TRANSFORT

Zero Emission Bus Transition and Implementation Plan

December 2022

Revised: July 2023

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HATCH LTK

Positive Change for the Next Century

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1 Introduction

Transfort is a municipal department of the City of Fort Collins (City), located in Northern Colorado within Larimer County. Transfort's prime service area covers approximately 54 square miles and mainly operates within the city limits of Fort Collins. However, Transfort also operates a regional route, FLEX, that extends from Fort Collins south through the communities of Loveland, Longmont, Berthoud and Boulder. Transfort contracts for all *Americans With Disabilities Act (*ADA) complementary paratransit service and some supplemental fixed-route service.

Transfort began converting the fleet to compressed natural gas (CNG) in 2008 and all but two buses currently are operated with CNG. Transfort replaced two diesel buses with battery electric buses (BEBs) in 2022. Transfort currently has one remaining diesel bus that is out of commission and will be replaced with a BEB in 2023. The City has adopted aggressive climate action goals and aims to become carbon neutral by 2050. To align with these goals, Transfort has begun exploring fleet electrification and has secured funding for its first eleven (11) BEBs.

At this time, Transfort has one maintenance and operational facility (TMF) located at 6750 Portner Road in Fort Collins. The facility includes a CNG fueling station. Transfort is currently planning for the potential addition of a second maintenance facility located in the northern area of Fort Collins.

The objectives of the Zero Emission Bus Transition Study are to:

1. Determine the most cost-effective capital approach to a 100 percent (%) ZEB fleet by 2040
2. Determine capital improvements requirements required to achieve a 100% ZEB fleet
3. Provide financing and purchasing strategy that allows Transfort to sustainably meet internal ZEB deadlines
4. Develop a comprehensive understanding – both positives and negatives – of how compliance with the City of Fort Collins *Climate Action Plan* objective (100% zero emission by 2050) will impact Transfort in the future, and how federal legislation may impact the plan

The analysis is being conducted in two phases. Phase I was a screening level technology analysis to assess Transfort's service related to the technology options and provide 'order of magnitude' costs for multiple ZEB transition scenarios. The Phase I screening evaluation included analysis of multiple deployment scenarios as detailed below:

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

Results from the Phase I analysis were provided in the *Transfort Zero Emission Bus Transition Screening Assessment* dated October 2021. As a result of the Phase I analysis, Transfort elected to completed this detailed Phase II analysis of BEB On-Route and Depot Charging operations.

This *Zero Emission Bus Transition and Implementation Plan* was developed to provide further evaluation of the BEB On-Route and Depot Charging scenario for Transfort and to provide recommendations to support successful deployment of BEBs in service. The plan was developed to support Transfort in understanding the challenges and managing the constraints associated with zero-emission technologies and was based on best-practice strategies for deploying ZEBs. The deployment will be focused on initially operating BEBs out of the TMF, supplemented with on-route charging at four (4) transit centers. The year that each of the facilities is expected to be able to support charging for planning purposes is as follows:

- Foothills Transit Center (FTC) - 2025
- Downtown Transit Center (DTC) - 2027
- South Transit Center (STC) - 2028
- Colorado State University Transit Center – (CSU) - 2033

In addition, Tranfort is planning for a new depot to be constructed on the north side of Fort Collins; however, the current location, schedule, and availability of funding have not been finalized. For the purposes of this analysis, the new depot construction was assumed to occur by 2030.

The *Zero Emission Bus Transition and Implementation Plan* provides the following: a summary of the detailed bus and route modeling that was completed following the screening analysis; rate evaluation to understand the expected costs to operate the BEBs; a bus recommendation and procurement best practices; infrastructure requirements and recommendations; an updated total cost of ownership assessment; resiliency discussion; training recommendations; data collection plan; and analysis of cutaway operations.

This *Zero Emission Bus Transition and Implementation Plan* is arranged in the following sections:

- Section 1 – Introduction
- Section 2 – Baseline Data
- Section 3 – Service Assessment
- Section 4 – Fleet Assessment
- Section 5 – Fuel Assessment
- Section 6 – Maintenance Assessment
- Section 7 – Facilities Assessment
- Section 8 – Total Cost of Ownership
- Section 9 – Emission Analysis
- Section 10 – Bus Procurement Best Practices
- Section 11 – Technical Specifications and Fleet Recommendations
- Section 12 – Training Recommendations
- Section 13 – Data Collection Recommendations
- Section 14 – Cutaway Fleet Evaluation

This study reflects the state of technology at the time that it was prepared. The transition to a full zero-emission fleet, as detailed in this plan, is expected to take over a decade to complete. As a result, CTE recommends that the study be reviewed and updated periodically to reflect the latest state of technology development, costs, regulatory environment, service requirements, and supply chain to ensure that the Transfort continues to meet their mission in the most effective and efficient way possible.

2 Baseline Data Review

It is essential to understand the key elements of Transfort's service to evaluate the rough order magnitude (ROM) costs associated with a full-ZEB transition.

Fleet

At the time of this study, Transfort's bus fleet consisted of 50 CNG and 2 BEB heavy-duty vehicles of various lengths that provide service for 22 fixed-routes. In addition, Transfort has one out of commission diesel bus (40') that will be replaced with a BEB in 2023. There are also 2 routes that are contracted out (FHS and GOLD) that operate utilizing three (3) liquid propane gas (LPG) fueled cutaway vehicles and four LPG cutaways that support paratransit service. All of Transfort's previously operated diesel fleet vehicles were retired by 2021 with the exception one out of commission 40' bus.

The following table provides a breakdown of the existing fleet vehicles by length and fuel type.

Table 1 - Current Bus Quantity by Length and Fuel Type

Vehicle Length	CNG	BEB	Diesel	LPG
Cutaway (Paratransit)	0	0	0	4
Cutaway (Contracted)	0	0	0	3
30'	7	0	1	0
35'	13	2	0	0
40'	22	0	0	0
60'	8	0	0	0
TOTAL	***50***	***2***	***1***	***7***

All service operates out of the TMF, located at 6570 Portner Road in Fort Collins. Tranfort also has three separate transit centers for transit connections currently in service (DTC, STC, and CSU) and one additional transit center planned (FTC) that is scheduled to begin operations in approximately 2025. In addition, Transfort is evaluating expansion to a second storage and maintenance facility to be constructed on the north side of Fort Collins by approximately 2030. Transfort's goal is to maintain heavy duty buses for a minimum of 15 years before retirement and cutaway vehicles for a minimum of 10 years.

Transfort is planning for fleet growth to 82 heavy duty vehicles by 2040. The expected mix of vehicle sizes is provided in the following table:

Table 2 - Future Bus Quantity by Length and Fuel Type (2040)

Vehicle Length (ft)	BEB
35	31
40	31
60	20
TOTAL	***82***

Routes and Blocks

Transfort's fixed-route service currently consists of 22 routes run on 80 blocks as detailed in **Table 3.**

Table 3 - Number of Blocks by Bus Length and Weekday

Vehicle Length (ft)	Weekdays	Saturday	Sunday
30	7	4	1
35	11	6	2
40	22	11	2
60	6	6	2
TOTAL	***46***	***27***	***7***

Tranfort's peak pullout take place during the weekdays, with a total of 46 total blocks in operation. For the analysis, it was assumed that new service blocks to support expansion of the fleet will be planned such that they can be operated with BEBs charged overnight at a depot. It is recommended that these new vehicles be outfitted to support on-route charging and be capable of utilizing on-route charging infrastructure that may exist at the time of deployment to increase their operational range as capacity allows. The average mileage per bus length per day will remain constant for the new buses that are added to the fleet. In addition, the current 30' buses will be replaced in the future with 35' or 40' buses in accordance with Transfort's fleet replacement plan.

3 Service Assessment

During the Phase I analysis, CTE conducted a screening level service assessment to determine the approximate feasibility of BEB operations by block length. The results from the screening analysis were provided in the *Zero Emission Bus Transition Screening Assessment* (October 2021). A more detailed analysis of service feasibility was conducted to support development of this *Zero Emission Bus Transition and Implementation Plan* and is described below.

Bus efficiency and range are primarily driven by vehicle specifications; however, it can be impacted by a number of variables including the route profile (i.e., distance, dwell time, acceleration, sustained top speed over distance, average speed, traffic conditions, etc.), topography (i.e., grades), climate (i.e., temperature), driver behavior, and operational conditions such as passenger loads and auxiliary loads. As such, BEB efficiency and range can vary dramatically from one agency to another. Therefore, it is critical to determine efficiency and range estimates that are based on an accurate representation of the operating conditions associated with Transfort's system to complete the assessment.

The first task in the Service Assessment is to develop route and bus models to run operating simulations for representative Transfort routes. CTE uses Autonomie, a powertrain simulation software program developed by Argonne National Labs for the heavy-duty trucking and automotive industry. CTE has modified software parameters specifically for electric buses to assess energy efficiencies, energy consumption, and range projections. GPS data was collected from twelve (12) of the twenty-two (22) Transfort routes for analysis. GPS data includes time, distance, vehicle speed, vehicle acceleration, GPS coordinates, and roadway grade that is used to develop the route model. CTE used component-level specifications and the collected route data to develop a baseline performance model by simulating the operation of BEB on each of the twelve (12) routes.

Ideally it would be best to collect data and model every route in Transfort's network; however, this is impractical due to the amount of time and labor this approach would require. Instead, a sampling approach was used where sample routes were identified with respect to topography and operating profile (e.g. average speeds, etc.). The modeling results of the sample routes were then applied to the routes and blocks that share similar characteristics.

The data from the routes, as well as the specifications for each of the bus types selected, was used to simulate operation of each type of bus on each type of route. The models were run with varying loads to represent "nominal" and "strenuous" loading conditions. Nominal loading conditions assume average passenger loads and moderate temperature over the course of the day, which places marginal demands on the motor and heating, ventilation, and air conditions (HVAC) system. Strenuous loading conditions assume high or maximum passenger loading and either very low or very high temperature (based on agency's latitude) that requires near maximum output of the HVAC system. This Nominal/Strenuous approach offers a range of operating efficiencies to use in estimating average annual energy use (Nominal) or planning minimum service demands (Strenuous). Modeled operating scenarios are included in **Table 4** below.

Table 4 – Modeled Operating Scenarios

Load Case	Temperature (°F)	Vehicle Size (ft)	Occupants (@ 150 lbs)	Average Auxiliary Load (kW)
Nominal	55	35	8	6.5
		40	14-27*	6.5
		60	17	10
Strenuous (Aux Diesel Heat/Electric Heat)	12	35	90	6.5/27.5
		40	108	6.5/27.5
		60	125	16/36

*Range of occupants is based on average passenger loads for different routes serviced by 40' buses

Route modeling ultimately provided the average energy use per mile (kilowatt-hour/mile [kWh/mi]) associated with each route, bus size, and load case. Using the results shown in **Table 5,** system-wide energy use and costs were estimated in the subsequent assessments.

Table 5 – Modeling Results Summary

Bus Length (ft)	Route	Average Speed (mph)	Nominal Efficiency (kWh/mi)	Strenuous Efficiency w/ Aux Diesel Heat [kWh/mi]	Strenuous Efficiency Electric Heat [kWh/mi]
35 or 40	Flex (Boulder)	32.8	1.7	1.9	2.6
	Route 3	11.2	1.8	2.1	4.0
	Route 5	13.7	1.6	2.0	3.5
	Route 7	15.2	1.6	2.0	3.4
	Route 14	16.7	1.5	1.8	3.0
	Route 16	15.9	1.8	2.2	3.5
	Route 18	13.9	1.6	1.9	3.4
	Route 31	10.2	1.9	2.2	4.2
	Route 81	15.5	1.6	2.0	3.4
	HORN	10.1	1.7	2.0	4.1
60	MAX	10.0	3.2	4.3	6.2

Using vehicle performance predicted from route modeling, combined with educated assumptions for battery electric technology, CTE analyzed the expected performance and range needed on every block in Transfort's fixed-route network and assessed the achievability of each block by BEBs over time, as range improves. The analysis focuses on bus endurance and range limitations to determine if the BEBs could meet the service requirements of the blocks throughout the transition period. The energy needed to complete a block is compared to the available energy for the respective bus type that is planned for the block to determine if a BEB can successfully operate on that block. This assessment also determines a timeline for when blocks become for eligible for zero-emission vehicles as technology improves. This information is used to then inform BEB procurements in the Fleet Assessment.

Research suggests that battery density for electric vehicles has improved by an average of 5% each year.[1] For the purposes of this study, considering the extended period of a complete fleet transition (e.g., through 2034), CTE assumes a more conservative 5% improvement every two years. If the trend continues, it is expected that buses may continue to improve their ability to carry more energy without a weight penalty or reduction in passenger capacity. Over time, BEBs are expected to approach the capability to replace all of an agency's fossil-fuel buses one-for-one.

The block analysis, with the assumption of 5% improvement in battery capacity every other year, was used to determine the timeline for when routes and blocks become achievable for BEBs to replace CNG buses one-for-one. This information was then used to inform BEB procurements in the Fleet Assessment. The results from the block analysis are used to estimate the number of BEBs required to replace the CNG fleet, including the expected expansion of service to increase from 53 to 82 vehicles by 2040. As discussed previously, for the analysis, it was assumed that new service blocks to support expansion of the fleet will be planned such that they can be operated with BEBs charged overnight at a depot. The average mileage per bus length per day will remain constant for the new buses that are added to the fleet.

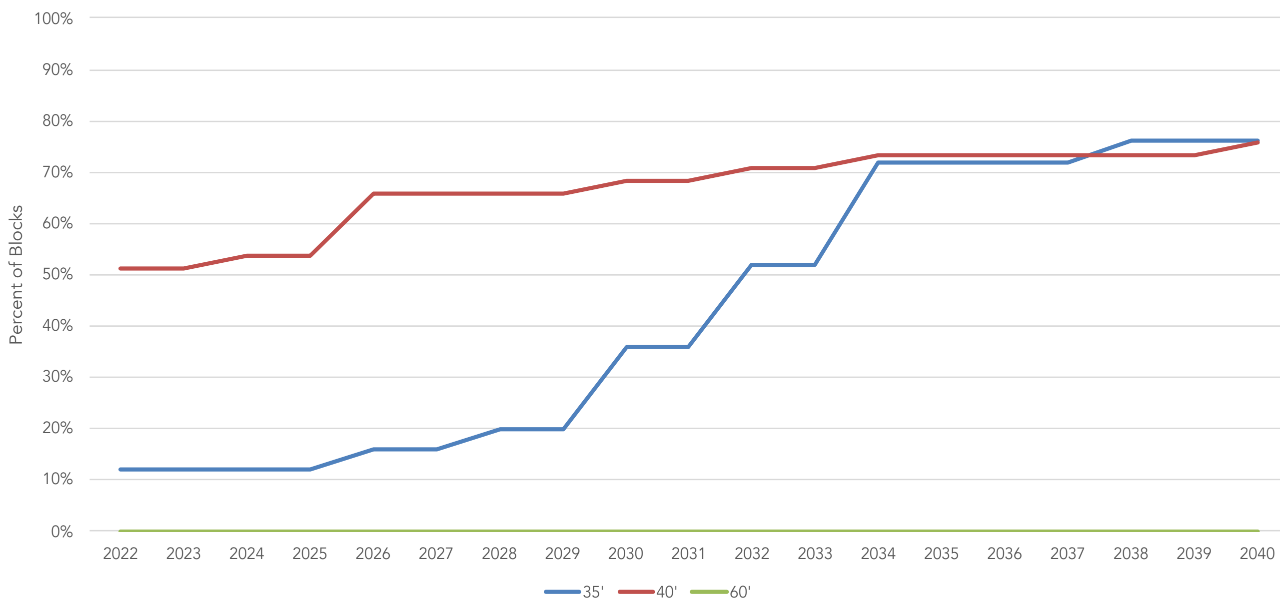
Results from this analysis were also used to determine the specific energy requirements and develop the estimated costs to operate the ZEBs in the Fuel Assessment.

Results from the analysis indicate that today, approximately 12% of blocks assigned to 35' vehicles; 51% assigned to 40' vehicles, and none of the blocks assigned to 60' vehicles can be completed with a single overnight depot charge. Analysis indicates that an estimated 76% of the blocks assigned to 35' or 40' vehicles will be feasible by 2040 but still none of the blocks assigned to 60' buses are expected to be feasible with a single overnight depot charge. The feasibility analysis used buses that Transfort has already agreed to purchase in 2023 and 2024 (Gillig BEBs with 588 kWh nameplate capacity battery) as well as currently available 60' bus configurations (525 kWh).

Results from the block analysis that indicate the yearly block achievability by bus length throughout the transition period for BEBs is included in **Figure 1** below.

[1] U.S. Department of Energy; LONG-RANGE, LOW-COST ELECTRIC VEHICLES ENABLED BY ROBUST ENERGY STORAGE, MRS Energy & Sustainability, Volume 2, Wednesday, September 9, 2015; https://arpa-e.energy.gov/?q=publications/long-range-low-cost-electric-vehicles-enabled-robust-energy-storage

Figure 1 – BEB Block Achievability Percentage by Length



While routes and block schedules are unlikely to remain the same over the course of the transition period, these projections assume the blocks will retain a similar structure to what is in place today including a similar distribution of distance, relative speeds, and elevation changes by covering similar locations within the city.

It should be noted that BEB range is negatively impacted by battery degradation over time. A BEB may be placed in service on a given block with beginning-of-life batteries (BOL); however, it may not be able to complete the entire block at some point in the future before the batteries are at end-of-life (EOL) which is typically considered 80% of available service energy. Conceptually, older buses can be moved to shorter, less demanding blocks and newer buses can be assigned to longer, more demanding blocks.

Further evaluation was conducted to determine if on-route charging could be implemented to meet the remaining energy demands to successfully complete all routes within Tranfort's service. Analysis conducted indicated that on-route charging would be required to support all 60' blocks, including the MAX service that operates through the South Transit Center (~2027) as well as the new BRT service that will operate through the Foothills Transit Center (~2025). Analysis of the blocks for the future service that will operate through the Foothills Transit Center indicated that there appears to be sufficient time in the proposed schedule to adequately charge the buses to complete the service. Evaluation of the MAX service indicates that changes to the schedule to increase the expected layover or the addition of relief buses may be required to adequately complete the daily service needs under strenuous operating conditions. Specifically, MAX-2, MAX-4, and MAX-6 are not achievable under strenuous conditions without extended charging time throughout the day (between 30 minutes and one hour is expected to be required).

In addition, evaluation of the remaining 24% of the 35' and 40' blocks indicated that these blocks are feasible based on the current operating schedule assuming further development of on-route charging infrastructure at the Downtown Transit Center (~2027) and the CSU

Transit Center (~2033); however, it should be noted that accelerated advanced in battery capacity may mitigate the need for on-route charging of the 35’ or 40’ BEBs in the future.

4 Fleet Assessment

A Fleet Assessment was completed as part of the Phase I analysis and provided in the *Transfort Zero Emission Bus Transition Screening Assessment* dated October 2021. As a result of the Phase I analysis, Transfort elected to completed a detailed Phase II analysis of BEB On-Route and Depot Charging, including updating the Fleet Assessment. The fleet assessment was conducted specifically for the heavy duty transit buses. Transfort's cutaway operations are discussed in Section 14 of this plan.

