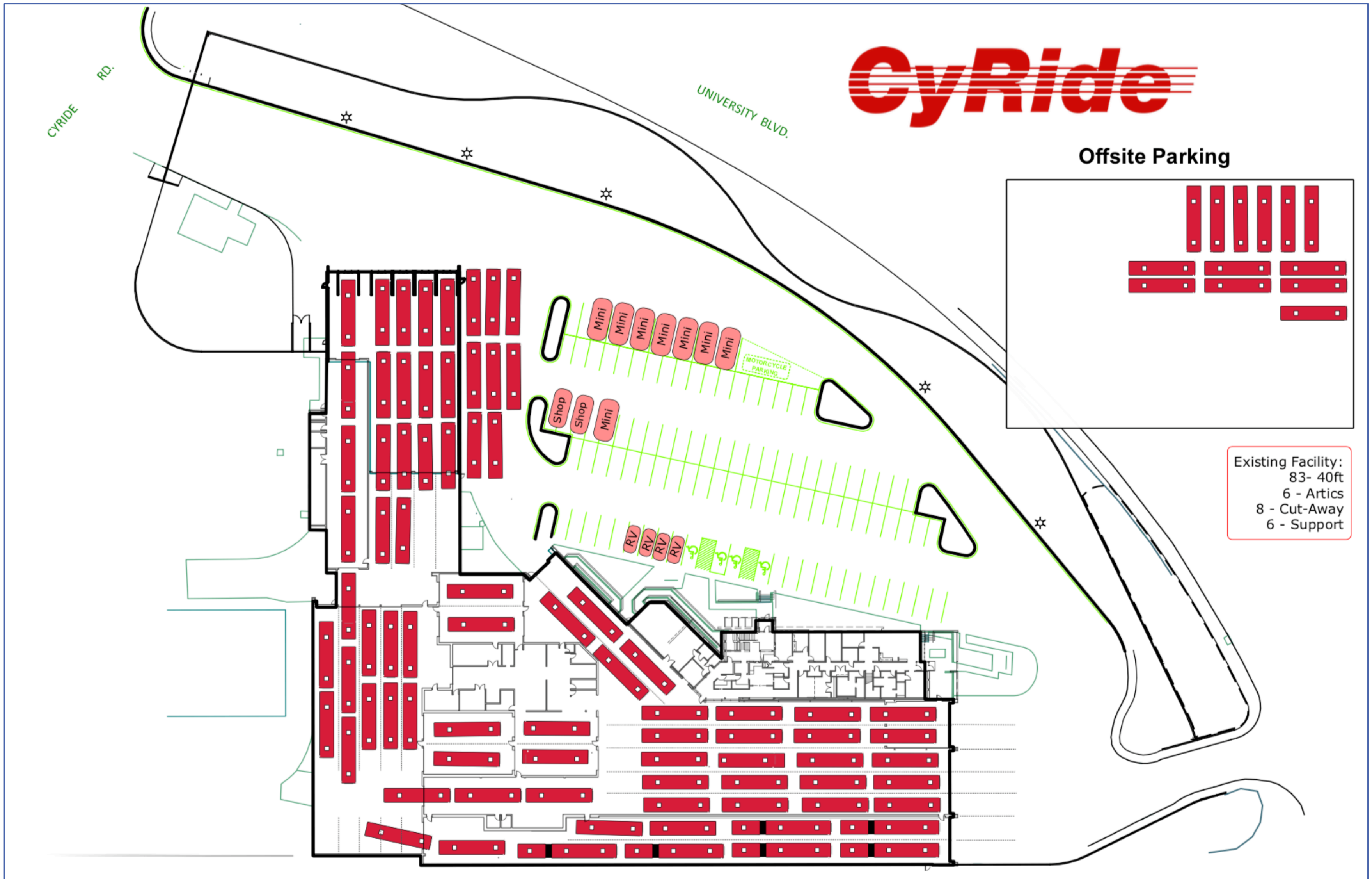