Cost Assumptions

CTE developed cost assumptions for each bus length and technology type (e.g., CNG, BEB). Key assumptions for bus costs are as follows:

- Bus costs are based on current Transfort procurements, industry quotes, and the State of California statewide procurement contract for BEBs executed in 2019
- Bus costs are inclusive of configurable options
- Bus costs are inclusive of battery warranties
- Future bus costs are based on current year costs based on discussion with Transfort
- Bus replacement costs are only for the fixed route, heavy duty vehicles and do not include any cutaway

Table 6 provides estimated bus costs used in the analysis.

Table 6 – Fleet Assessment Cost Assumptions

Length [ft]	CNG	BEB
35	$ 586,000	$ 1,037,534
40	$ 588,000	$ 1,063,034
60	$ 868,000	$ 1,600,000

Baseline

The Baseline scenario is used for comparative purposes only. It assumes no changes to Transfort's current fleet composition throughout the life of the study. The Baseline scenario incorporates growth with all new buses purchased for fleet expansion in 2030, 2035, and 2040 being CNG. The Baseline scenario creates context for incremental costs incurred or benefits accrued by transitioning the fleet to zero-emission. The baseline scenario includes incorporation of a total of 17 BEBs in 2022 through 2025 that Transfort has already identified funding to support (Volkswagen Settlement and Low-No) or has committed to purchasing for the service (West Elizabeth BRT),

Figure 2 provides the number and fuel type for the buses purchased each year according to Transfort's fleet replacement schedule.

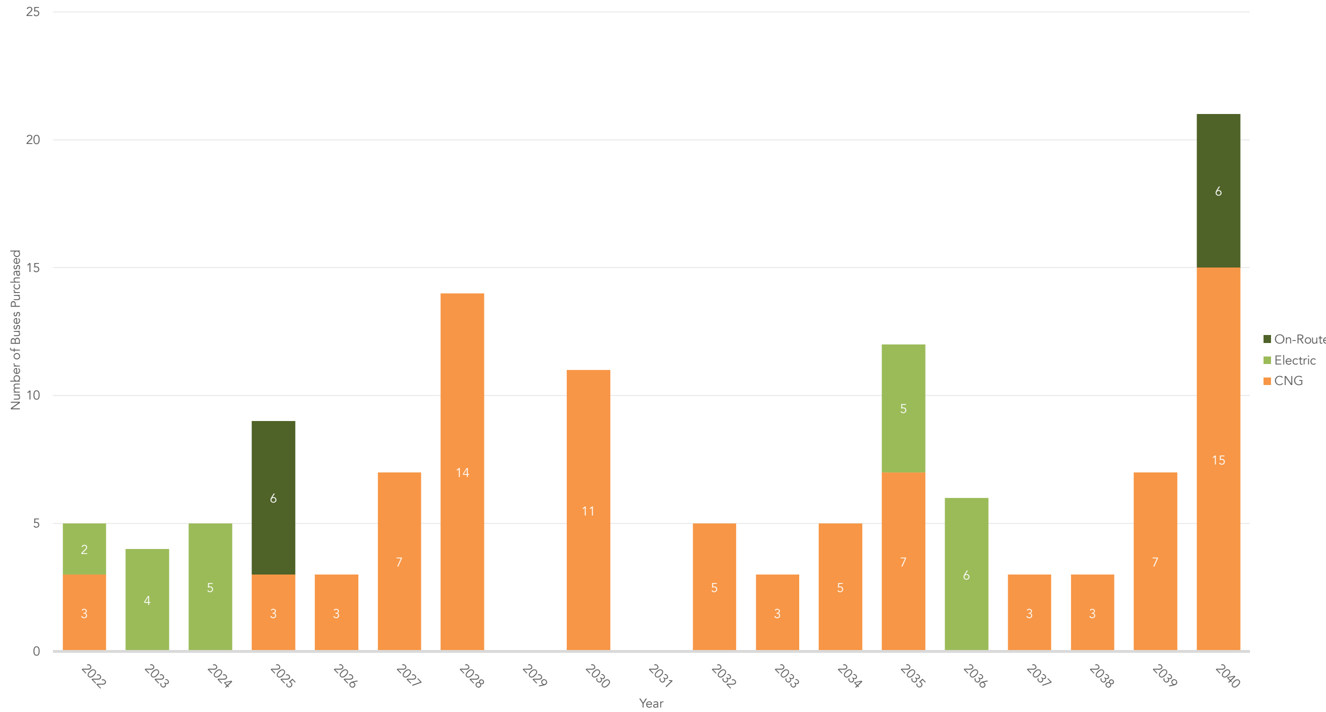


Figure 2 – Annual Vehicle Purchases by Fuel Type, Baseline

Figure 3 shows the annual capital costs based on the purchase schedule and bus cost assumptions for the Baseline Scenario. Annual bus purchase costs range from no purchases to up to approximately $18 million a year.

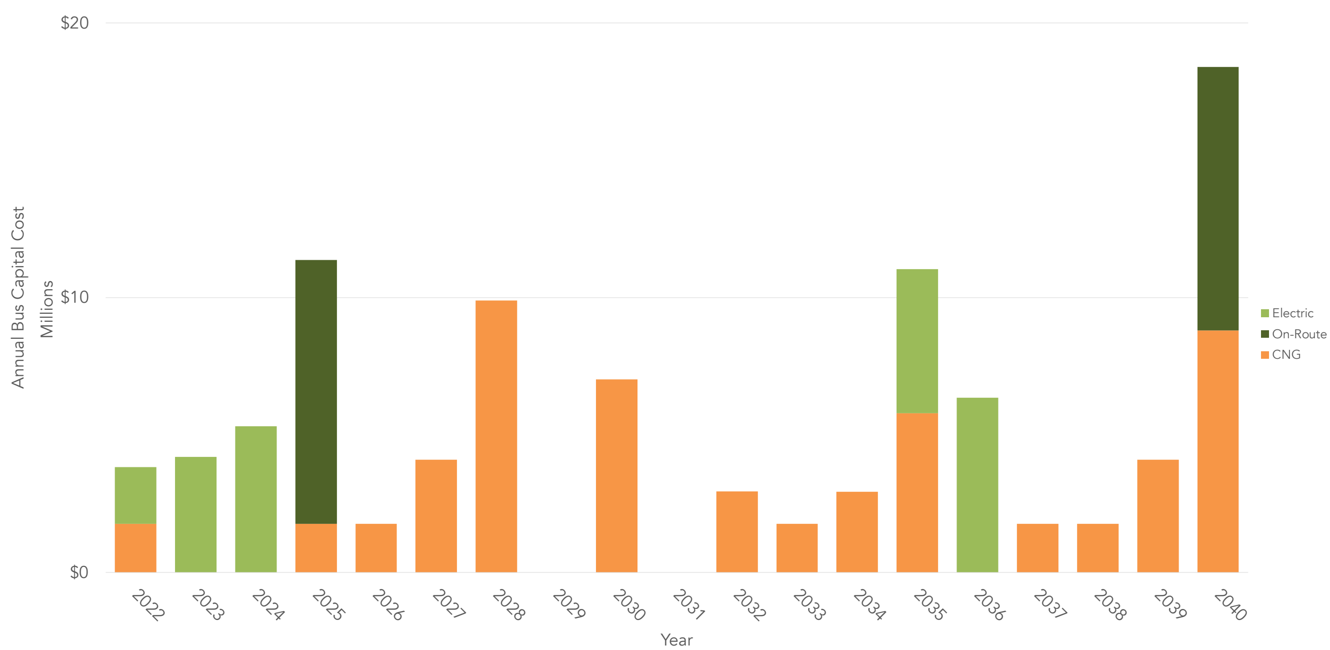


Figure 3 – Annual Capital Costs, Baseline

BEB On-Route and Depot Charging

The BEB On-Route and Depot Charging scenario assumes that BEBs will replace the current CNG vehicles on a one-to-one basis following Transfort's vehicle replacement schedule. All vehicles that support service expansion in 2030, 2035, and 2040 are assumed to follow similar blocking and be able to complete all blocks planned for service with overnight charging at a depot. BEBs added in 2025 to support the new West Elizabeth BRT service that operates through the Foothills Transit Center are assumed to be on-route charged. Additional BEBs are added over the course of the replacement schedule distributed among purchase years to account for service blocks that cannot be completed with a one-to-one replacement including for the MAX service (60' BEBs that operate through the South Transit Center). **Figure 4** provides the number of vehicles purchased each year through 2040.

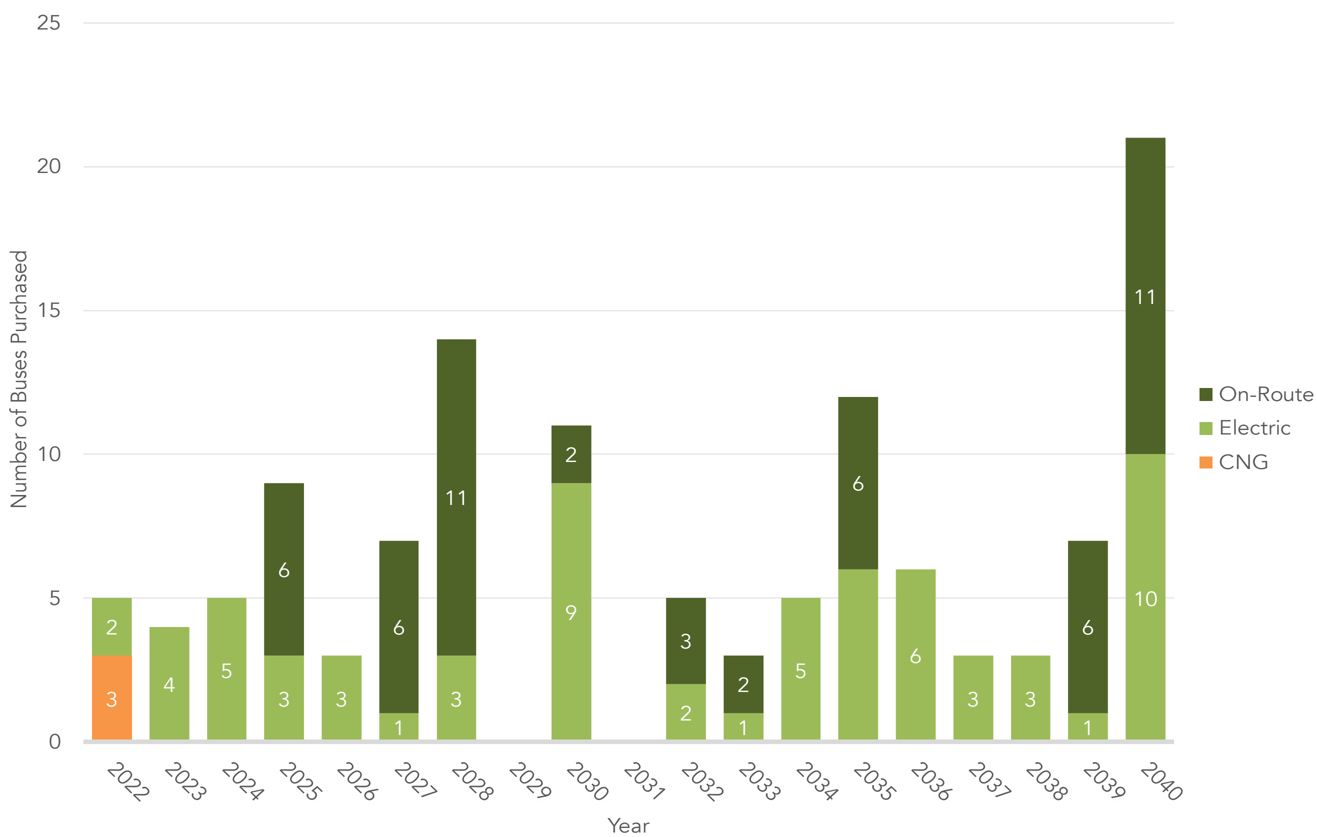


Figure 4 – Projected Vehicle Purchases, BEB On-Route and Depot Charging

Figure 5 depicts the annual fleet composition through 2040.

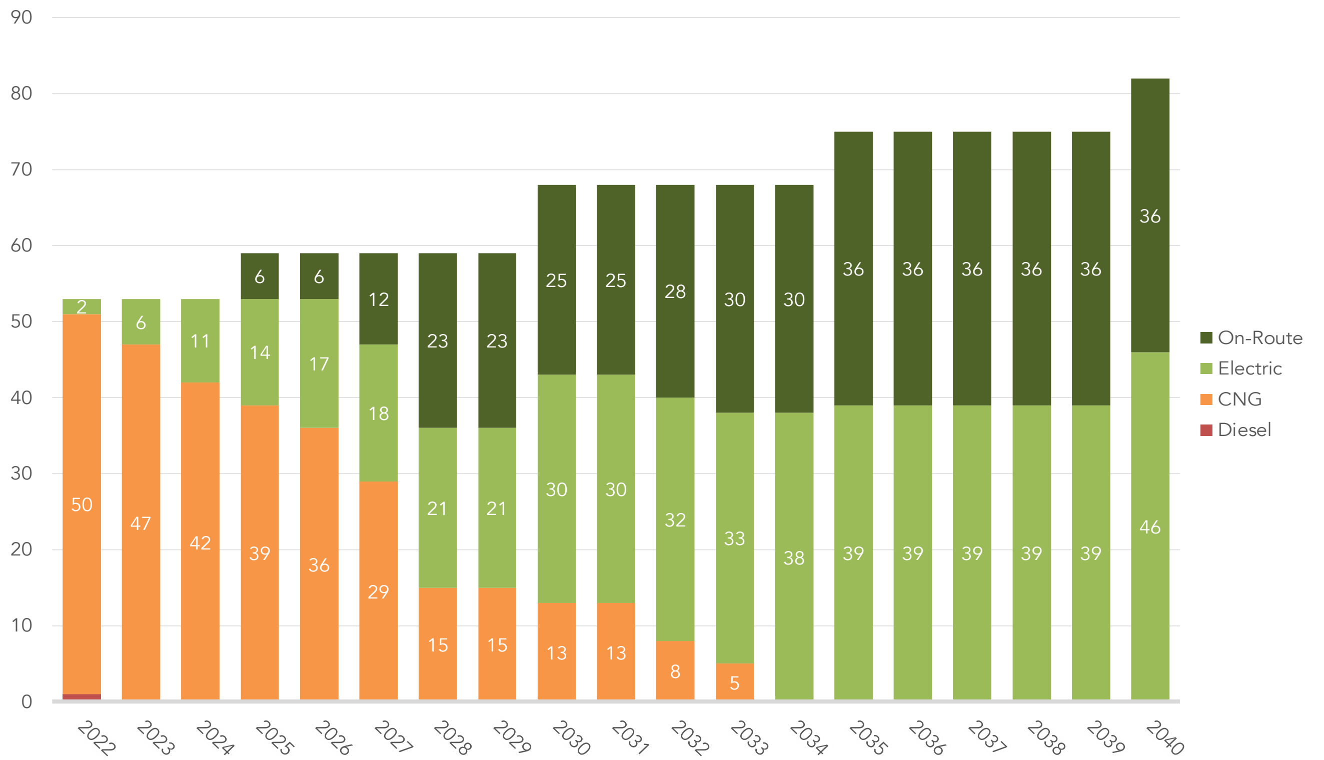


Figure 5 – Annual Fleet Composition, BEB On-Route and Depot Charging

Figure 6 shows the annual bus cost for BEBs in a given year for the BEB On-Route and Depot Charging Scenario.

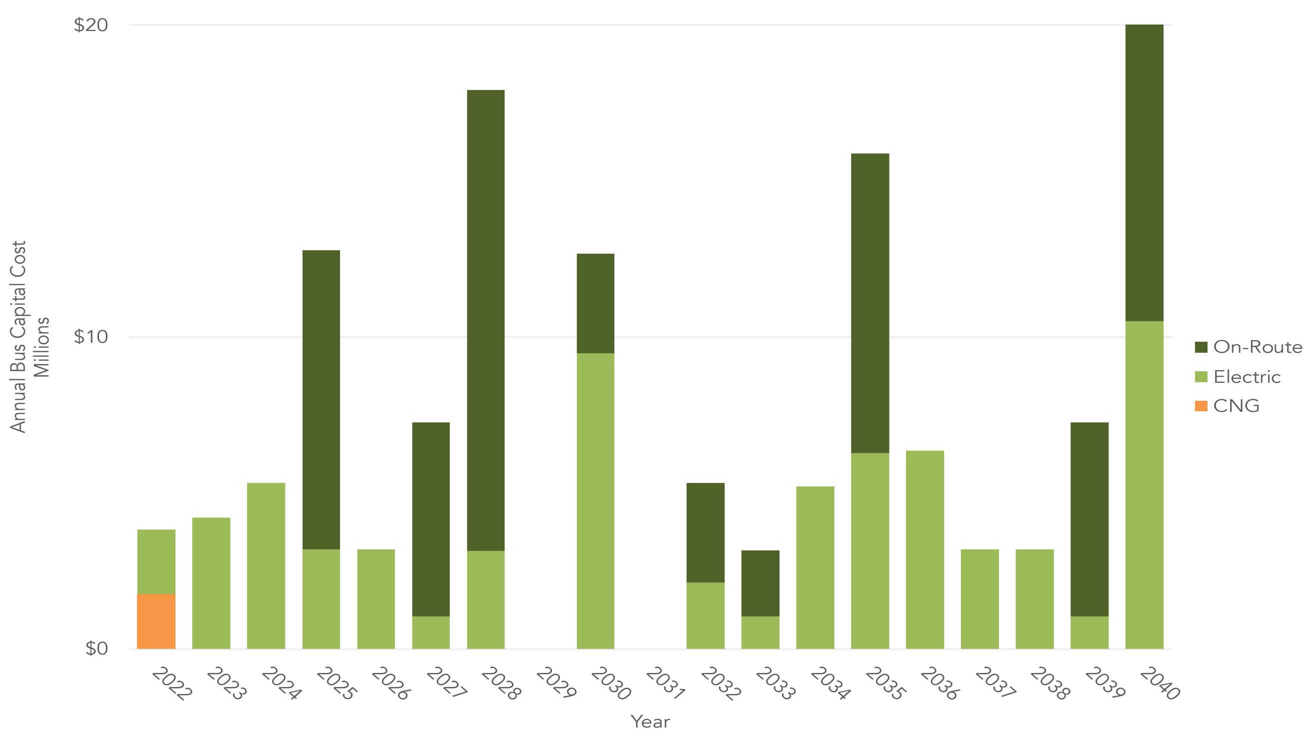


Figure 6 - Annual Capital Costs, BEB On-Route and Depot Charging

BEB Fleet Transition Costs

The fleet composition throughout the transition period were used to develop estimated costs to replace the entire fleet. The cost represents the total investment to purchase all of the vehicles included in the fleet replacement schedule through 2040. This includes multiple purchase rounds of vehicles purchased prior to 2025 due to the 15 year replacement schedule. While it is expected that changes in costs over time are likely to occur, given the rapid change in the industry at this time, CTE has no reliable basis upon which to incorporate price changes in these projections and, as a result, costs are provided in 2022 dollars. Estimated capital costs for bus replacement are included in **Table 7**. Note that the addition of a potential relief bus(es) to support the MAX service are not included in the costs.

Table 7 - BEB Capital Costs

Scenario	# of Vehicles	# of BEBs	% BEB	Estimated Fleet Replacement Cost (2021 $)	Incremental Cost to Replace Vehicles compared to Baseline (2022 $)	% Cost compared to Baseline
Baseline	82	17	21%	$98,547,000	--	--
BEB On-Route and Depot Charging	82	82	100%	$142,034,000	$43,487,000	144%

5 Fuel Assessment

Using BEB performance data from the screening analysis, CTE evaluated the expected performance on each block in Transfort's service network to calculate daily energy requirements. The projection scenarios from the Fleet Assessment are used to estimate associated annual fuel and energy costs unique to each fleet projection. The Fuel Assessment estimates quantities and costs for Transfort's CNG vehicles as well as electrical energy costs for the BEBs projected in each scenario.

The terms "fuel" and "energy" are used interchangeably in this analysis, as ZEB technologies do not require traditional liquid fuel. For clarity, in the case of BEBs, "fuel" is electricity, and costs include energy, demand and other utility charges. Operation and maintenance costs to maintain charging infrastructure are built into the Fuel Assessment. Fuel cost estimates are based on the assumptions in **Table 8**.

Table 8 - Fuel Assessment Assumptions

Fuel	Cost	Source
CNG	$2.26/Diesel Gallon Equivalent (DGE)	September 2022 Department Vehicle Fuel Summary (Transfort); includes maintenance for CNG equipment
Electricity	Varies	City of Fort Collins Utilities E-400 (Industrial)
Energy Used (kWh)	35' BEB: 1.8 kWh/mi 40' BEB: 2 kWh/mi. 60' BEB: 3.5 kWh/mi	Assumes a nominal driving efficiency based on CTE modeling results
Demand (kW)	150 kW depot chargers 450 kW on-route opportunity chargers or fast-lane chargers at depot	3 buses to 1 charging station for first 6 charging stations; 2 buses to 1 charging station for remaining
Charger Maintenance	$800/charger per year	Existing maintenance agreement

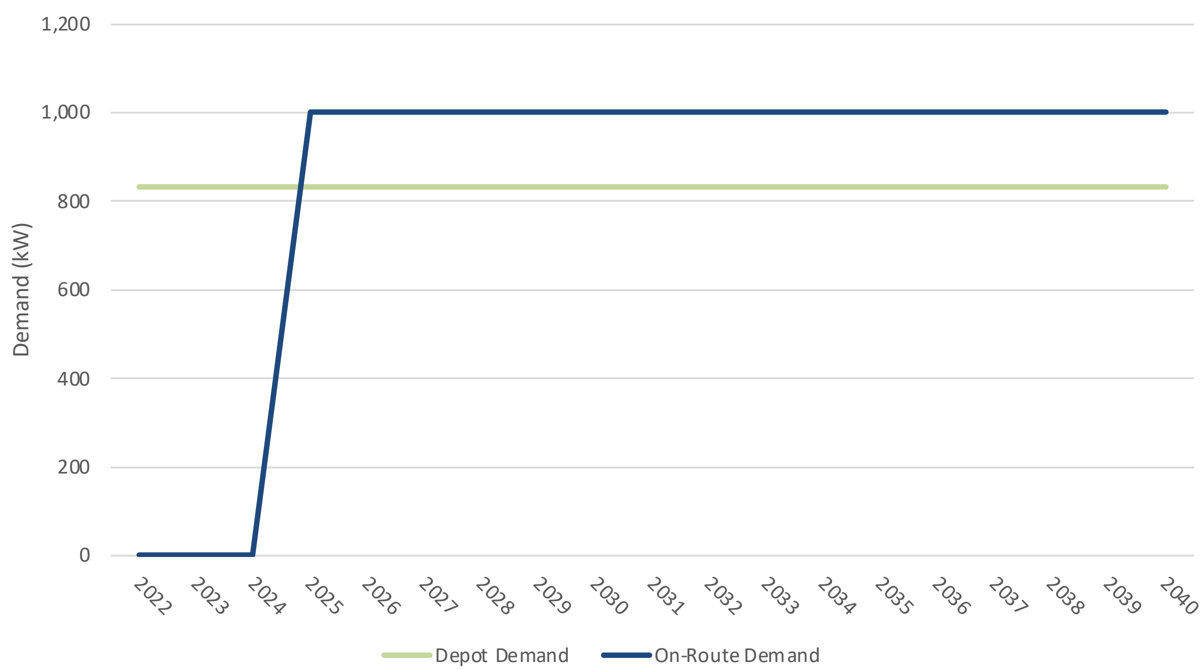
Electrical costs are often complex to understand and predict compared with other fuels. This is because pricing is generally driven by three factors: the amount of energy (as with conventional fuels), demand charges—which depend on how fast that energy is pulled from the grid (i.e. charging speed and number of buses charging at the same time)—and other additional fees. Demand charges are often the major cost contributor for BEB operations and very sensitive to charging behavior. Transfort's utility rate structure includes all of these typical components. The E-400 Plan (Industrial, higher demand) was used for this analysis.

The rate schedule also includes additional fees for "coincident peak demand" which is demand from charging that coincides with peak demand periods of the immediate region, as defined by the utility. If demand occurs during this time period, a significant unit cost rate is applied per kW of demand (higher than and in addition to the normal demand fees). The project team agreed that best practice is to avoid the coincident periods during the day wherever possible. Therefore, for depot charging of BEBs, the charging schedule was managed to avoid this time period. In the case of on-route charging this was unavoidable, as buses will be charging at multiple times during the middle of the day.

Baseline Fuel Use

Baseline electrical demand and energy use to support the BEBs that are planned were calculated for the fuel analysis. Demand associated with the Baseline, including expected demand at the Foothills Transit Center to support the West Elizabeth BRT using on-route chargers and the depot demand for the planned eleven (11) BEBs, is depicted in **Figure 7.**

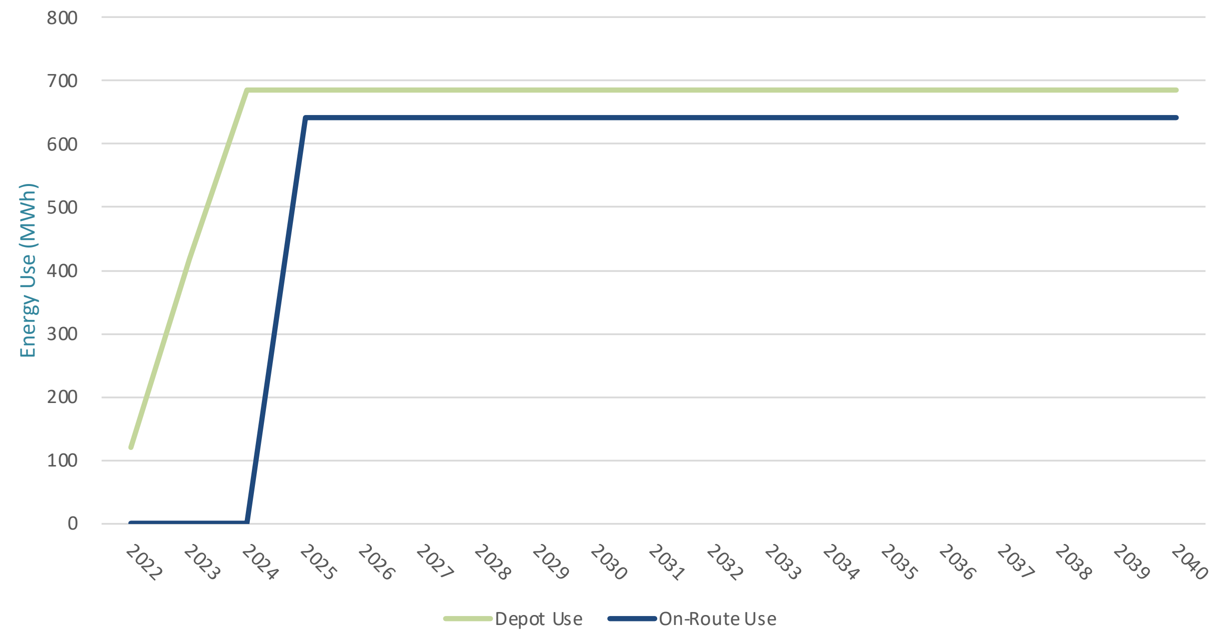
Figure 7 – Estimated Maximum Electrical Demand, Baseline



The depot demand assumes operation of up to six (6) 150 kW chargers to support the charging of already planned BEBs. The total maximum demand for on-route charging of approximately 1,000 kW is estimated to occur beginning in 2025 at the Foothills Transit Center. The demand estimates for on-route charging, and the costs associated with demand, are worst case assuming that both chargers are operating at the maximum capacity over the same 15-minute interval for the month.

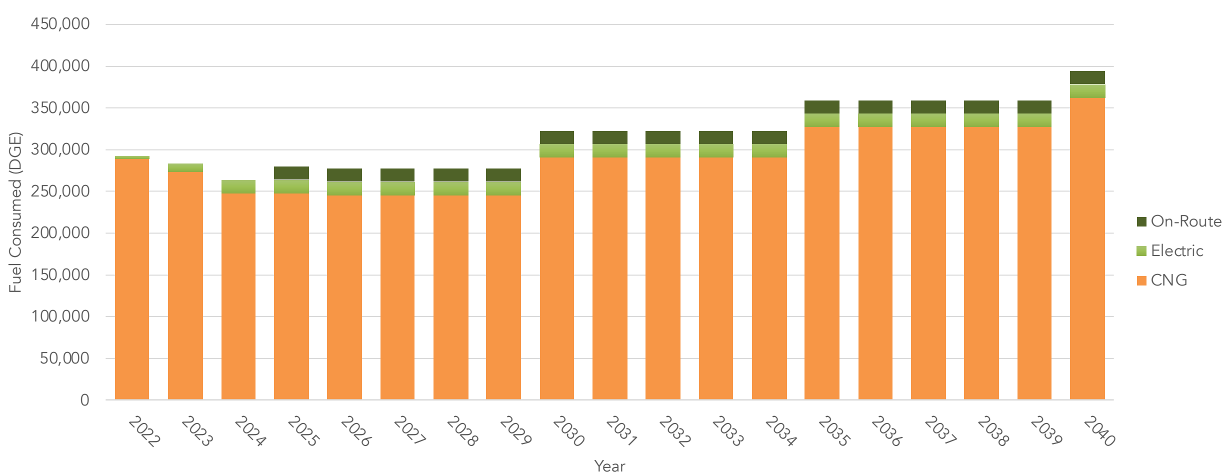
Figure 8 provides the estimated annual electrical use in megawatt-hours (MWh) for Baseline BEB operations. Electrical use was calculated based on the energy needs of operating each block in the service under nominal conditions.

Figure 8 – Estimated Annual Electrical Use, Baseline



Annual fuel use in diesel gallon equivalents (DGE) based on the expected operating mileage for each vehicle for the Baseline is provided in **Figure 9**.

Figure 9 - Annual Fuel Use, Baseline

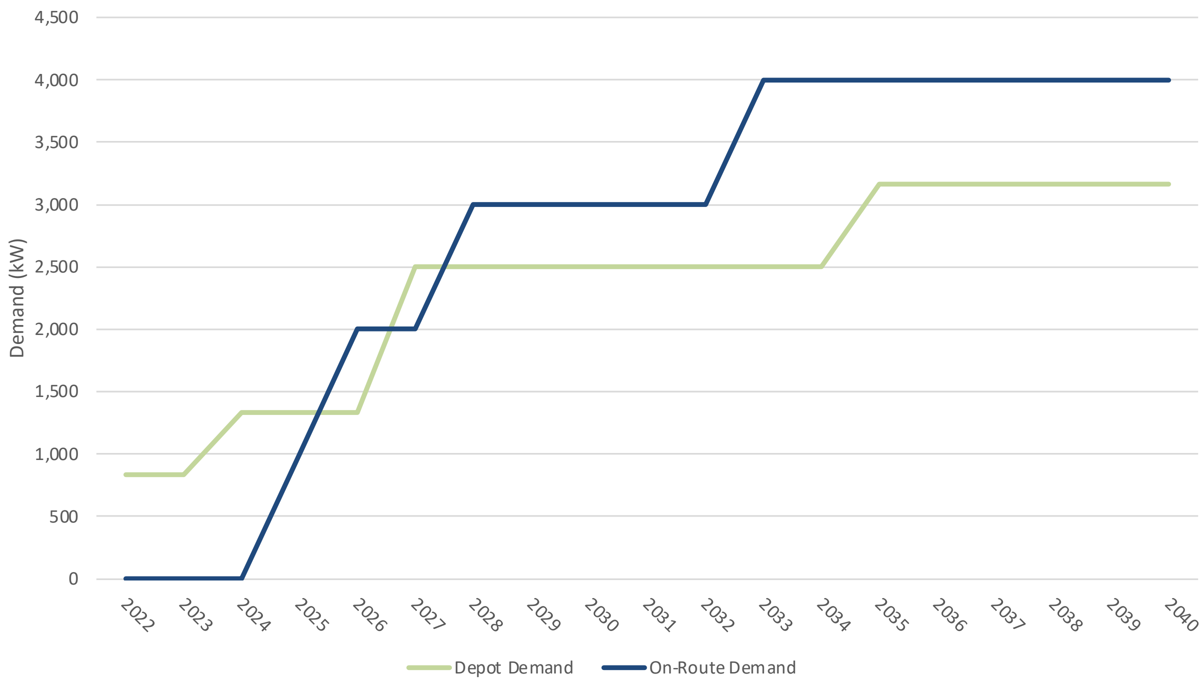


Results indicate that the fuel use is expected initially be reduced due to the planned replacement of eleven (11) CNG vehicles with BEBs and the service expansion with six (6) BEBs to support the West Elizabeth BRT in 2025; however, fuel use begins to increase in 2030 as all future vehicle purchases are planned as CNG in the Baseline. The initial decrease in fuel use is expected because BEBs are up to four times more fuel efficient than CNG vehicles, and thus require less fuel (electricity in this case) to operate the same number of miles annually.

BEB On-Route and Depot Charging Fuel Use

Electrical demand and energy use to support the transition to BEBs for the BEB On-Route and Depot Charging scenario were calculated for the fuel analysis. **Figure 10** provides the estimated demand increase over time as new BEBs are brought into service and new charging facilities are constructed for the BEB Depot and On-Route Charging Scenario. The demand on-route at the transit centers and at the TMF (or new depot) are depicted separately.

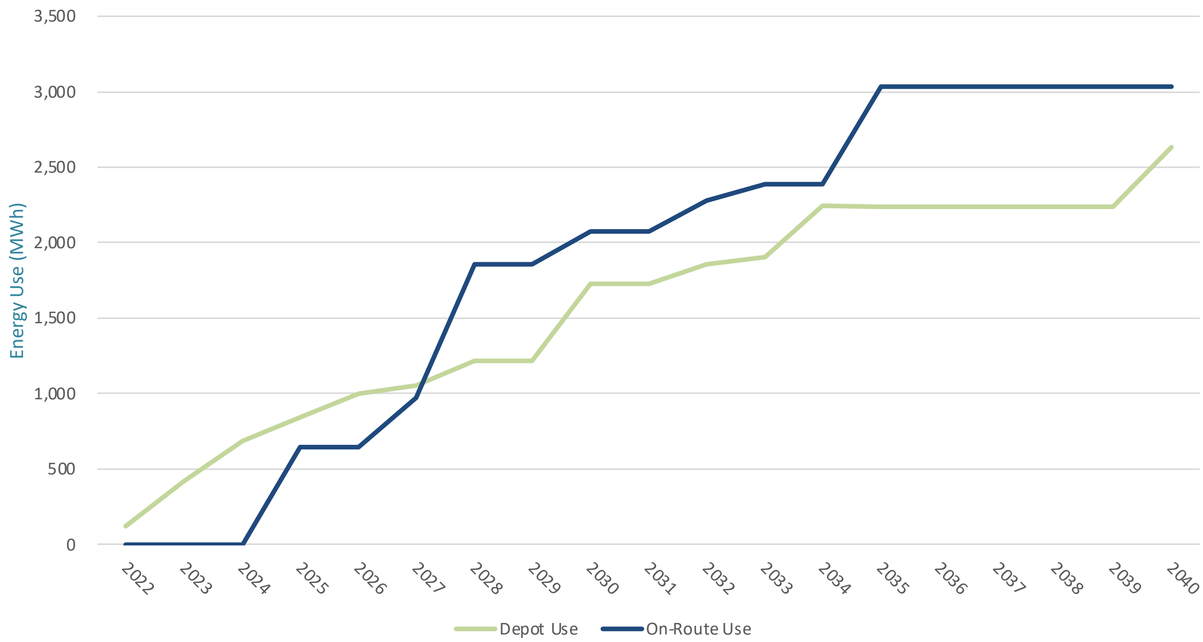
Figure 10 – Estimated Maximum Electrical Demand, BEB On-Route and Depot Charging



Review of the results indicates that a maximum demand of approximately 3,200 kW is estimated at the depot facilities (TMF and new facility) in 2035. The total maximum demand for on-route charging of approximately 4,000 kW is estimated to occur beginning in 2033. On-route demand is split between four (4) charging facilities, each equipped with two (2) 450-kW opportunity chargers for this analysis. As such, the demand at each facility is estimated at a maximum of approximately 1,000 kW. These demand estimates, and the costs associated with demand, are worst case assuming that all chargers (except for spares) are operating at the maximum capacity over the same 15-minute interval for the month.

Figure 11 provides the estimated annual electrical use in MWh for BEB On-Route and Depot Charging.