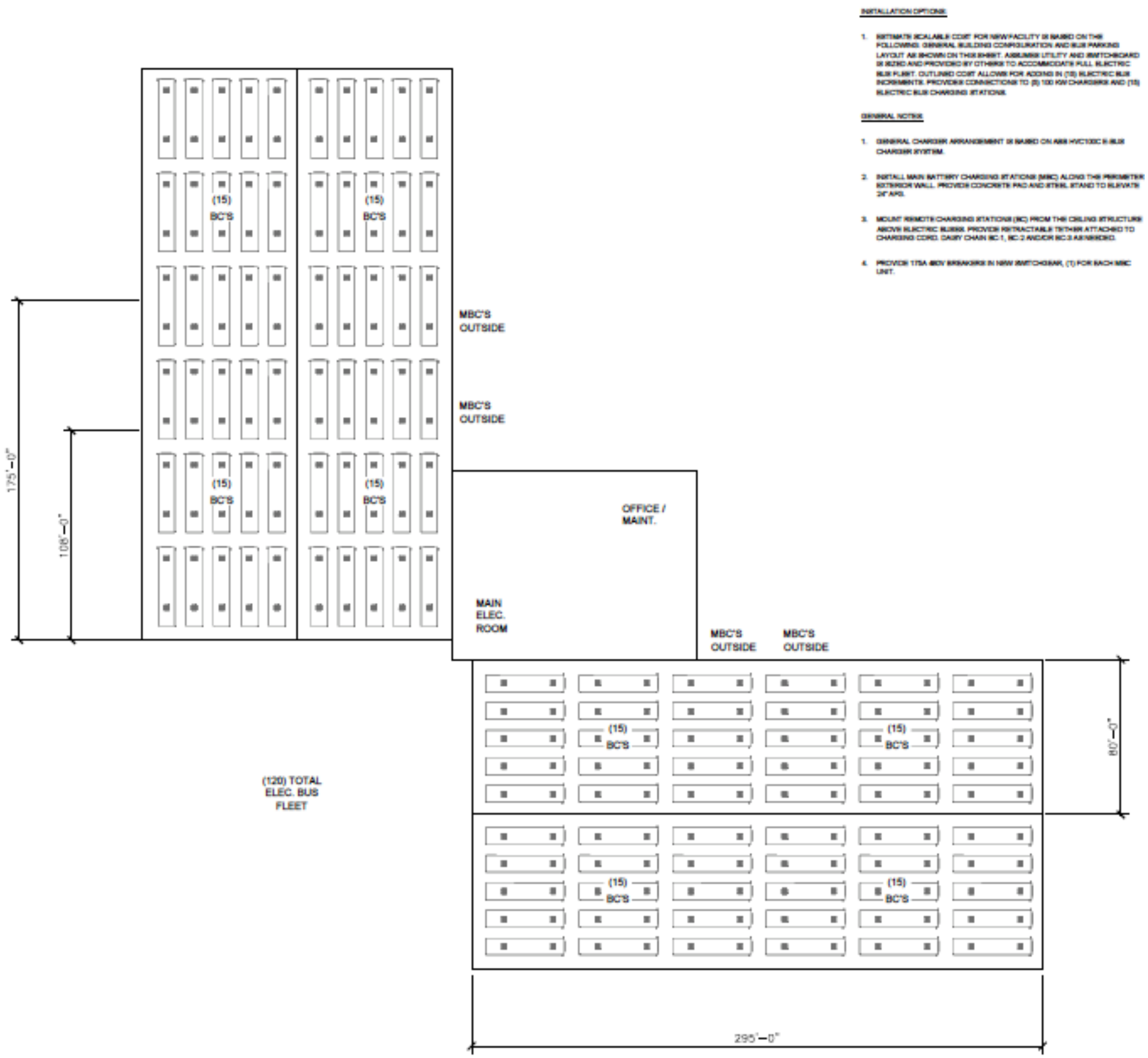