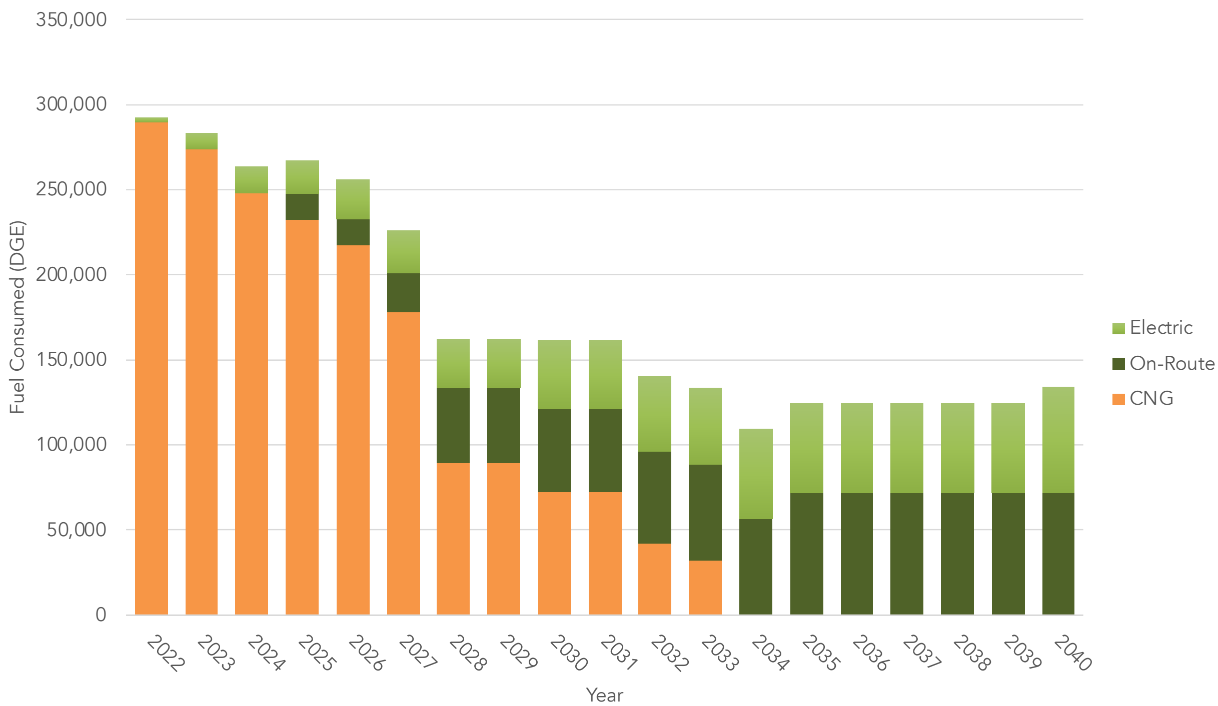
Figure 11 – Estimated Annual Electrical Use, BEB On-Route and Depot Charging



Electrical use was calculated based on the energy needs of operating each block in the service under nominal conditions. The estimates consider the fleet expansion. Each new bus entering service in 2030, 2035, and 2040 was assumed to operate the average mileage for the vehicle type in the fleet for the purposes of estimating energy use. As discussed previously, all service expansion, with the exception of the West Elizabeth BRT, was assumed to be supported by BEBs that would charge at the depot. However, it is recommended that these new vehicles be outfitted to support on-route charging and be capable of utilizing on-route charging infrastructure that may exist at the time of deployment to increase their operational range as capacity allows.

Annual fuel use in DGE required to operate Transfort's service, including expansion, is provided in **Figure 12.**

Figure 12 - Annual Fuel Use, BEB On-Route and Depot Charging



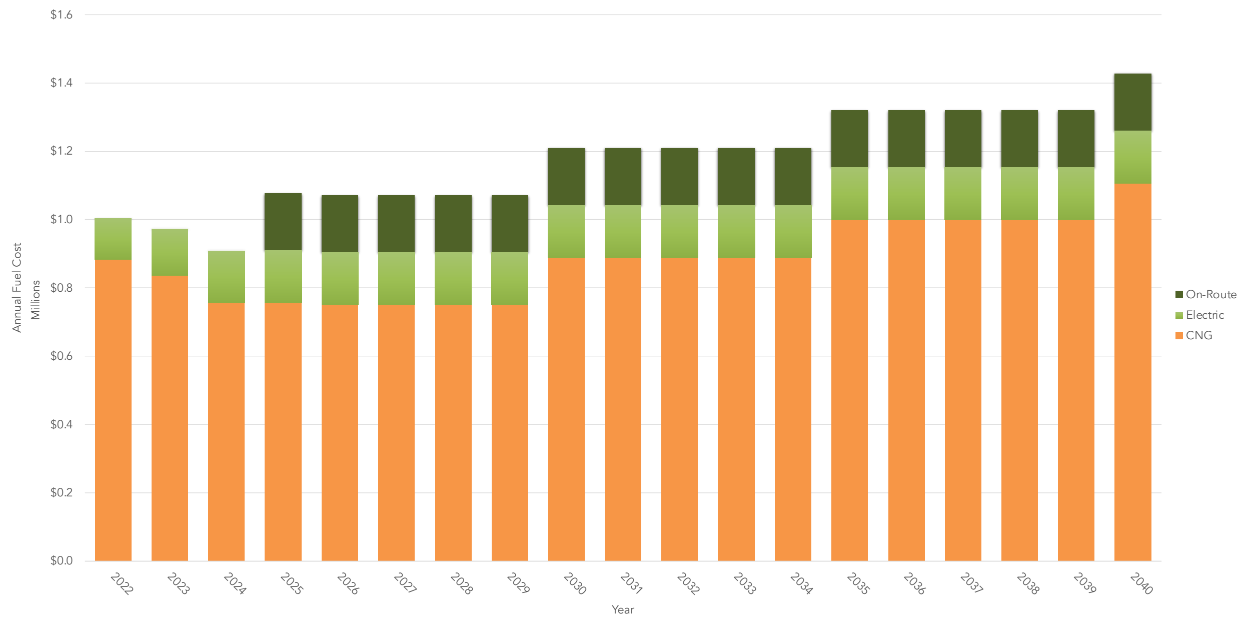
Results indicate that, despite the increase in number of vehicles and associated vehicle mileage, the fuel use in DGE actually decreases by approximately 50% throughout the transition period. This decrease is because operating BEBs is considerably more efficient (with some estimates as much as 4 times) than CNG vehicles.

Fuel Costs

Inputs from the fleet transition schedule/composition, fuel cost assumptions for CNG and the energy rate plan available from the City of Fort Collins Utilities were used to calculate the cumulative fuel costs and average fuel costs per mile. Following discussions with Transfort, it was determined that BEBs would be equipped with auxiliary diesel heaters to improve comfort and range in cold weather. As a result, CTE estimated 10 gallons of diesel use per day per achievable block for auxiliary heating, assuming it would be used 90 days per year. The cost for diesel fuel is incorporated into the cost analysis for the energy costs associated with BEB operations. In addition, cost of maintaining the charging equipment is also included in the electrical fuel costs. Fuel costs assumptions were previously provided in **Table 8.**

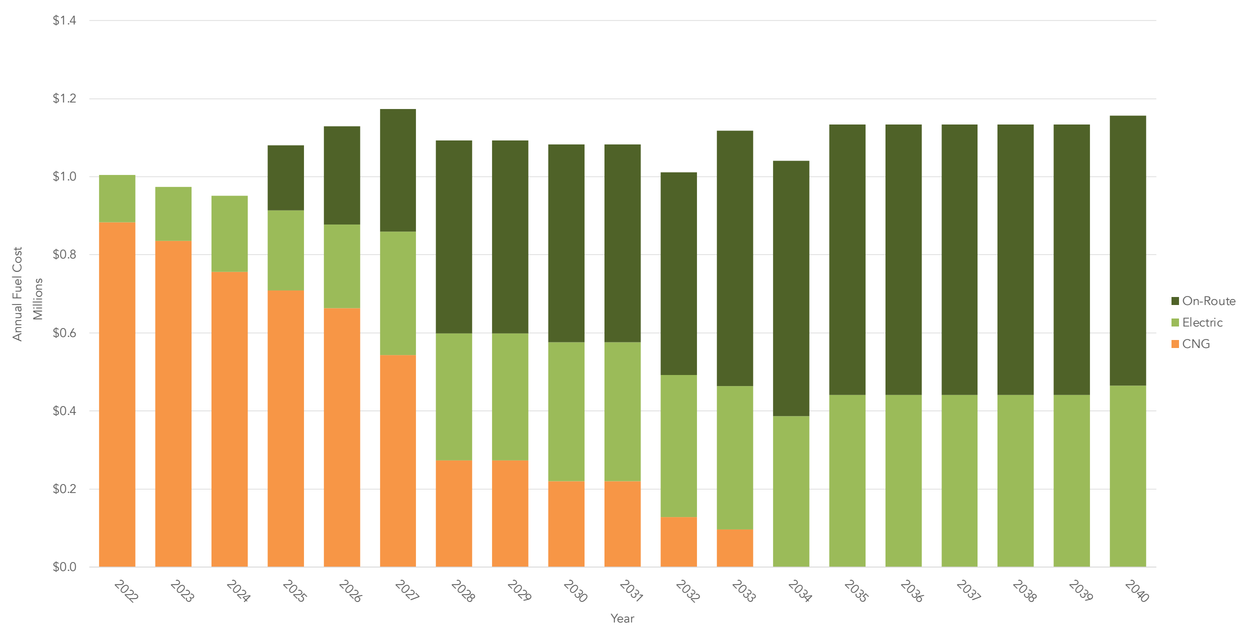
Baseline fuel costs for the transition period are provided in the below figure.

Figure 13 – Annual Fuel Costs, Baseline



BEB On-Route and Depot Charging annual fuel costs are provided in **Figure 14.**

Figure 14 - Annual Fuel Cost, BEB On-Route and Depot Charging



The total fuel costs for the transition period as well as the average fuel cost per mile for the Baseline and BEB On-Route and Depot Charging scenario are provided in the below table.

Table 9 - Fuel Cost Evaluation Results

Scenario	% BEB	Total Fuel Cost ($)	Incremental Cost compared to Baseline (2022$)	Fuel Cost per Mile ($/mi)
Baseline	21%	22,319,000	--	0.66
BEB On-Route and Depot Charging	100%	20,659,000	(1,660,000)	0.61

Results from analysis indicate an estimated savings of approximately $1.7M, or $0.05/mile, by switching to BEBs during the transition period. It should also be noted that the annual cost to operate BEBs decreases to approximately $0.52/mile once all vehicles have been transitioned to BEBs by 2040. This equates to an approximate annual savings of $271,000 in fuel cost when the fleet is fully transitioned to BEB.

6 Maintenance Assessment

One of the expected benefits of moving to a BEB fleet is a reduction in maintenance costs. Conventional wisdom estimates that a transit agency may attain significant reduction in maintenance cost savings for BEBs. 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 CNG bus. The savings in traditional maintenance costs may be offset by the cost of battery replacements over the life of the vehicle; however, for this analysis, it was assumed that Transfort would purchase extended battery warranties that are included with the capital cost of the vehicles as they are with the first set of BEBs Transfort has purchased. As a result, mid-life replacements were not considered in the maintenance costs but were included in the capital cost of the vehicles at purchase.

BEB maintenance costs were derived from analysis of four different studies performed by the U.S. Department of Energy National Renewable Energy Laboratory (U.S. DOE NREL). Maintenance cost assumptions are included in **Table 10** and **Table 11.**

Table 10 - Maintenance Cost Assumptions

Type	Estimate	Source
CNG	35’ and 40’: $0.58/mile 60’: $1.18/mile	Transfort actual costs
BEB	35’ and 40’: $0.47/mile 60’: $0.96/mile	U.S. DOE NREL[1,2,3,4]

[1] *Zero-Emission Bus Evaluation Results: King County Metro Battery Electric Buses,* Leslie Eudy and Matthew Jeffers, US DOE NREL, February 2018

[2] *Long Beach Transit Battery Electric Bus Progress Report; Data Period Focus: Jan 2019 through Jun 2019,* Leslie Eudy and Matthew Jeffers, US DOE NREL, January 2020

[3] *Zero-Emission Bus Evaluation Results: County Connection Battery Electric Buses,* Leslie Eudy and Matthew Jeffers, US DOE NREL, 2018

[4] *Foothill Transit Agency Battery Electric Bus Progress Report – Data Period Focus Jul 2019 through Dec 2019,* Leslie Eudy and Matthew Jeffers, US DOE NREL, March 2020

Table 11 - Mid-Life Overhaul Cost Assumptions

Type	Overhaul Scope	Estimate	Source
CNG	Engine & transmission overhaul	$30k per bus	Transfort data
BEB	Battery replacement	$500 per kWh	Bus Manufacturer (Not used in this analysis)

Total maintenance costs for the transition period were calculated based on the operating mileage of each vehicle type during the period. Annual maintenance costs for the Baseline and the BEB On-Route and Depot Charging are depicted in **Figure 15** and **Figure 16,** respectively.

Figure 15 - Annual Maintenance Costs, Baseline

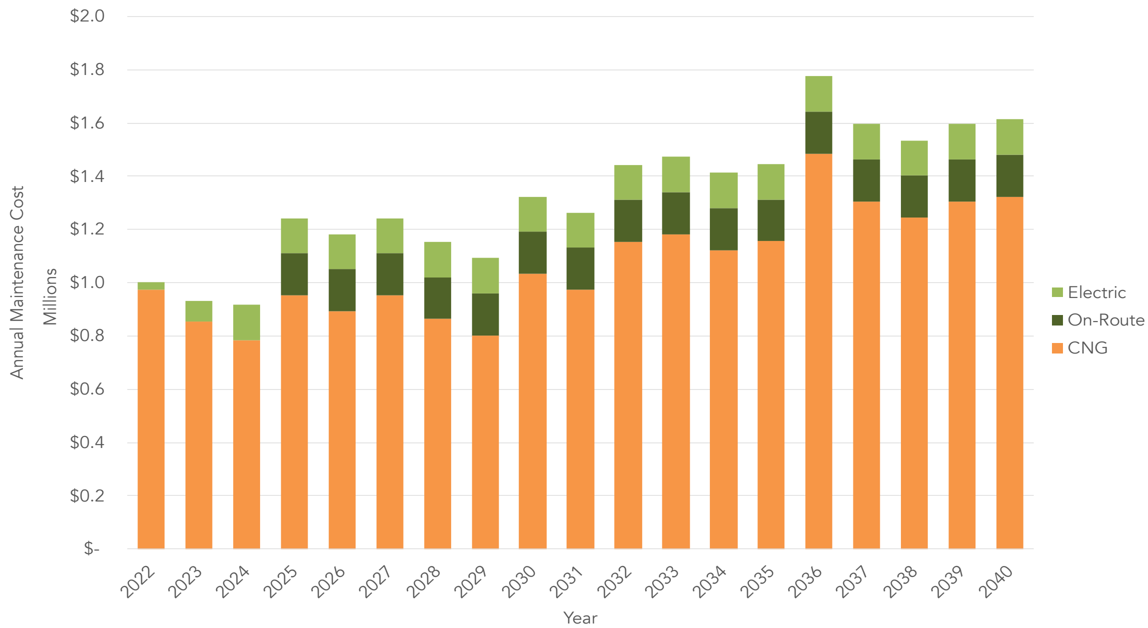
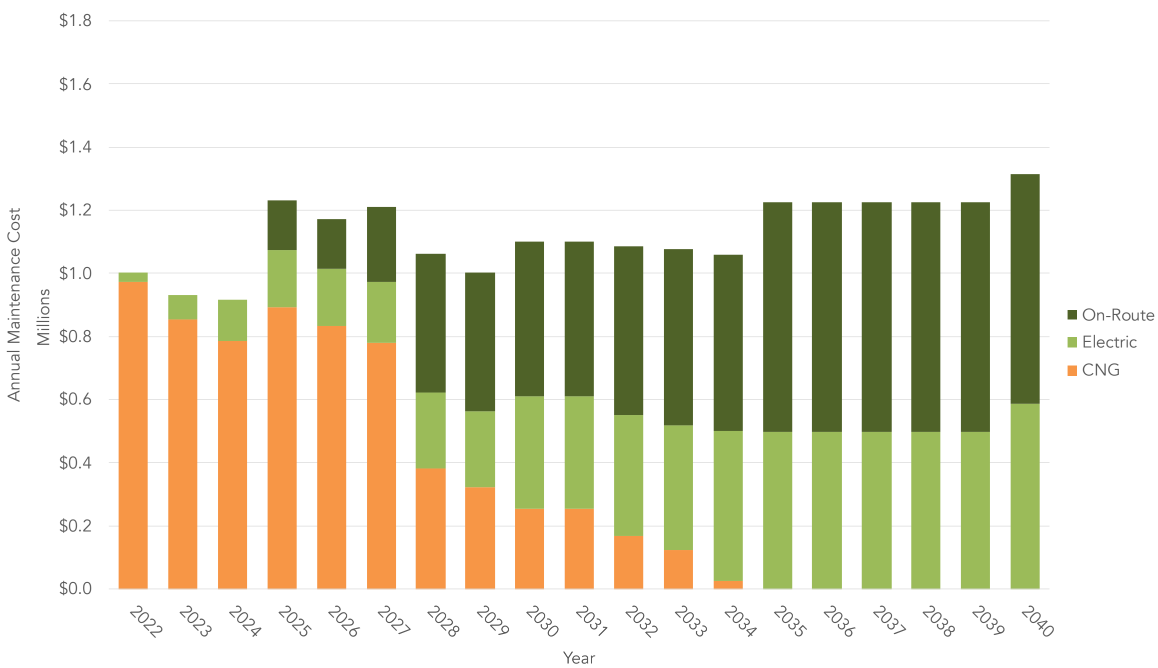


Figure 16 - Annual Maintenance Costs, BEB On-Route and Depot Charging



A summary of the maintenance costs, including estimated maintenance cost per mile, are included in **Table 12.**

Table 12 – Maintenance Cost Evaluation Results

Scenario	% BEB	Total Maintenance Cost ($)	Incremental Cost compared to Baseline (2022$)	Maintenance Cost per Mile ($/mi)
Baseline	21%	25,197,000	--	0.74
BEB On-Route and Depot Charging	100%	21,322,000	85%	0.59

Results from the analysis indicate that BEBs are expected to be more cost effective to maintain on a per mile basis at an estimated cost of $0.59/mile compared to $0.74/mile for the current CNG fleet (based on 2022 data). The maintenance costs per mile are inclusive of mid-life overhauls and replacement costs.

7 Facilities Assessment

Once the bus and fueling requirements were determined for the BEB transition, the requirements for supporting infrastructure were determined including the charging equipment and electrical infrastructure.

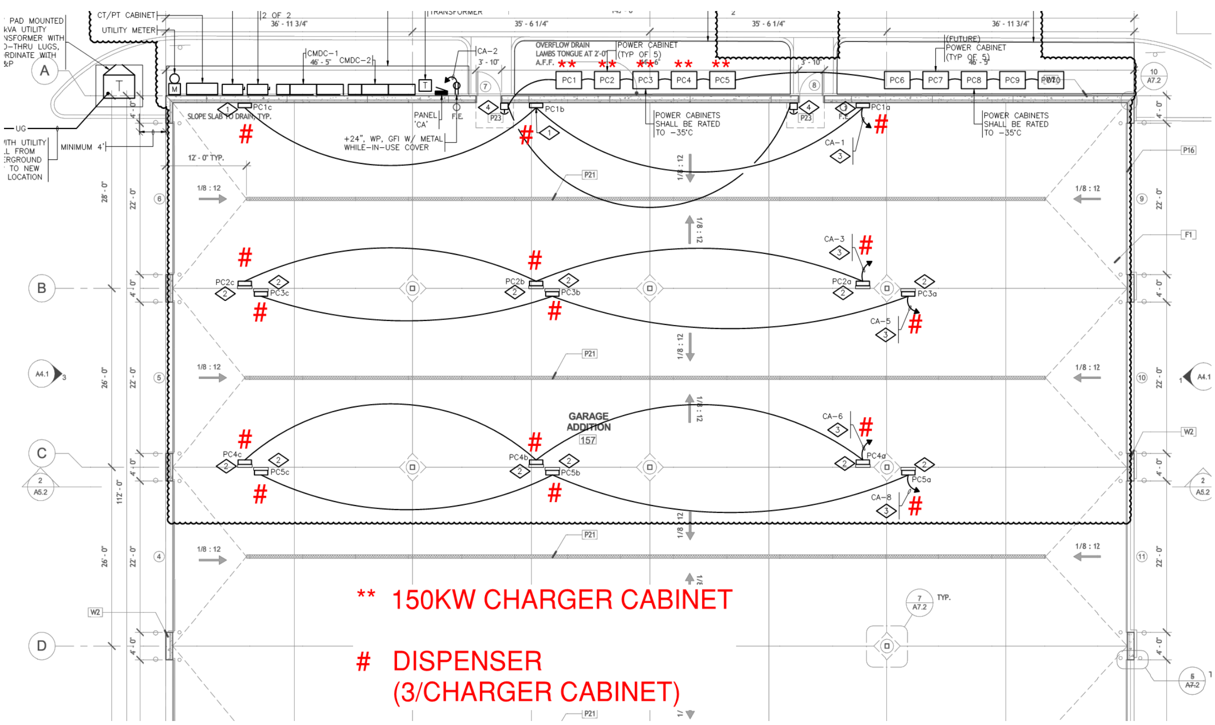
Transfort Maintenance Facility

The City of Fort Collins Utilities (a department of the City of Fort Collins) provides primary electric service to the TMF and has an operational high voltage transmission and medium voltage distribution substation directly across the street. According to Fort Collins Utilities, there are several spare medium voltage circuit breaker feeders available to serve the TMF in the future.

Phase I Charger Installation

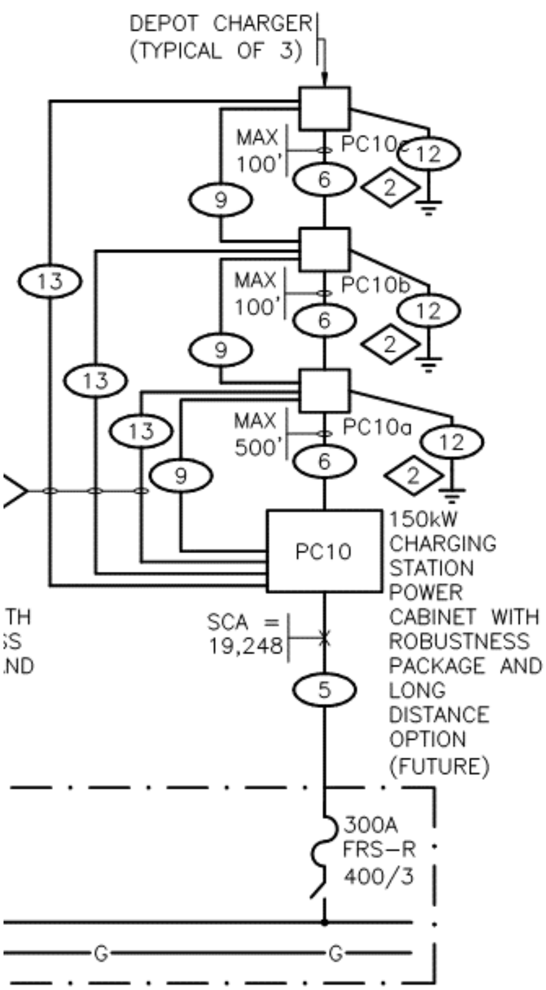
Transfort has developed a design to accommodate up to ten (10) 150-kW ABB depot chargers as part of their current Electric Bus Service Upgrade Project to support pilot deployment of BEBs. The first two (2) BEBs were delivered in December 2021. Design work for the initial installation was prepared by *[au]workshop Architects+Urbanists* working in conjunction with the City of Fort Collins Utilities. Phase I, completed in September 2022, included installation of the first three (3) chargers, each equipped with three (3) dispensers A schematic of the current and future planned installation is included on **Figure 17.**

Figure 17 - Phase I BEB Deployment Charging Infrastructure



As part of this transition analysis, Hatch LTK reviewed the existing and expected demand associated with the installation of the first ten (10) chargers. The analysis was conducted for the first ten (10) chargers because Transfort has already paid the necessary capacity fees to Fort Collins Utilities for installation of these units. Each 150 kW direct current charging cabinet is fed by a separate fused disconnect and a typical feeding schematic is shown in **Figure 18.**

Figure 18 - Typical Charger Feed Schematic



Per the NEC *ARTICLE 625 Electric Vehicle Power Transfer System*, the power transfer equipment shall have sufficient rating to supply the load served. Electric vehicle charging loads shall be continuous loads and shall have a rating of not less than 125% of the maximum load of the equipment. According to the ABB HVC-150 charger specifications, the input power rating for the chargers is 174 kilovolt-amperes (kVA) at a maximum depot charging current of 200 amps. NEC code allows decreasing the maximum equipment load for a charging station if an automatic load management system is used. The maximum load will then be determined based on the maximum load permitted by the automatic load management system. Based on the load requirements, and including the subpanel requirements, a total maximum load of 1,756 kVA (1,668 kW at a 95% power factor) for the 480-volt, 3-phase service is required to supply the chargers. This calculation does not include the additional 25% ampacity rating required for being in continuous load but that can be managed by the automatic load management system.

Fort Collins Utilities installed a 750 kVA transformer to support the initial Phase I deployment of three (3) chargers. The utility has indicated that they derate transformers based on the expected operational profile and will upgrade the sizing based on performance needs to support the additional charger installations, as necessary. Ultimately the utility is responsible for supply, installation, and maintenance of the transformer.

The cost to complete the installation of the first three (3) chargers and associated nine (9) dispensers is detailed in **Table 13.** Charger costs were based on contracted rates from Winn Marion while the electrical service and charger installation costs were actual costs for installation. Capacity fees are based on the size of the service required. Capacity fees and the service feed installation are charged by the utility to install the service.

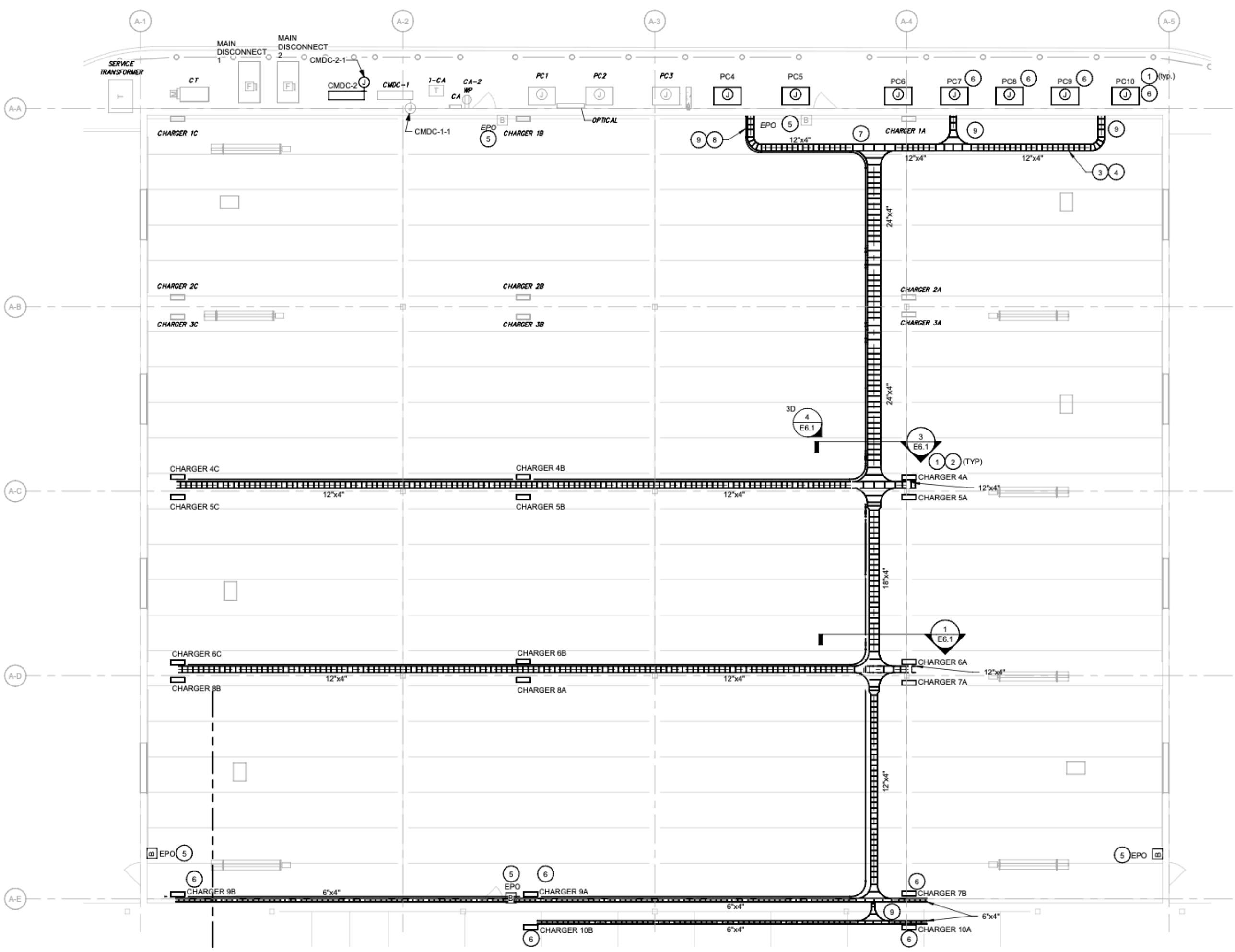
Table 13 - Phase I Charger Installation Costs

Item	Cost ($)	Source
Charger Purchase	450,000	Winn Marion
Electrical and Charger Install	412,000	Weifield (actual costs)
Capacity Fees*	277,000	Fort Collins Utilities
Service Feed Installation	23,811	Fort Collins Utilities
TOTAL	***1,162,811***	

Phase II Charger Installation

The Phase II charger installation includes the installation of the remaining seven (7) chargers that were included in the original deployment approach to have a total of ten (10) chargers available at the TMF. A 100% design for this implementation has been completed by Farnsworth Group and is currently in review. A schematic is included in Figure 19.

Figure 19 - Phase II Charger Installation at TMF



The estimated cost to complete the installation of the seven (7) additional chargers and associated fifteen (15) dispensers is detailed in **Table 14.** Charger costs were based on contracted rates from Winn Marion while the electrical service and charger installation costs were based on estimates provided by Rider Levett Bucknall at the 30% design stage. As discussed previously, Transfort previously paid the required capacity fees to support installation of the first ten (10) chargers so no fees are required for Phase II.

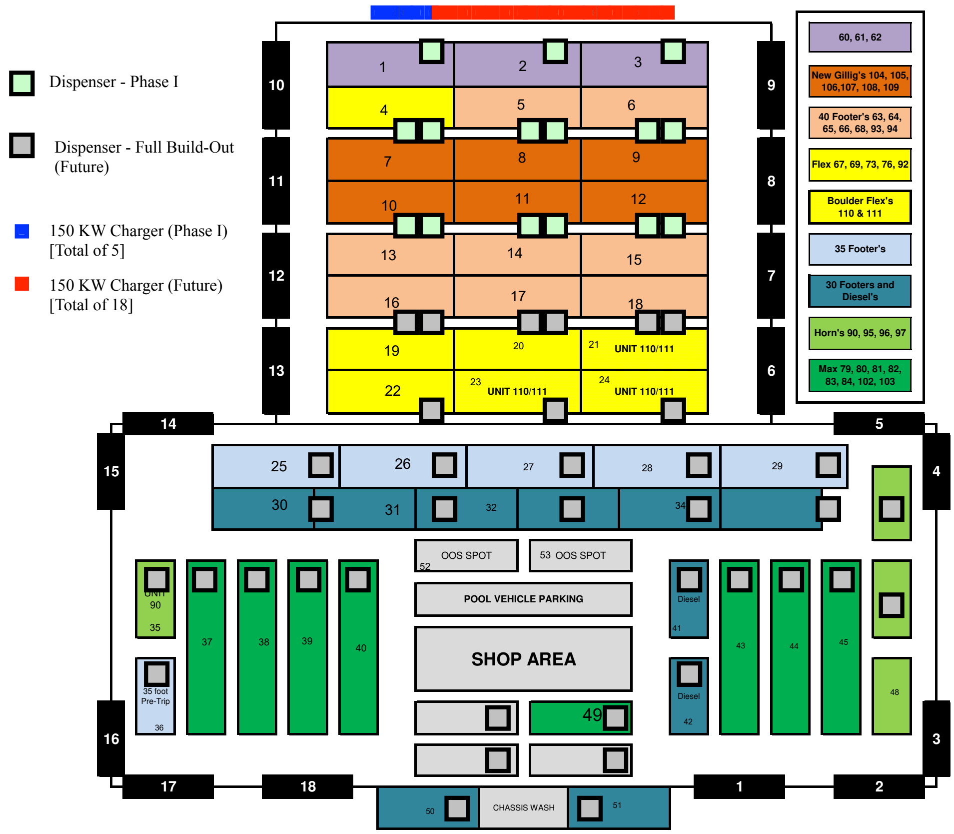
Table 14 - Estimated Phase II Charger Infrastructure Costs

Item	Units (EA)	Unit Cost ($)	Total Cost ($)	Source
Charger Purchase: Includes charger, pedestal or cable reel, dispenser boxes, long distance package, installation support and commissioning	7	150,000	1,050,000	Winn Marion
Roof Construction	1	262,260	262,260	Rider Levell Bucknall
Rain Water Drainage	1	30,107	30,107	
Electrical Service & Distribution	1	339,480	339,480	
Communications & Security	1	52,215	52,215	
Other Electrical Systems	1	40,738	40,738	
Building Elements Demolition	1	5,000	5,000	
Site Development	1	70,500	70,500	
Margin & Adjustments: General Conditions & Requirements (12%); Contingency (15%); Insurance & Bonding (2%); OH and profit (6%); escalation (5%)	1	353,558	353,558	
TOTAL			***2,203,858***	

Future Service at the TMF

The BEB block feasibility indicates that Transfort can support 100% of the future blocks with BEBs by charging at the depot as well as utilizing on-route charging. The current TMF accommodates a total of 53 vehicles. As such, a conceptual approach was developed to fully electrify the existing facility to support BEB deployment. This estimate includes additional costs to provide charging infrastructure for the West Elizabeth BRT buses at the TMF (3 additional 150-kW chargers or one 450-kW opportunity fast-lane charger). In addition, infrastructure costs were developed to support charging of the remaining vehicles (total of 24) at a new facility expected to be located on the north end of Fort Collins. A conceptual layout for full electrification of the current TMF is included as **Figure 20**. Based on the charging analysis, a minimum of 26 chargers are required to adequately charge the vehicles and limit the need to move vehicles. It is possible that the number of depot based chargers could be reduced if required by space restrictions if more on-route charging is utilized; however, on-route charging infrastructure is more expensive to install and energy generally costs more to deliver due to demand charges.

Figure 20 - Full Electrification of the TMF



Six (6) of the chargers will be equipped with three (3) dispensers each and the remainder with two (2) dispensers each. Dispensers installed in the north storage area stalls 1 through 12 will be pedestal mounted either on the wall or adjacent to an existing structural pillar that does not impede traffic flow. Due to limited space in the remainder of the building, the dispensers located in the remaining stalls 13 through 51 and the service bays will be installed overhead with a drop down cable reel or overhead pantograph. Examples of the drop down reel and overhead pantograph style dispenser are included in **Figure 21.** The charger cabinets will be installed on the north side of the building (outside) adjacent to the charger cabinets planned for Phase I and Phase II. However, due to space limitations charging cabinets and associated infrastructure for future phases may have to be installed in a portion of the existing driving lane, along the eastern exterior wall of the maintenance building, or along the property boundaries in currently landscaped areas.

Figure 21 - Cable Reel (Left) and Overhead Pantograph (Right)

Estimated ROM costs to complete the full-scale installation (assuming Phase II has been completed) are detailed in **Table 15**. Charger costs were based on contracted rates from Winn Marion while the electrical service and charger installation costs were based on estimates prepared by Hatch LTK. Estimated design fees of approximately 6% of the capital costs are included in the estimate. Capacity fees are based on the size of the service required upgrades (beyond what has already been paid to Fort Collins Utilities for the first 10 chargers). Capacity fees and the service feed installation are charged by the utility to install the service. A cost range of -20% to +30% was applied to the estimate due to the conceptual nature at this time.