Figure A3-2: Conceptual Charging Design for 17 Buses

Figure A3-3: Conceptual Charging Design for 120 Bus Layout at Future Facility

(SEE NEXT PAGE)


(15)
BC'S
MBC'S
OUTSIDE
OFFICE /
MAINT.
MAIN
ELEC.
ROOM
(120) TOTAL
ELEC. BUS
FLEET
175'–0"
108'–0"
80'–0"
295'–0"

Appendix 4: BEB Best Practices

#	Category	Name	Sub-Category	Description
1	Planning	Plan for utilizing ZEBs during emergencies	Emergency Response Planning - Resilience and Redundancy	In the event of a power outage, you may want to consider implementing a backup power or other power storage solution to ensure uninterrupted operation of the ZEB fleet. Your agency may provide assistance for community critical functions, such as evacuations. A backup power source will allow your ZEB fleet to continue to support these functions as needed.
2	Planning	Model fuel costs for planned operation	Energy Modeling & Charge Planning	For BEBs, estimate the total electricity costs, including energy charges, demand charges, time of use rates, and other surcharges from the utility. Conduct this analysis early in the planning process to allow for time to plan for operational adjustments to minimize electricity costs. Electricity rates often include an additional "demand charge" related to the maximum power consumed during a 15-minute interval for the month. This means that spikes in electricity demand can add significantly to the cost of vehicle charging and erode the savings of electricity compared to other fuels. The impact of demand charges can be most acute when fleets have a small number of electric vehicles and charging causes large, relative spikes in electricity demand. With a larger number of vehicles, fleet owners can space out charging over a period of time, minimizing the spikes (Chandler et al., 2016, page 27).

3	Planning	Select charging technology	Energy Modeling & Charge Planning	Three options exist for charging BEBs: plug-in charging, overhead conductive charging, and wireless inductive charging. When selecting charging infrastructure, agencies must consider their route demands (speeds, grades, stops, lengths, layovers), bus service or blocking demands (deadheads, duration, and frequency), seasonal temperatures, passenger loads, available garage space and power, layover or transit center locations and space, and utility rate schedules and costs.
4	Planning	Select charging technology	Energy Modeling & Charge Planning	Plug-in charging is usually installed at the depot, shop, or garage and is used to charge buses overnight. It is usually the sole charging method for buses with large battery packs and higher range. This method has fewer infrastructure and installation requirement, is generally lower cost, allows you to take advantage of lower off-peak electricity rates, and allows for more flexibility for route selection and future route changes. However, buses must be taken out of service to charge with this method, and typically utilizes slower charging rates. The infrastructure may require more space per bus, and the total power requirements could be high if all buses are charging simultaneously.
5	Planning	Select charging technology	Energy Modeling & Charge Planning	Overhead conductive charging is typically installed on route or at transit centers where layovers may occur. This method usually serves multiple buses, and is utilized with buses with smaller battery packs and shorter range. Buses will charge at these stations anywhere from 5 to 20 minutes at a higher power. Optimal utilization of this method can allow for 24-hour continuous bus operation. Disadvantages of this charging method include higher infrastructure costs and higher impacts from peak demand charges. Land rights must be obtained at deployment sites, and overhead systems may interfere with road clearances, or may require a dedicated pull-off. This type of fixed infrastructure is costly to relocate, which may constrain future route changes for buses.