Table 15 - Full Scale Depot Charger Infrastructure Costs, TMF

Item	Units (EA)	Unit Cost ($)	Total Cost ($)	Source
Charger Purchase: Includes charger, pedestal or cable reel, 2 dispenser boxes, long distance package, installation support and commissioning	16	150,000	2,700,000	Winn Marion
Electrical and Charger Install : Includes switchgear; 3-phase feeders and breakers; DC charging power conduits; low voltage conduit; communication wiring	1	1,253,800	1,253,800	Hatch LTK
Indirect Costs (General Contractor): General Conditions; Mobilization/Demobilization; Overhead; Profit; Insurance & Bonding; Permits	1	596,000	663,200	Hatch LTK (34% of Construction Costs)
Capacity Fees for installation of 16 additional 150 kW chargers	1	592,000	365,000	Fort Collins Utilities
Service Feed Installation	1	50,000	50,000	Fort Collins Utilities
Design Fees (10% of Construction)			184,980	
Contingency (20% on Construction Costs)			379,960	
TOTAL			***5,596,940***	
Cost Range (-20% to +30%)			***4,477,500 - 7,276,000***	

North Maintenance Facility (Future)

Although a location and conceptual layout have not been prepared for a future storage an maintenance facility on the north end of Fort Collins, it is expected that the facility would need to be able to accommodate charging of up to 24 heavy duty BEBs. Three additional chargers are assumed at the North Maintenance Facility to serve support charging of potential battery-electric cutaways and as spares to provide redundancy. The charging burden at the current TMF could be reduced by moving vehicles to the new facility for charging as well. A ROM cost estimate was prepared for a new facility assuming charging of up to 24 heavy duty BEBs using the same assumptions from the full-scale implementation at the TMF as well as the three additional chargers. ROM costs are provided in **Table 16.**

Table 16 – Estimated Depot Charger Infrastructure Costs, New Facility

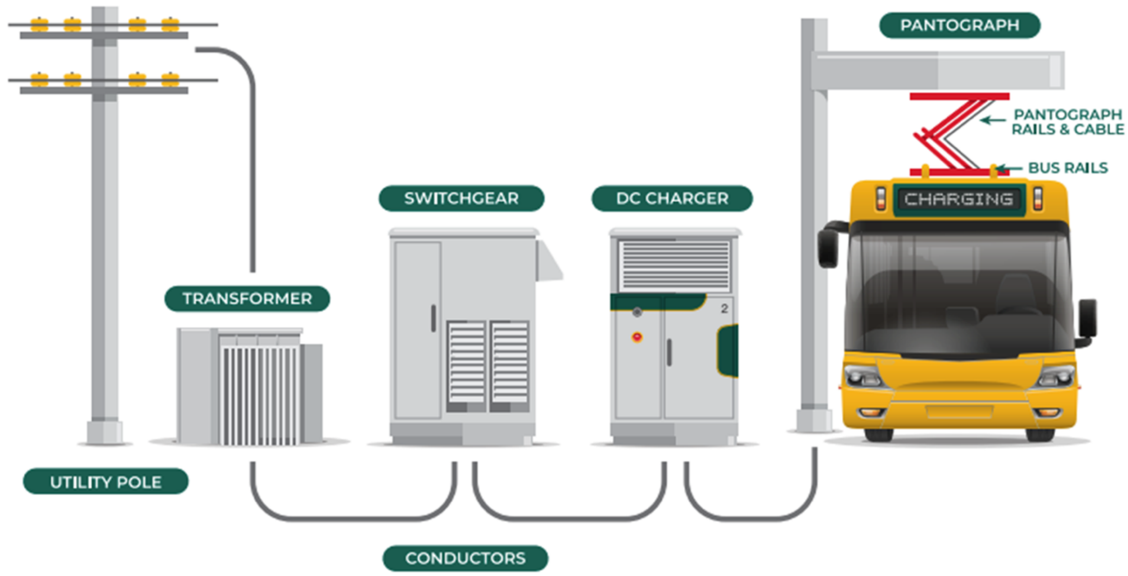
Item	Units (EA)	Unit Cost ($)	Total Cost ($)	Source
Charger Purchase: Includes charger, pedestal or cable reel, 2 dispenser boxes, long distance package, installation support and commissioning	15	150,000	2,250,000	Winn Marion
Electrical and Charger Install : Includes switchgear; 3-phase feeders and breakers; DC charging power conduits; low voltage conduit; communication wiring	15	105,000	1,575,000	Hatch LTK
Indirect Costs (General Contractor): General Conditions; Mobilization/Demobilization; Overhead; Profit; Insurance & Bonding; Permits	15	35,700	535,500	Hatch LTK (34% of Construction Costs)
Capacity Fees for installation of 16 additional 150 kW chargers	1	553,191	553,191	Fort Collins Utilities
Service Feed Installation	1	402,855	402,855	Fort Collins Utilities provided estimate
Design Fees (10% of Construction)			211,050	
Contingency (20% on Construction Costs)			422,100	
TOTAL			***5,949,696***	
Cost Range (-20% to +30%)			***4,759,757 - 7,734,605***	

On-Route Charging

As detailed in the Service Assessment, a total of 21 blocks were identified as initially being feasible for on-route charging (not including blocks that could be feasibly charged at the depot overnight); however, further evaluation indicated service changes (e.g., additional charging time, relief vehicle, etc.) may be required to support three of the six MAX blocks during strenuous conditions. In addition, separate analysis of the West Elizabeth BRT indicated that all of the proposed blocks for the service are feasible with on-route charging.

On-route charging can be accomplished either using conductive or inductive charging methods. A schematic depicting typical on-route charging equipment is provided in **Figure 22.**

Figure 22 - Typical On-Route Charging Equipment Schematic



Conductive Charging

Conductive charging equipment includes a DC charging cabinet and a mast that supports an overhead pantograph charger that delivers energy to the bus through conductive rails mounted on the bus roof. The DC charger takes the utility provided alternating current (AC) power and converts it to DC by using a rectifier located within the charging cabinet. This DC power, along with control and signal power, and low voltage wiring, is then carried through a series of underground conduits to the charging mast, rising up within the vertical mast and across the horizontal arm to the pantograph

The mast includes the Automatic Control System (ACS) module for the charging equipment. The ACS module manages the incoming electrical DC and AC power, interlocks and communications with the DC Charging Cabinet and coordinates these systems with the charging Pantograph's systems of WiFi / Radio Frequency Identification (RFID) bus interlocks, charging status indicator, emergency stop (E-Stop), pantograph heater, and pantograph actuators and control systems. A typical charging mast occupies a footprint of approximately 4' x 2' and requires an approximate 3 feet of clearance in front of the mast for service.

The pantograph is the moving armature that raises and lowers from the horizontal arm of the mast and transfers the electrical power to the charging bars located on the bus to charge the on-board batteries. The communications between the bus and the charger are set by the adopted charging standard (SAE J3105). These standards must be matching and compatible for both the bus and pantograph for a successful charging session. The charging process is initiated automatically with the pantograph arm being lowered upon the charging bars on the bus's roof and transferring energy from the pantographs charging bars to the buses charging bars through direct contact.

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

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

Note that heavy snow and leaves can obstruct ground mounted stop / position indicators. Consider training operators to stop based on orientation to vertical mast or to other vertical alignment indicators.

Inductive Charging

Inductive charging, also known as wireless charging, utilizes magnetic resonant inductive charging from an inductive ground assembly to deliver energy to an assembly mounted on the bus, which connects to the high voltage system of the vehicle. The vehicle assembly is also connected to the cooling system and the CAN network of the bus. The ground assembly can be installed flush with the ground surface or surface mounted. An inductive charger is modular, with individual charge pads that can deliver between 60 and 75 kWh per pad. For BEB charging, inductive charger OEMs such as Wave and Momentum Dynamics typically recommend up to a 300 kW systems. An inductive charging system includes similar equipment to the conductive equipment such as the charging cabinet but the actual delivery of the energy to the vehicle is through the drive-over charging pad, reducing the total footprint required. As of the preparation of this plan, the number of bus OEMs that support inductive charging is limited (BYD and GILLIG); however, other OEMs have expressed an interest in the technology and may include inductive charging in their future product roadmaps.

Load Requirements

Load analysis was completed to understand the sizing requirements for the service at each of the transit centers identified to support on-route charging. Analysis was previously completed to identify the maximum demand that would be required by the buses to calculate estimated demand chargers; however, the load summary is driven by the specified size of the charging equipment and is a requirement of the electrical design. The updated load summary was based on the assumption that two (2) 450 kW conductive chargers would be utilized for charging at each location to meet charging requirements and provide redundancy. The load summary is provided in **Table 17.** Further evaluation of the on-route charging at the South Transit Center, indicated that a third charger should be considered to meet charging requirements and to provide redundancy.

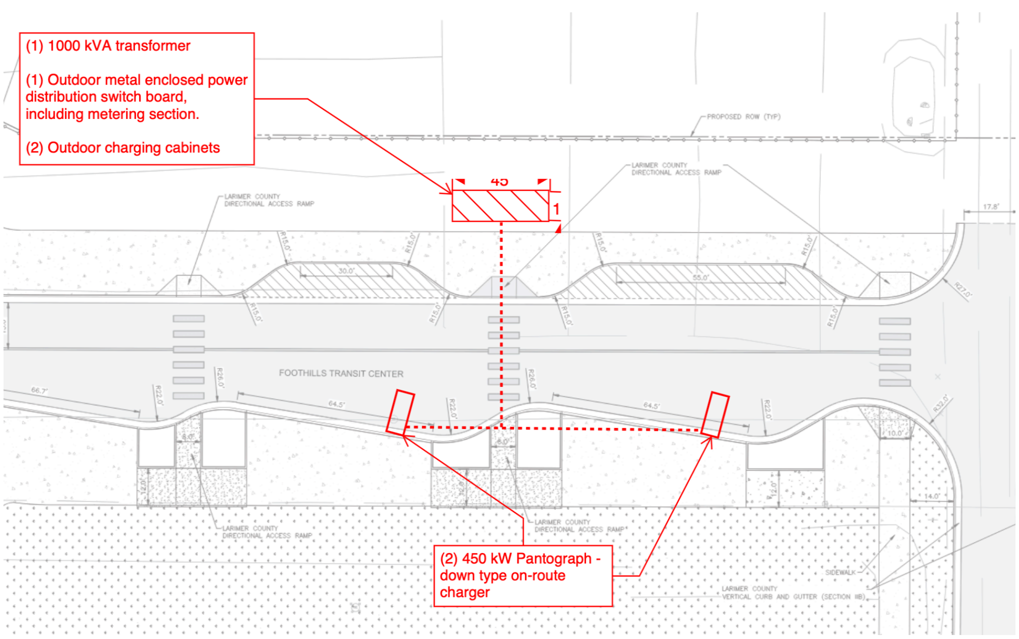
Table 17 - Load Summary for On-Route Charging

Transit Center	# Buses	# Chargers (450 kW)	Load Summary (kW)
Foothills	6	2	900
Downtown	6	2	900
South	10	3	1350
CSU	5	2	900

Foothills Transit Center

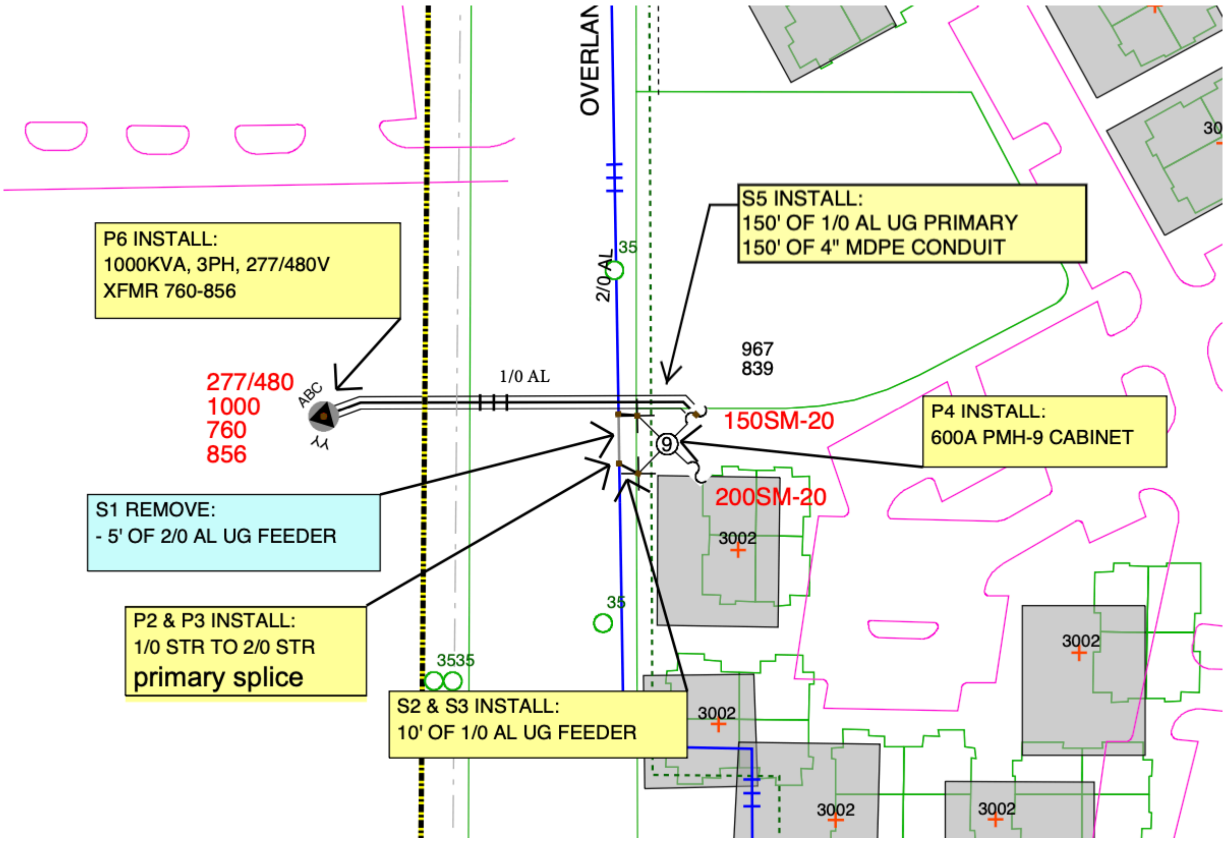
The Foothills Transit Center is expected to support the deployment of six (6) 60' BEBs for the West Elizabeth BRT. Installation of charging equipment is expected to occur in 2025 in conjunction with build out of the BRT facilities. A conceptual approach for installation of the charging equipment is included in the below figure.

Figure 23 – Foothills Transit Center Charging Layout



Transfort identified two proposed charging locations as depicted in **Figure 23.** The charging infrastructure, including the chargers and switchgear, is expected to be located on the northern portion of the property; however this location could change depending on the location of the electrical service entrance provided by Xcel Energy. The proposed location of the service entrance and associated 1,000 kVA transformer (277/480V) provided by Xcel Energy is included in **Figure 24**. Xcel has indicated that the installation will be done at no charge to Transfort.

Figure 24 - Electrical Service Location for Foothills Transit Center



A single line electrical diagram prepared by Hatch LTK is included in **Appendix A.** As the location of the Foothills Transit Center is new construction, information about power outages was not readily available. Additional information will be requested from Xcel to determine if permanent resilient measures should be included in the design; however, it is expected that a mobile generator, delivered to the site in the event of an outage, will be sufficient to provide backup service. Provisioning for a connection to a mobile generator to support charging in the event of a power outage is included.

A cost estimate, including a -20% to +30% range, for installation of on-route charging infrastructure at the Foothills Transit Center is included in **Table 18.**

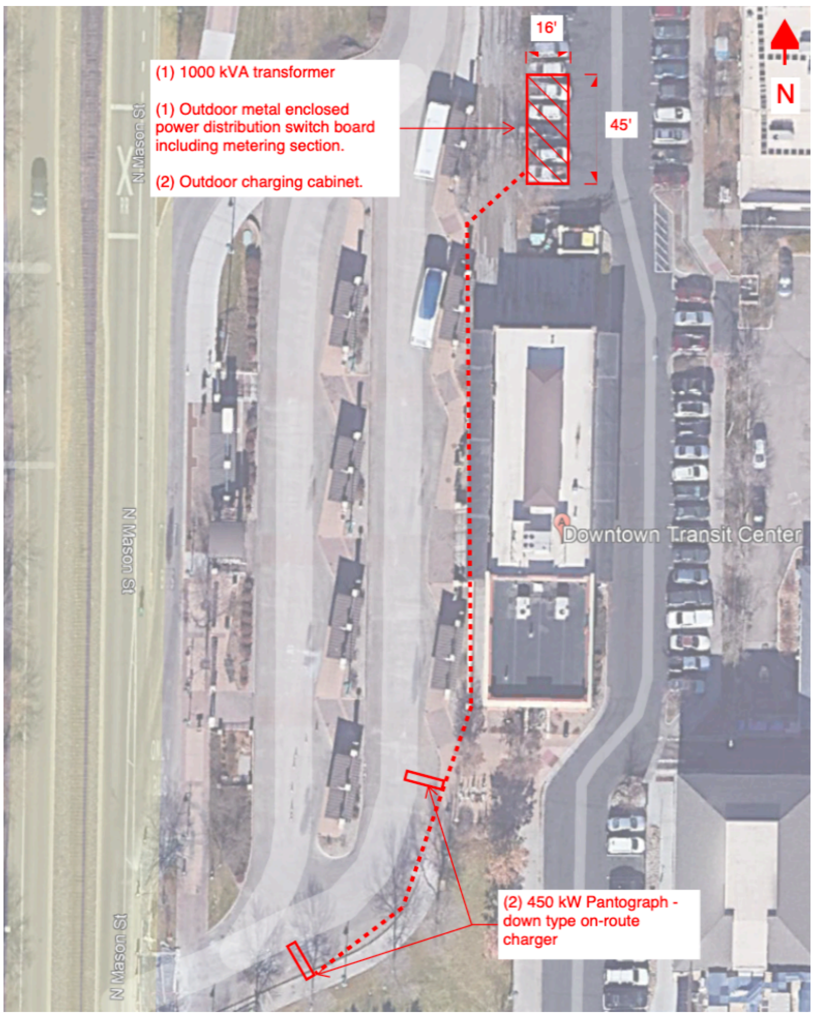
Table 18 - ROM Cost Estimate for On-Route Charging at Foothills Transit Center

Item	Units (EA)	Unit Cost ($)	Total Cost ($)	Source
Charger Purchase: Includes charger cabinets, charge pole, top-down pantograph, installation support and commissioning	2	473,000	946,000	ABB
Electrical and Charger Install: Includes switchgear; step-down transformer; 3-phase feeders and breakers; DC charging power conduits; low voltage conduit; communication wiring; trenching	1	98,848	98,848	Hatch LTK
Civil Services	1	22,309	22,309	Hatch LTK
Indirect Costs (General Contractor): General Conditions; Mobilization/Demobilization; Overhead; Profit; Insurance & Bonding; Permits	1	256,118	256,118	Hatch LTK
Capacity Fees	1	--	--	Excel Energy
Service Feed Installation	1	--	--	Excel Energy
Contingency (20% on equipment and construction)			264,655	
TOTAL			**1,587,930**	
Cost Range (-20% to +30%)			***1,270,300 - 2,064,300***	

Downtown Transit Center

The Downtown Transit Center is expected to support the deployment of a minimum of six (6) BEBs, and potentially more depending on future block development. Installation of charging equipment is expected to be necessary at the Downtown Transit Center in approximately 2026 to support electrification; however, this schedule can be adjusted if Transfort prefers to install charging infrastructure at the South Transit Center before the Downtown Transit Center. A conceptual approach for installation of the charging equipment is included in **Figure 25.**

Figure 25 - Downtown Transit Center Charging Layout



Transfort identified two charging positions to be located along the southern entrance to the transit center. The balance of the charging infrastructure, including the chargers and switchgear, are expected to be located north of the transit center building. The location of the charging equipment will result in the loss of multiple parking stalls.

Fort Collins Utilities has indicated that there is sufficient electrical capacity to support on-route charging at the Downtown Transit Center. A 1,000 kVA transformer (277/480V) will be installed by Fort Collins Utilities adjacent to the existing 150 kVA transformer as depicted in **Figure 26** below. A single line electrical diagram prepared by Hatch LTK is included in **Appendix A.** Fort Collins Utilities indicated that service at the facility is very reliable with the last power outage occurring in 2017. As a result, permanent backup generation was not considered to provide redundancy. As with the Foothill Transit Center, provisioning for a connection to a mobile generator to support charging in the event of a power outage is included.

Figure 26 - Electrical System Location at Downtown Transit Center

Transfort engaged Sandbox Solar to evaluate the site to determine options for solar infrastructure to generate energy. Sandbox provided estimates for a 14.40 kW system that could produce approximately 20,397 kWh of electricity annually at a capital cost of approximately $50,400. The energy generated from the solar infrastructure would be sold back to the utility to off-set the cost of energy rather than being stored on-site as it is impractical and cost prohibitive to provide battery storage on-site for storage of solar energy at this facility to support on-route charging. The capital cost for solar infrastructure was not included in the cost estimate for on-route charging.