6	Planning	Select charging technology	Energy Modeling & Charge Planning	Wireless inductive charging is typically installed on route or at a transit center where layovers may occur. This method usually serves multiple buses, and is utilized with buses with medium-to-large battery packs and medium range. Buses are able to remain in service while charging on route, and has a smaller infrastructure footprint. This method has no manual connections or moving parts, and does not interfere with road clearances or require a dedicated pull-off. Disadvantages of this charging method include a slightly less efficient charge, higher infrastructure costs, and higher impacts from peak demand charges. Land rights must also be obtained at deployment sites. This type of fixed infrastructure is costly to relocate, which may constrain future route changes for buses.
7	Planning	Select a suitable location for chargers	Energy Modeling & Charge Planning	For depot chargers, transit centers are ideal infrastructure siting locations. Transit centers are already agency owned and maintained, typically have route layovers built in, are usually at the midway or at the end of the line for routes, and are closed to other vehicular traffic. It is important that the placement of the depot chargers do not block the flow of traffic within the transit center. The chargers must be installed where power utilities can provide a dedicated supply line capable of delivering the high currents demanded.

8	Planning	Select a suitable location for chargers	Energy Modeling & Charge Planning	On route chargers must be located somewhere multiple buses can utilize it. The agency must have access or rights to property to install the infrastructure. This can limit options for charger locations, particularly in dense urban environments.On route charging types of entrances that agencies used for accessing the on-route charging infrastructure, whether it is on road, a pull-off lane, or a pull-in driveway entrance. Many transit agencies that utilize this technology have the buses align with the charger using visual cues on road or roadside as opposed to video or audible cues, or cues on the dash. Semi-automated controls to align with the charger have also been used. Allow for irregular charging times in your operational plan due to traffic conditions.
9	Planning	Smart charging	Energy Modeling & Charge Planning	Third party software exists that can help manage the power allowed to depot chargers. Smart charging or charge management can allow transit agencies to better limit peak demand charges. Contact the OEM or charger manufacturer for more information on options for smart charging.
10	Planning	Develop a fueling procedure for the buses	Energy Modeling & Charge Planning	Establish a procedure for plugging in the buses once they arrive back at the yard so that the roles and responsibilities are clear and to maximize the time available for charging.
11	Planning	Model fuel costs for planned operation	Financial Planning	Based on the planned usage of each ZEB (i.e., mileage and time), estimate fuel costs for operating the ZEB fleet to include in an operational budget.
12	Planning	Life cycle cost analysis	Financial Planning	Assess total costs over the service life of the bus, including infrastructure costs, component replacement costs, maintenance labor, preventative maintenance, and fuel costs (i.e., electricity or hydrogen).

13	Planning	Planning for maintenance costs	Financial Planning	Maintenance costs are rising as the warranty period ends and agency contractor staff take over the maintenance of the BEBs. Costs are expected to increase as maintenance staff learn how to troubleshoot and repair BEB systems, and then stabilize as workers become familiar with the technology differences.
14	Planning	Planning for infrastructure for end goal of ZEB fleet	General Planning	Consider what your long-term goals are for deploying zero-emission buses when planning infrastructure installations. Identify opportunities for scaling up to avoid repeating costly construction activities. Consider placement of buses and charging infrastructure, adequate maintenance facilities, and ensuring access to adequate power resources. For example, consider building out all of the underground infrastructure that may be needed rather than to retrofit as the fleet size increases.
15	Planning	Plans are living documents	General Planning	Transit agencies should revisit any long-term fleet transition plans every two years to ensure that your assumptions are still valid. Technological advancements, regulatory requirements, and changes to your agency's operations should be incorporated into your plans
16	Planning	Develop an operational plan for deployment	Operational Impacts/Changes	Use the results of modeling efforts to identify routes or blocks that are available for ZEB operation. Establish operational goals and estimate the daily/monthly/annual mileage and operating hours of the fleet.
17	Planning	Audible signal that the bus is approaching	Operational Impacts/Changes	Due to the quiet nature of ZEBs, some transit agencies have elected to add external sounds to alert pedestrians and cyclists that the bus is approaching. While there is currently no regulatory requirement to add an external sound, agencies should discuss options for adding an external sound with their regulatory specialists, accessibility specialists, and the visually impaired communities in the service area.

18	Planning	Identify necessary changes to operational schedules	Operational Impacts/Changes	Utilizing all of the information gathered from modeling and planning efforts, determine what changes must be made to the bus operational schedules to accommodate the ZEB technology, such as incorporating charging layovers and available range.
19	Planning	Incorporating charging time into block planning g	Operational Impacts/Changes	Adjust route schedules to accommodate BEB charging time; this is part of the transition from conventional technology buses to electric buses. An agency may need to add deadhead miles prior to the start of the route depending on the location of the on-route charging station and availability of an in-depot charger.

20	Planning	Model bus performance in the service area	Route Modeling & Service Planning	Bus modeling and route simulation is a cost effective method to assess the operational requirements of your zero-emission bus fleet. Consider modeling a representative set of routes or blocks from your service area. The results will help you understand range requirements, determine energy consumption on various routes, identify routes that are feasible for the ZEB to complete, and inform charging schedule requirements. Include considerations of (1) energy usage of HVAC systems and (2) battery degradation in the analysis to understand what routes would be feasible for the ZEB fleet at the end of their service life. Note that modeling will provide a more accurate assessment of range than Altoona tests, which are conducted on flat grades, at seated load weight, and with no HVAC loads. Therefore, the results may not be directly applicable to the expected performance while in service. A tool such as the Argonne System Modeling and Control Group's Autonomie could be used to perform powertrain modeling and simulation. By supplying different duty cycles, powertrain configurations, and bus components, Autonomie can run a simulated operation of a bus on route to determine how the bus will perform in the given situation.
21	Planning	Vehicle weight and passenger capacity	Route Modeling & Service Planning	Long-range buses have battery packs that weigh up to 6,500 pounds. Gross vehicle and axle weight rating limitations may reduce passenger capacity. Conduct this analysis before committing to a long-range or quick-charge bus strategy.
22	Planning	Impact of HVAC systems on range	Route Modeling & Service Planning	The higher use of air conditioning lowers the effective range in warmer months; Foothill Transit adjusts its summer schedule to account for more charging time.

23	Stakeholder Engagement	Coordinate with external stakeholders	General Stakeholder Engagement	Coordinate with utility companies, unions, community leaders, executive boards, regulatory agencies, and environmental justice groups to avoid issues after deployment. Consider demonstrating the positive environmental impacts and potential operational benefits to obtain support for the project. Stakeholders may question the higher up-front costs, and concerns about the increased load on power plants. Effective up front planning will allow you to build the case for the benefits of ZEBs.
24	Stakeholder Engagement	Discuss your plans with peers	General Stakeholder Engagement	Find a transit agency of a similar size and located in a similar climate that has deployed ZEBs to learn from their experiences. Connecting with other agencies can help you avoid pitfalls to ensure that you deploy the right technology effectively. Consider joining the Zero Emission Bus Resource Alliance (ZEBRA), a national professional association for transit agencies to share lessons learned about zero-emission buses.
25	Stakeholder Engagement	Coordinate with the electrical utility	Utilities	Begin coordinating with your electric utility during the planning process. Gain an understanding of how your rate schedule may change as you add ZEBs to your fleet. You may be able to work with your electric utility to identify ways to reduce your electricity bill, such as utilizing time of use rates, or methods to limit demand charges.
26	Design	Charging solutions for maintenance bays	General Design	Ensure that you have the ability to fuel ZEBs in maintenance facilities, such as a portable charger, or an additional charging pedestal.
27	Procurement	Technical specifications	Technical Specifications: Bus	The American Public Transit Association (APTA) provides a template for technical specifications that can be adapted for ZEBs. Utilize the knowledge of your service area, agency operational requirements, and results of modeling efforts to ensure that all requirements are included in the specifications.