A cost estimate, including a -20% to +30% range, for installation of on-route charging infrastructure at the Downtown Transit Center is included in **Table 19.**

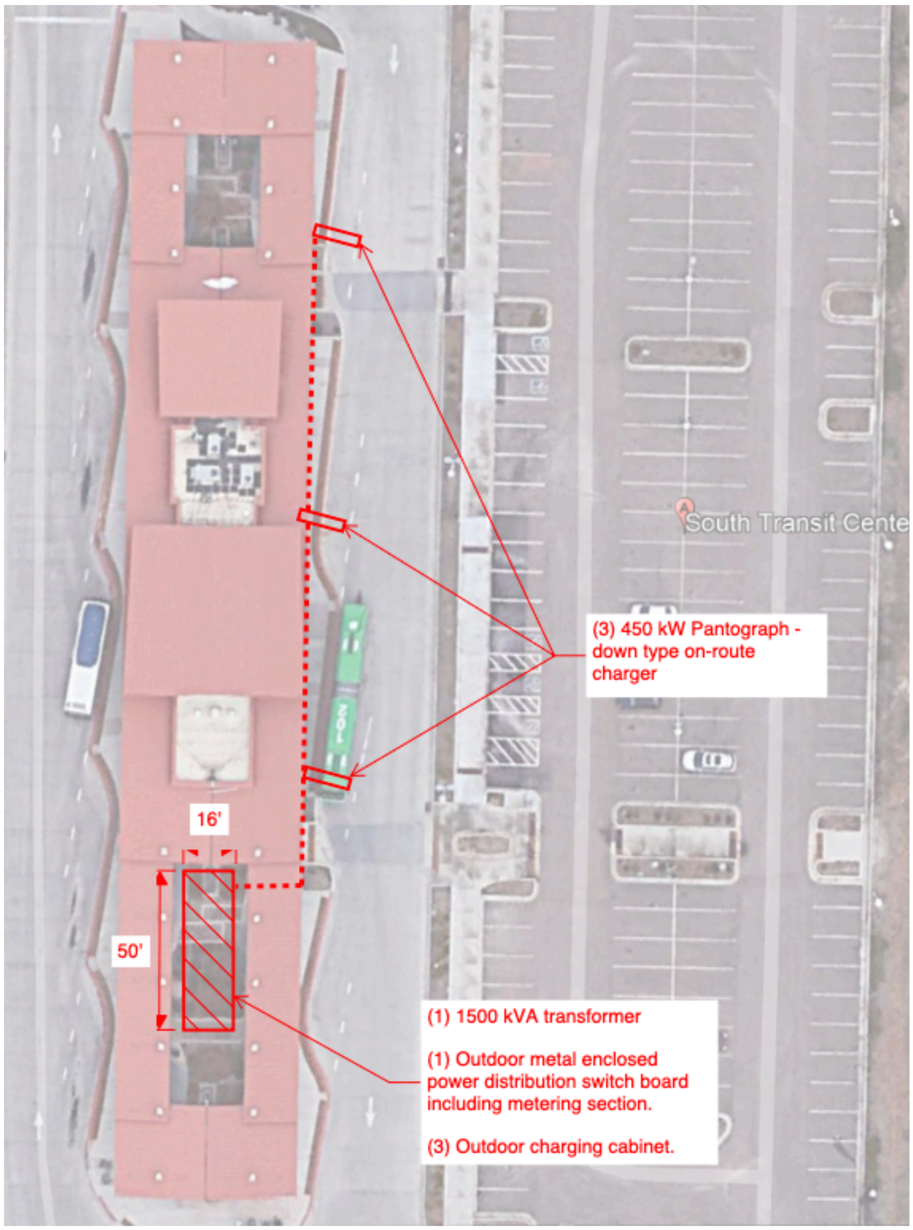
Table 19 - ROM Cost Estimate for On-Route Charging at Downtown Transit Center

Item	Units (EA)	Unit Cost ($)	Total Cost ($)	Source
Charger Purchase: Includes charger cabinets, charge pole, top-down pantograph, installation support and commissioning	2	473,000	946,000	ABB
Electrical and Charger Install: Includes switchgear; step-down transformer; 3-phase feeders and breakers; DC charging power conduits; low voltage conduit; communication wiring; trenching	1	96,992	96,992	Hatch LTK
Civil Services	1	50,494	50,494	Hatch LTK
Indirect Costs (General Contractor): General Conditions; Mobilization/Demobilization; Overhead; Profit; Insurance & Bonding; Permits	1	262,437	262,437	Hatch LTK
Capacity Fees	1	238,000	238,000	Fort Collins Utilities
Service Feed Installation	1	30,000	30,000	Fort Collins Utilities
Contingency (20% on equipment and construction)			277,185	
TOTAL			**1,901,108**	
Cost Range (-20% to +30%)			***$1,520,900 - $2,471,400***	

South Transit Center

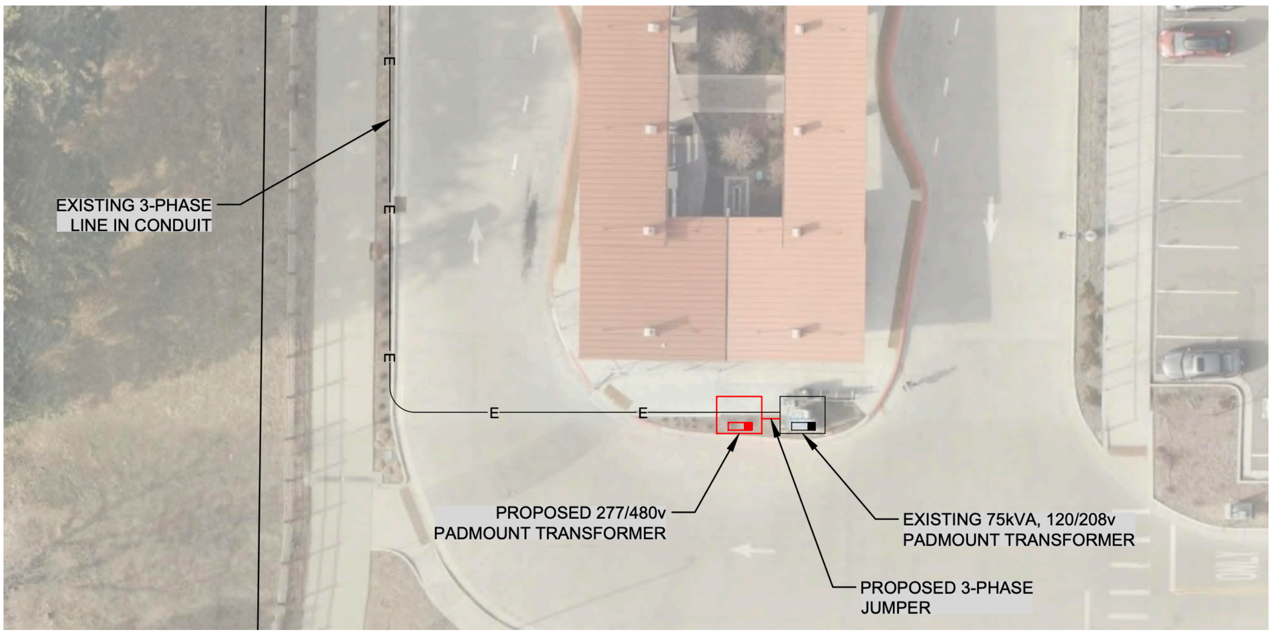
The South Transit Center will support the deployment of at least ten (10) BEBs including the MAX service that operates with 60' articulated buses. A conceptual approach for installation of the charging equipment is included in **Figure 27.** Installation of charging equipment is not expected to be necessary at the South Transit Center until approximately 2028.

Figure 27 - South Transit Center Charging Layout



A total of two (2) on-route chargers were originally proposed for the South Transit Center; however, based on further evaluation of the MAX service needs and other blocks that operate through the facility, a third charger is included to meet service needs and provide redundancy. Based on discussions with Transfort, the courtyard in the southern half of the facility was identified to support the charging infrastructure including the required switchgear and remote charging cabinet. A 1,500 kVA transformer (277/480V) supplied by the utility is expected to be installed at the south end of the building as depicted in **Figure 28.** Fort Collins Utilities has indicated that there is sufficient capacity to support electrification at the South Transit Center to support at-least two chargers and provided the estimate costs necessary to support the service upgrade as depicted in **Figure 28.**

Figure 28 - Proposed Electrical Service at South Transit Center



A single line electrical diagram prepared by Hatch LTK is included in **Appendix A.** Fort Collins Utilities indicated that service at the facility is very reliable with only one outage reported over the last six years. As a result, permanent backup generation was not considered to provide redundancy. Note that provisioning for a connection to a mobile generator to support charging in the event of a power outage is included.

In addition to the charging infrastructure, Transfort engaged Sandbox Solar to evaluate the site to determine options for solar infrastructure to generate energy. Sandbox provided estimates for a 53.60 kW system that could produce approximately 76,000 kWh of electricity annually at a capital cost of approximately $187,000. The energy generated from the solar infrastructure would be sold back to the utility to off-set the cost of energy rather than being stored on-site. It is impractical and cost prohibitive to provide battery storage on-site for storage of solar energy at this facility. The capital cost for solar infrastructure was not included in the cost estimate for on-route charging.

A cost estimate, including a -20% to +30% range, for installation of on-route charging infrastructure at the South Transit Center is included in **Table 20.**

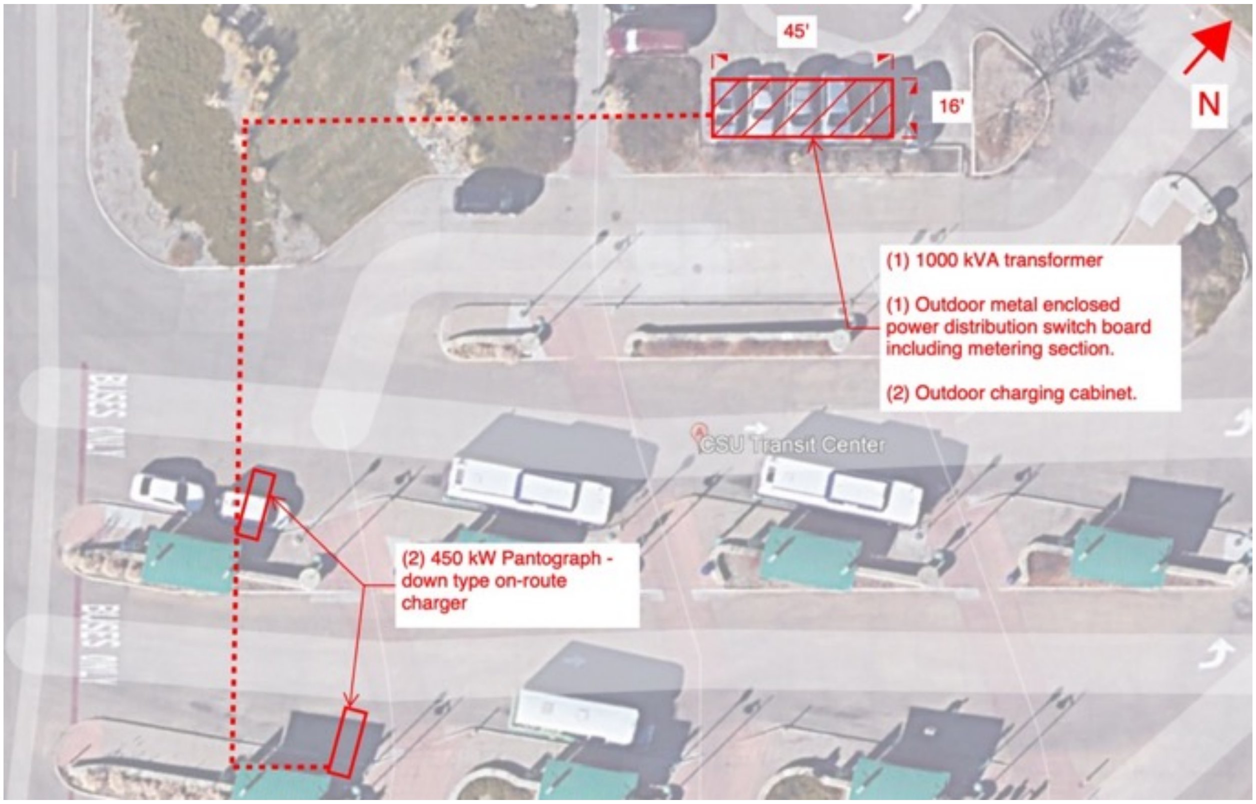
Table 20 - ROM Cost Estimate for On-Route Charging at South Transit Center

Item	Units (EA)	Unit Cost ($)	Total Cost ($)	Source
Charger Purchase: Includes charger cabinets, charge pole, top-down pantograph, installation support and commissioning	3	473,000	1,419,000	ABB
Electrical and Charger Install: Includes switchgear; step-down transformer; 3-phase feeders and breakers; DC charging power conduits; low voltage conduit; communication wiring; trenching	1	116,600	116,600	Hatch LTK
Civil Services	1	26,465	26,465	Hatch LTK
Indirect Costs (General Contractor): General Conditions; Mobilization/Demobilization; Overhead; Profit; Insurance & Bonding; Permits	1	374,895	374,895	Hatch LTK
Capacity Fees	1	360,300	360,300	Fort Collins Utilities
Service Feed Installation	1	30,000	30,000	Fort Collins Utilities
Contingency (20% on equipment and construction)			387,392	
TOTAL			**2,714,652**	
Cost Range (-20% to +30%)			***2,171,700 – 3,529,000***	

Colorado State University (CSU) Transit Center

The CSU Transit Center is expected to support the deployment of a minimum of six (6) BEBs, and potentially more depending on future block development. Installation of charging equipment is not expected to be necessary at the CSU Transit Center until approximately 2033. A conceptual approach for installation of the charging equipment is included in **Figure 29.**

Figure 29 – CSU Transit Center Charging Layout



Transfort identified two charging locations as the westernmost bay at each of the islands as depicted in **Figure 29.** The charging infrastructure, including the chargers and switchgear, are expected to be located north of the bus parking bays in an area that is currently passenger vehicle parking. A portion of the CSU Transit Center, including the location of the proposed charging equipment, is expected to undergo redevelopment to support the addition of a service platform for the West Elizabeth BRT service.

CSU Facilities Management has indicated that there is sufficient electrical capacity to support on-route charging at Transit Center. Service is expected to be provided from CSU's North Switching Station that was built in 2018. A single line electrical diagram prepared by Hatch LTK is included in **Appendix A.** CSU Facilities Management indicated that service at the facility is very reliable with only one power outage occurring in the last four years. Based on the reliability as well as the site constraints, permanent backup generation was not considered to provide redundancy. As with the other transit centers, provisioning for a connection to a mobile generator to support charging in the event of a power outage is included. As the facility is owned by CSU, any upgrades to support solar generation would be completed by CSU.

A cost estimate, including a -20% to +30% range, for installation of on-route charging infrastructure at the CSU Transit Center is included in **Table 21.**

Table 21 - ROM Cost Estimate for On-Route Charging at CSU Transit Center

Item	Units (EA)	Unit Cost ($)	Total Cost ($)	Source
Charger Purchase: Includes charger cabinets, charge pole, top-down pantograph, installation support and commissioning	2	473,000	946,000	ABB
Electrical and Charger Install: Includes switchgear; step-down transformer; 3-phase feeders and breakers; DC charging power conduits; low voltage conduit; communication wiring; trenching	1	96,593	96,593	Hatch LTK
Civil Services	1	47,511	47,511	Hatch LTK
Indirect Costs (General Contractor): General Conditions; Mobilization/Demobilization; Overhead; Profit; Insurance & Bonding; Permits	1	261,625	261,625	Hatch LTK
Capacity Fees	1	238,000	238,000	Fort Collins Utilities
Service Feed Installation	1	30,000	30,000	Fort Collins Utilities
Contingency (20% on equipment and construction)			276,346	
TOTAL			**1,896,075**	
Cost Range (-20% to +30%)			***1,516,900 – 2,464,900***	

Total Infrastructure Costs

Estimated costs to install the infrastructure at each facility and the year that the work is expected to be completed is provided in **Table 22.** Costs are rounded to the nearest $1,000 and do not include estimates for solar infrastructure, battery storage, or backup generation.

Table 22 - Total Estimated Infrastructure Costs

Facility	Expected Year	Estimated Cost ($)
TMF – Phase I – (charger 1-3 purchase and install)	2021	1,163,000
TMF – Phase II (charger 4-10 purchase and install)	2023	2,204,000
Foothills Transit On-Route	2025	1,588,000
Downtown Transit On-Route	2026	1,901,000
TMF – Full Build-Out	2027	5,597,000
South Transit On-Route	2028	2,715,000
North Maintenance Facility (Future)	2032	5,950,000
CSU Transit On-Route	2033	1,896,000
TOTAL		**23,014,000**
Cost Range (-20% to +30%)		***18,411,200 – 29,918,200***

Resilience

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

Redundant Utility Feed: In order for multiple feeders to be effective in providing redundancy they need to originate from separate utility circuits and/or substations. Use of multiple utility service is economically feasible then the local utility can provide two or more service connections over separate lines and from supply points that are not apt to be jointly affected by system disturbances, storms, or other hazards.[2] Due to the location of the TMF immediately adjacent to a utility operated substation and the historical reliability of the power feed to the facility, a separate feed from another substation to the TMF is not proposed. Fort Collins Utilities indicated that a redundant feed may be feasible at the South and Downtown Transit Centers; however, limited historical outages suggest that this level of resilience is unnecessary. The potential for multiple feeds to the future North

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

Maintenance Facility has not been discussed to date, though Fort Collins Utilities has provided estimated costs to supply service to several proposed locations.

***Back-up generators*:** The conventional approach to energy resiliency is through back-up generators. Generators can be powered by diesel fuel or other liquid fuel sources like natural gas or propane. Renewable diesel is a hydrocarbon diesel fuel produced by the hydroprocessing of fats, vegetable oils, and waste cooking oils that could be substituted for standard petroleum diesel. According to industry sources like Neste (https://www.neste.us/neste-my-renewable-diesel), such a substitution reduces lifecycle emissions by up to 80% compared to petroleum diesel. A typical 800 kW generator, roughly sized to operate a single 450 kW high-capacity charger, has a footprint of approximately 15' long by 7' wide. Adding a sound attenuation cabinet and integrated fuel tank can increase the size to 20' or longer by 8' wide. Generators can be permanently installed at facilities for dependability and ease of operations or can be mounted on trailers to provide greater flexibility for fleet operators. As discussed previously, each of the on-route charged locations should be provisioned such that a mobile back-up generator can be delivered to the site and connected in the event of a power outage. Permanent generators are not proposed for the on-route charging locations due to a lack of available space. Back-up generation using a natural gas generator could be considered at the TMF. The existing CNG compressor location could be repurposed to provide space for a back-up natural gas generator, with the permanent natural gas feed already in place.