28	Build	Install charging infrastructure before your buses are delivered	Infrastructure Build	Ensure that your charging infrastructure is installed and functional before any buses are delivered to your agency. This will ensure that you can begin testing and using your bus immediately, and that you do not have to accept the bus without the charging infrastructure in place. Otherwise, you may run the risk of being unable to charge your bus while waiting for the charging infrastructure to be installed. This waiting period may take time away from the available window to test the bus prior to acceptance.
29	Acceptance	Develop a testing plan to ensure that the buses match the technical specifications	Bus Delivery and Acceptance	In advance of your bus(es) being delivered to your transit agency, develop a plan that will outline and schedule all tests that you will conduct during your acceptance period. Refer back to your technical specifications, and ensure that your tests allow you to confirm that the bus meets all contractual requirements.
30	Acceptance	Develop an acceptance test route	Bus Delivery and Acceptance	Develop a route for testing that allows the bus to drive on a representative portion of the service area, and complete any challenging areas that will test maneuverability (e.g., steep grades, difficult turns).
31	Acceptance	Test performance at low SOC	Bus Delivery and Acceptance	Below a certain threshold of state of charge, many buses will limit functionality to preserve battery life. Test the performance of the bus at low battery state of charge to gain a better understanding of what the limitations may be. Confirm with the bus OEM how "low" SOC is defined for the bus.
32	Acceptance	Test at various weights and with various HVAC loads	Bus Delivery and Acceptance	Testing should confirm that the bus shows acceptable performance under various conditions. Conduct all testing at various weights (e.g., Curb Weight, Gross Vehicle Weight Rating) and with high and low HVAC loads.
33	Acceptance	Test charging infrastructure compatibility with all buses	Charging Equipment Acceptance	Plug in each bus to each charger to ensure that the all buses charge at the expected rate.

34	Training	First Responder Training	First Responder - Vehicles	Coordinate training for local first responders in advance of revenue service deployment. Ensure that emergency personnel have the contact information for a designated staff member within the transit agency in the event of an emergency. Training could include: -How to distinguish electric buses from conventional buses through decals or the absence of engine noise or combustion gas exhaust vent -How to best approach a battery electric vehicle fire and how a battery electric vehicle fire differs from a conventional internal combustion vehicle fire -Overview of the location of important components on an ZEB, such as batteries, electric motors, controller panel, and inverters -Location of emergency cut-out switches to disconnect the electrical system from energy storage devices -Proper procedures for disconnecting batteries and isolating them from the bus -How to treat chemical burns and neutralize battery fluid, due to the chemicals found in electric bus batteries -Information on any potential explosive or toxic gas hazards that batteries may pose to them Emergency Response Guides for battery electric bus manufacturers including Proterra, Novabus, BYD, and Gillig are available on the National Fire Protection Association's (NFPA) website.

35	Training	Training suggestions	General Training	Consider training in smaller groups for one-on-one development, hands-on training (vs. classroom training) with the bus present, have a factory technical representative on-site and operating an intial shadow service, train first responders, and train drivers and first responders together to ensure consistency in response methods.
36	Training	Training resources from OEM	General Training	Confirm what direct staff training or "train-the-trainer" training will be provided by the OEM, and ensure that your agency has access to the materials.
37	Training	Safety training	General Training	Operations, facilities, and maintenance staff should be trained on safety and emergency procedures related to the bus and associated infrastructure. Safety training could include:-Overview of hazards associated with battery chargers and hydrogen fuel cells, when compared to conventional fuels-Battery-specific safety hazards, such as electrocution, arcing, and fires from short circuits-Locations of emergency cut-off switches and fire response equipment (Emergency Response Guides for battery electric bus manufacturers including Proterra, Novabus, BYD, and Gillig are available on the NFPA's website)-Actions to take to avoid an emergency and what to do during an emergency (e.g., contact first responders, evacuate passengers, power off vehicle, not storing a vehicle with a damaged Li-ion battery within 50 feet of a structure or another vehicle until the battery is safely discharged)
38	Training	Periodic re-training	General Training	APTA recommends that bus operators are periodically re-trained, based on the operator's performance. When monitoring bus data, transit agencies may be able to identify drivers that are less energy efficient, and suggest additional training to improve performance.

39	Training	Maintenance training	Mechanic	Provide training so that technicians understand how to service and troubleshoot all-electric propulsion and auxiliary systems, how to work with the on-board diagnostic systems, and be trained in the safe handling of high voltage systems. When conducting inspections, transit agency staff should be aware of unique hazards associated with battery chargers and hydrogen fuel cells, specifically the presence of high voltage cables in BEBs that do not exist in conventional buses.
40	Training	Driver training	Operator	FTA recommends training on concepts, working principles, and details on regenerative braking, mechanical braking, hill holding, and roll back. Driving habits can significantly affect BEB efficiency and performance due to regenerative braking. Training on the differences between regenerative braking and conventional friction braking is recommended. Training on optimal driving habits, such as the optimal levels of acceleration and deceleration to maximize the efficiency, should be provided.
41	Training	Driver training - Operator's compartment	Operator	The operator's compartment may have different gauges, compared to conventional buses. An overview of dashboard controls and warning signals should be conducted, as well as training on the correct procedure when a warning signal is initiated. Drivers should be trained on how to understand and use readings such as the state of charge, remaining operating time, and estimated range. There should also be training on the procedure when a "low battery power" scenario occurs and how to safely power down the bus.
42	Training	Driver training - Fueling	Operator	APTA recommends that operators are familiar with processes, procedures, and hazards associated with the fueling process. The "fueling" process of a BEB would present minimal hazards, as BEBs would only need to be plugged in. However, if a FCEB is used, additional training should be provided on safe operation of the hydrogen fueling station.

43	Training	Driver training simulations	Operator	New Flyer partnered with FAAC to create a simulator that simulates New Flyer's new Xcelsior Charge BEBs. FAAC's simulator can be used by engineers, maintenance crews, and training operators. Simulators allow the trainee to experience a life-like scenario in a controlled, guided environment, allowing them to gain skills and learn procedures for dangerous or rare scenarios in a safe environment.
44	Training	Operations training	Operator	Operations staff should receive training on what route and schedule adjustments may be necessary given the range limitations and fueling requirements of ZEBs. For example, BEBs' operation time can become limited if a scheduled charge is missed or delayed for any reason.
45	Operation	Data monitoring	Data collection and monitoring	After your ZEB fleet is in revenue service, consider collecting and analyzing bus data to better understand the performance, reliability, durability, and cost. Evaluating the performance and limitations of the technology will allow you to determine the most effective and efficient use of the buses throughout your service area. Consider analyzing metrics such as: -Cost per mile (could include fuel and maintenance costs) -Energy performance (kWh/mile) -Availability (days when the bus(es) were capable of being put into service) -Utilization (days when a bus is available and put into service) -Comparison to diesel fleet (e.g., mileage, operating hours, cost per mile) -Emissions reductions (e.g., gallons of diesel avoided, CO_2 emission reductions)
46	Maintenance	Spare parts inventory	Inventory - Spare Parts	Allow for additional time for spare parts to arrive. Ensure that the OEM provides a list of suggested spare parts and preventative maintenance activities so that a stock of spare parts can be maintained to speed repairs.

Appendix 5: CTE Qualifications

The Center for Transportation and the Environment (CTE) is a 501(c)(3) non-profit organization founded in 1993. CTE's mission is to improve the health of our climate and communities by bringing people together to develop and commercialize clean, efficient, and sustainable transportation technologies. CTE collaborates with federal, state, and local governments, fleets, and vehicle technology manufacturers to advance clean, sustainable, innovative transportation and energy technologies. Since 1993, CTE has managed a portfolio of more than $530 million in team research, development, and demonstration projects funded by a variety of federal and state organizations including the U.S. Departments of Transportation, Energy, Defense, and Interior, as well as the California Air Resources Board and California Energy Commission.

As a non-profit, CTE does not have an ownership structure, but is led by an Executive Director with governing oversight provided by a Board of Directors. Founded as the Southern Coalition for Advanced Transportation, CTE was one of the original regional consortia organizations formed under the Defense Advanced Research Projects Agency (DARPA) Electric and Hybrid Electric Vehicle Program. When the electric and hybrid electric vehicle program at DARPA ended in 2001, the organization was no longer limited to projects in the southeastern United States. This enabled CTE to begin expanding its portfolio to include projects from across the country and the organization's name was changed to remove reference to the geographic boundary.

CTE is experienced in developing, implementing, and administering advanced transportation technology projects, with a focus on zero-emission transit buses. The lack of widespread deployments can present challenges for transit agencies unfamiliar with zero-emission technology, as there are specific operating characteristics and fueling requirements associated with deployment. CTE has provided technical assistance and project management services on many battery electric bus deployment projects made possible through the Federal Transit Administration's (FTA) Low or No Emission Vehicle Program, TIGGER Program, and Clean Fuels Program. CTE has also demonstrated experience in the fuel cell arena as one of the three National Fuel Cell Bus Program Consortia responsible for deploying fuel cell transit buses for FTA. In addition, CTE is leading a consortium deploying 20 fuel cell electric buses with a grant from the California Air Resources Board (CARB) through California Climate Investments. Through these programs, CTE has assisted more than 60 transit agencies that have either deployed, or will soon deploy, more than 265 zero-emission buses (ZEBs).

CTE has developed a Zero-Emission Smart Deployment Methodology to assist transit agencies through their initial or pilot zero-emission bus deployment programs. The cornerstone of CTE's approach is to ensure that the fleet operator matches the most appropriate propulsion technology to the intended use, operational strategy, and deployment situation. CTE works with transit agencies to understand and address the following:

- Meeting the power and energy needs of current duty cycles
- Matching vehicle technologies (depot charge, on-route conductive charge, on-route wireless charge, fuel cell) to the most appropriate routes
- Understanding the capabilities of the various bus manufacturer's zero-emission vehicles and objectively comparing them on an apples-to-apples basis

- Preparing for performance impact of variables such as extreme weather conditions, passenger loads, and battery degradation
- Establishing charge locations, site requirements, and operational schemes
- Understanding any limitations on the ability to install sufficient charging infrastructure to support large quantities of electric buses
- Understanding the impact of varied utility rate structures on the operational costs of the fleets
- Understanding the timing and impact of standards development regarding purchasing decisions
- Understanding the technical and reliability risks associated with zero-emission technology
- Making objective decisions considering competing goals and requirements associated with deploying advanced technology buses
- Understanding and addressing risks associated with deploying medium size to large fleets of advanced vehicles without a precedent in the industry
- Understanding the effects of missing a scheduled charge
- Understanding the total cost of ownership for the different available technologies

CTE has leveraged this experience to develop a Zero-Emission Bus Transition Planning Methodology for transit agencies. These plans consider bus and service requirements, fleet procurement timelines, infrastructure assessments, bus and facilities capital costs, operating and maintenance cost impacts, and emission benefits.

CTE has also established a strong industry presence through its participation and leadership in industry-led initiatives. CTE is a founding member of the American Public Transportation Association's (APTA) Zero Emission Bus Procurement Guidelines Working Group that is focused on establishing standard procurements guidelines to help transit agencies specify and purchase zero-emission buses. CTE is a participating member on the Electric Power Research Institute's Bus and Truck Charging Group that is promoting the creation of standard charging interfaces and interoperability between manufacturers of plug-in, overhead charged, and wireless battery electric buses and associated infrastructure. CTE is also participating member on the J-3105 Overhead Charging Standards Development committee.