Figure 30 - Mobile Diesel Generator

Solar*:* Solar power is becoming an increasingly viable source of power for BEB charging due to improving energy collection and storage technology, lack of carbon emissions, and resiliency due to independence from electrical grid disruptions during emergencies. As discussed previously, Transfort engaged Sandbox to evaluate the potential for adding solar at the TMF, the Downtown Transit Center, and the South Transit Center. Solar generation can provide a limited off-set by installing photovoltaic panels on existing roof structures; however, the large footprint required for solar would only off-set a portion of the existing electrical demand, not including any additional needs for charging. For reference, a typical 5 kW solar system for powering a home requires a minimum of approximately 275 square feet of solar panels. An average Transfort block has a daily energy demand approaching 300 kWh.

Stored energy*:* Battery energy storage (BES) systems can provide immediate backup power to a facility in the event of a complete utility outage. The size and ratings of the BES along with the amount of backed-up load will determine how much time the BES will provide power without need for recharging. BES systems can be coupled with on-site generation (e.g. generator or solar) or grid power to create additional resiliency or to be used to off-set peak charging needs. Energy can be stored in PEVs, which collectively can act as a large battery. A smart charger would control the flow of energy and can send energy from the grid to vehicle batteries, or draw energy from the bus batteries back onto the grid through bi-directional charging equipment. Along with cost, one challenge caused by energy storage is physical space as the area required for enough batteries to store the electricity produced may be prohibitive. A BES system with a capacity of 3,600 kWh (assuming 4 hours of backup storage for a single 450 kW charger), would occupy an approximately footprint of 125 square feet, including working clearances, similar to that of a utility transformer and switching cabinet. Sandbox previously provided Transfort with a preliminary design for solar infrastructure at the TMF that could include 533 kWh of battery storage.

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

Microgrids*:* In recent years, microgrid technology has been a valid resiliency measure for critical facilities such as military bases, hospitals, and campuses. A microgrid is a single, controllable, independent power system comprising distributed generation (DG), load, energy storage (ES), and control devices, in which DG and ES are directly connected to the user side in parallel.[3] As a resiliency tool, when BES systems are combined with on-site generation such as photovoltaic systems or an appropriately sized emergency generator, a microgrid can not only provide resiliency and redundancy, but assist in meeting net-zero emissions goals and be a proven, cost-saving measure. Rough order magnitude costs were not developed at this stage for providing a microgrid to support charging; however, the potential can be explored with Fort Collins Utilities and microgrid developers.

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

8 Total Cost Comparison

Capital Costs

The capital cost comparison includes the cost of replacing the current CNG vehicles with BEBs based on block feasibility as well as the infrastructure costs to support the new fueling requirements. Estimated capital costs to support baseline operations and BEB On-Route and Depot Charging throughout the transition (and expansion) period (2022 to 2040) are included in **Table 23.**

Table 23 - Capital Costs by Scenario

Scenario	% BEB	Bus Capital Costs (2022 $)	Infrastructure Capital Cost (2022 $)	Total Capital Costs (2022 $)
Baseline	21%	98,547,000	3,367,000	101,961,000
BEB On-Route and Depot Charging	100%	142,034,000	23,014,000	165,048,000
Cost Compared to Baseline		**43,487,000**	**19,647,000**	**63,087,000**

Operational Costs

The operational costs include the costs to fuel the vehicles as well as the maintenance costs to keep the vehicles serviced (including preventative maintenance and major services). Estimated operational costs to support baseline operations and BEB On-Route and Depot Charging throughout the transition (and expansion) period (2022 to 2040) are included in **Table 24.**

Table 24 - Operational Costs by Scenario

Scenario	% BEB	Fuel Costs (2022 $)	Maintenance Costs (2022 $)	Total Operational Costs (2022 $)
Baseline	21%	22,319,000	25,197,000	47,516,000
BEB On-Route and Depot Charging	100%	20,659,000	21,322,000	41,991,000
Cost Compared to Baseline		**(1,660,000)**	**(3,875,000)**	**(5,535,000)**

Review of operational cost data indicates that Transfort can expect to save over $5M in fuel and maintenance costs during the transition period. By the end of the transition period in 2040, when all vehicles have been transitioned to BEB and the fleet has been expanded to the expected 82 vehicles, the average cost to operate Transfort's BEB fleet is expected to be approximately $1.11/mile; whereas, the cost to operate the CNG vehicles is expected to be approximately $1.40/mile. This yields a savings of approximately $0.29/mile in operational costs.

The total cost of ownership that incorporates the capital and operational costs for the transition period (2022 to 2040) is included in **Table 25.**

Table 25 – Total Cost of Ownership (2022 – 2040)

Category	Baseline (2022 $)	BEB On-Route and Depot (2022 $)	Cost Compared to Baseline (2022 $)
Fleet	98,547,000	142,034,000	43,487,000
Fuel	22,319,000	20,659,000	(1,660,000)
Maintenance	25,197,000	21,322,000	(3,875,000)
Infrastructure	3,367,000	23,014,000	19,647,000
Cost Over Baseline	**149,430,000**	**207,029,000**	**57,599,000**

9 Emissions Analysis

A primary benefit of transitioning an entire fleet from fossil-fuel vehicles to zero-emission is the reduction of GHG emissions. GHG emissions consist primarily of carbon dioxide (CO_2) but also include small amounts of methane (CH_4) and Nitrous Oxide (N_2O). In the transportation sector the vast majority of GHG emissions is from CO_2. For completeness, total GHG emissions are also calculated but the primary focus is on reduction of CO_2.

In addition to GHGs, additional emissions called "criteria pollutants" are generated when burning traditional transportation fuels. These include substances that are commonly thought of as "smog" and are known to damage human health. Some examples are carbon monoxide (CO), nitrogen oxides (NO_x), volatile organic compounds (VOC) and various classifications of particulate material under 10 microns and 2.5 microns in diameter (PM10 and PM2.5).

The primary sources of data to support this analysis are listed below:

- Argonne National Laboratory – *Alternative Fuel Life-Cycle Environmental and Economic Transportation (AFLEET) Tool*
- Transfort – data on existing fleet mileage and fuel economy

Net Carbon Emissions Reductions

There are three types of emissions generally referred to in the context of zero emission vehicle transportation: well-to-wheel (WTW) emissions, tailpipe emissions and upstream emissions.

WTW emissions include all emissions generated by the vehicle during operation *and* emissions generated by the powerplant or refinery to produce the energy used by the vehicle. WTW emissions are present for the generation of nearly all different fuels, be it diesel, gasoline, CNG, electricity, or hydrogen, as these fuels require a combination of petroleum, natural gas and coal for their production (except in the case of electricity produced by 100% renewable energy or green hydrogen).

Tailpipe emissions include all emissions generated by the vehicle during operation. It is assumed that BEBs do not produce any tailpipe emissions. Upstream emissions are generated by the fuel refinery or powerplant during extraction, processing and transportation of the fuel. In this analysis, upstream emissions are calculated by the difference between WTW and tailpipe emissions.

These emissions are calculated using Argonne National Labs' AFLEET tool. Emissions for electricity production use specific inputs based on the source of energy production as provided at https://www.fcgov.com/utilities/our-energy-vision for Fort Collins Utilities in 2021. Fort Collins Utilities has a goal to provide 100% renewable energy by 2030 with grid and local sources and to carbon neutral by 2050; however, for the purpose of this analysis, the 2021 fuel mix was used to calculate emissions throughout the transition period.

The tables below show the estimated reduction of fuel quantity in DGEs, the net GHG emissions reduction by operating BEBs compared to CNG buses, and the estimated annual equivalent vehicles removed from the road. Please note that the analysis assumes a diesel fired auxiliary heater during the winter months at 5 gallons per day for each block operated for a period of 90 days for each BEB. The emissions associated with the auxiliary heater are included in the emissions estimates. The emissions reduction compared to baseline for the transition period is included in **Table 26.**

Table 26 – Estimated Emissions Reduction for Transition Period (2022-2040)

Scenario	% BEB	Total ZEB Mileage	Diesel Gallon Equivalents (DGEs) Reduced	WTW GHG Emissions Reduced (tons)	CO Reduced (lbs)	NOx Reduced (lbs)	Equivalent Passenger Vehicles Removed from Road
BEB On-Route and Depot Charged	100%	24,815,700	4,958,240	48,584	660,332	3,656	9,495

The annual emissions reduction compared to baseline as estimated at the completion of the transition (and expansion) in 2040 in provided in **Table 27.**

Table 27 – Estimated Annual Emissions Reduction (2040)

Scenario	% BEB	Total ZEB Mileage	Diesel Gallon Equivalents (DGEs) Reduced	WTW GHG Emissions Reduced (tons)	CO Reduced (lbs)	NOx Reduced (lbs)	Equivalent Passenger Vehicles Removed from Road
BEB On-Route and Depot Charged	100%	2,229,686	514,810	3,687	68,561	380	794

The results of the emissions analysis indicate that once the transition to BEBs and expansion of the service to 82 vehicles is complete in 2040, operation of BEBs is expected to offset the use of over 500,000 DGE (as CNG) and reduce annual GHG emissions by over 3,600 tons. This has the effect of removing the emissions of 800 passenger vehicles from the road, annually. It should be noted that this assumes the current fuel mix for Fort Collins Utilities. As Fort Collins Utilities has committed to providing 100% renewable power by 2030, it is expected that these emission reduction estimates are very conservative.

Social Cost of Carbon

Externality costs of emissions can be quantified by their effect on agriculture, human health, property damage and other related factors. This estimate is widely known as the Social Cost of Carbon, or SCC. Using guidance developed by the Interagency Working Group on the Social Cost of Greenhouse Gases in the *Technical Support Document: Social Cost of Carbon, Methane, and Nitrous Oxide* (United States Government, February 2021), the annual SOC savings from operating BEBs is provided in **Table 28.**

Table 28 - Social Cost of Carbon

Scenario	% BEB	Annual ZEB Mileage	Carbon Savings from CNG (Metric Ton)	Savings (2022 $) @ $76/Metric Ton
BEB On-Route and Depot Charged	100%	2,229,686	2,675	$203,000

The social cost of carbon savings is expected to increase more rapidly as renewables are increasingly used for energy production.

10 Bus Procurement Best Practices

Transfort has already purchased two 35' GILLIG BEBs and has a contract to purchase an additional 35' GILLIG BEB for delivery in 2023. Additionally, Transfort was awarded a *Low or No Emission Vehicle Grant Program* (Low-No) Grant from FTA for the purchase of eight (8) 40' GILLIG BEBs. The BEBs are expected to be delivered in 2023 (3) and 2024 (5). The initial bus purchases will be from GILLIG as they were a named partner in the Low-No application; however, future BEB purchases may be made either through a competitive Request for Procurement (RFP) process or through an applicable state purchasing contract (e.g. Washington, California, Georgia, New Mexico, etc.).

In a typical bus procurement, the Agency defines the procurement schedule, submission requirements, evaluation criteria, evaluation procedures, and evaluation team. A typical RFP evaluation includes the following phases:

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

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

After the solicitation period is closed, the Procurement Officer qualifies proposals to ensure submitted proposal meet the minimum submission requirements, prior to allowing the evaluation team to review the proposals. The Agency may require that the technical proposals include a service demonstration (model) of how the proposed buses will operate in service with the proposed charging equipment. OEM model results may be validated as part of acceptance testing. The Procurement Officer then provides qualified technical proposals to the evaluation team.

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

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

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

During the final evaluation, the Agency combines previous scores to establish a final ranking of proposers. The Agency may then proceed to solicit Best and Final offers from the highest, or the first and second highest proposals. The final BEB OEM selection should be based on the results of the final evaluation.

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

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

- Verify the vehicle configuration/specifications
- Verify the terms of the production process
- Set up the resident inspection process (if applicable)
- Discuss Quality Assurance/Quality Control (QA/QC) requirements and associated inspections (if applicable)
- Establish lines of communication between Transfort's designated representative and the BEB OEM representative.
- Review and clarify required documentation/paperwork for the vehicles
- Clarify acceptance and delivery procedures
- Discuss change management procedures
- Discuss build schedule

Following completion of BEB fabrication and prior to delivery, the BEB OEM should conduct pre-delivery testing including visual and measured inspections as well as total bus operations. The testing program should be completed and documented in accordance with an Inspection and Acceptance Plan agreed upon by the Agency and the OEM. The pre-delivery testing should be scheduled such that it may be observed by the Agency inspector or maintenance staff (or other third-party inspector contracted by the Agency). Additional information regarding the bus acceptance and validation is included in the Deployment section of this plan.

If Transfort elects to purchase the buses through a state contract, the pricing and terms will be provided in accordance with the contract; however, the bus design, build, and delivery process will remain substantially the same.

11 Technical Specifications and Fleet Recommendations

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

Specification Development

The development of a battery electric bus (BEB) specifications should begin with one of the two starting points, either;

- A previously established bus contract from Transfort, or
- The APTA *Standard Bus Procurement Guidelines* are a valuable tool that should be referenced in preparing a BEB contract. As an additional resource, this document outlines information that CTE has found to be pertinent and agencies should consider in regards to BEB contracts.

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

Design Operating Profile

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

Turning Geometry, Approach and Departure Angles

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

Energy Storage System and Controller

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

The High Voltage BMS must:

- Be able to communicate all data to the bus level information system for storage and communication
- Balance the lithium ion cells or indicate and log which cells cannot be balanced
- Notify the operator in the event of a thermal event; notifications should be completed regardless of whether the vehicle is in service or out of service.

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

Electronic Propulsion System Controls

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

Regenerative Braking

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

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

Hill Hold

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

Charging Receptacles

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

Manuals and Schematics

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

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

Preconditioning

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

Auxiliary Heater and Control Strategy

Diesel-fired heaters provide auxiliary heat to the vehicle and are proposed for the initial Transfort BEBs. The control strategy should be designed to minimize the use of electric power for heat to ensure minimal range impact of heating energy demand.

Due to the comparatively low volume of auxiliary heater-equipped BEBs, the installation design of such systems on BEBs has resulted in challenges on previous buses. It is recommended, that 1) OEMs demonstrate a thorough application design process was conducted with the manufacturer of the heater, and all pumps, tubing/hoses, and valves; and that 2) no parts forward of the firewall have a service life shorter than the life of the bus (e.g. rubber hoses).

Specialized Equipment

Specialized equipment necessary to maintain BEBs is typically health and safety equipment necessary to conduct work on high voltage systems such as safety gloves for working on high voltage system components, fire protective clothing, etc. Bus OEMs may recommend the purchase of a lift table to change out batteries as necessary; however, the need for replacement or repair of batteries is typically very limited and is generally done under warranty but this can lead to delays in replacement and service reentry if the equipment is not available at the facility.

A diagnostic computer, adapter (specified by the OEM), and OEM supplied program will be required to complete diagnostic testing and complete maintenance on the vehicles. It is recommended that the diagnostic equipment be purchased with the vehicles. As Transfort already has two (2) 35' GILLIG BEBs in the fleet, the equipment to complete the diagnostic testing most likely has already been purchased. The diagnostic equipment is OEM specific.

Fire Protection

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

Operator Displays and Controls

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

Battery Warranty

While warranty options are specific to each OEM, Transfort may be offered an option to select an extended warranty, typically up to 12 years, for bus components including the propulsion system.

At a minimum battery warranty terms should specify:

- The usable capacity of the battery that is guaranteed throughout the warranty period; CTE recommends a minimum guaranteed battery capacity of 80% of useable energy.
- Procedure and tools (OEM or third-party) use to measure usable capacity and current state of health (SOH) of the battery.

Battery Lease

Battery leasing is a strategy that allows the cost of a typical BEB to be reduced to closer to that of a traditional fossil-fuel vehicle by paying for the battery lease through operational funding that normally would have been used to pay for fuel. If Transfort is considering leasing batteries, it is crucial that the lease terms are clearly understood and adjusted to suit the planned service life. A typical standard lease term is 12 years, which is not expected to cover the full operational life for the vehicles at Transfort (15 years). In addition, replacement terms for the battery lease should also be understood. Current battery leasing programs that CTE has reviewed typically allow one guaranteed replacement at the mid-life of the vehicle. Battery leasing of the first eleven (11) Transfort vehicles does not appear to provide a benefit as grant funding is currently available for the purchase of the vehicles.

Charge Management

Transfort should require that the charging OEM provide a method (either from the OEM or a third-party) of controlling the charging to manage the use of power from the utility grid for reduction of peak demand charges and general fleet charging management. The proposed solution must be able to be controlled by an Open Charge Point Protocol (OCPP)-compliant system, version 1.6 or later.

12 Training Recommendations

BEB training should include the following to ensure safe and efficient operation and maintenance of the vehicles by properly trained staff:

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

Operations training should consist of both classroom and hands-on activities, and should 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
- Regenerative braking

Maintenance training is typically completed by a combination of bus OEM and component OEM staff. Maintenance training should address the following BEB components, at a minimum:

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

- HVAC

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

Minimum recommended training hours based on experience on other BEB deployment projects and the associated description of the training are included in **Table 29.**

Table 29 - Recommended Training Requirements

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

Training hours may be shifted between topics at the discretion of Transfort to ensure staff receive the training necessary for safe and efficient operation and maintenance of the BEBs. Some equipment may be the same as on other Transfort operated vehicles (e.g. doors, wheelchair ramp, etc.) and thus may require limited additional training. Training requirements should be included as part of the bus specifications.

13 Data Collection Recommendations

CTE recommends that Transfort collect, analyze and report on key performance indicators (KPIs) to track and analyze the performance of the BEBs following deployment. This KPI reporting will be completed for a period of one year from revenue service deployment for the BEBs purchased as part of the Low-No Award.

A third-party data collection tool (e.g. Viriciti or similar) deployed on the buses to optimize data collection is recommended to facilitate data collection and analysis. For the first eleven (11) BEBs, GILLIG is providing the Viriciti hardware and one year subscription. These KPIs, when combined, will allow Transfort to fully understand operational metrics to determine the benefits that have been realized from the deployment of the BEBs, including impact on emissions, reductions in fuel consumption and cost, and reductions in maintenance and costs. The analysis will also help Transfort to understand any impact that range limitations or charging of the BEBs may have on service operations and make decisions about future needs for on-route charging. By tracking and analyzing theses KPIs, project stakeholders will be fully informed regarding the overall impact of these vehicles on Transfort's service and implications for transition of the full fleet to BEBs.

CTE conducted an initial reporting workshop with the project team to discuss KPIs and identify data for collection in November 2021. Prior to deployment of the Low-No buses in 2023, the project team will conduct a follow-up workshop to discuss progress in data collection and reporting for the initial GILLIG buses, and to determine the KPIs that Transfort wishes to capture and the procedures for collecting the data for the Low-No project. The following KPIs are a sample of the type of information that may be analyzed and tracked:

1. Fuel Cost: The fuel cost analysis will provide information regarding the cost of powering the BEBs compared to the cost of operating the CNG fleet.
2. Energy Performance and Fuel Efficiency: Energy performance will provide an overall energy consumption and fuel efficiency comparison (to include CNG and electricity consumption) post-electric bus deployment. Overall CO_2 emissions will also be compared.
3. Availability and Utilization: The bus availability data will be analyzed to determine the overall availability of the BEBs versus the CNG fleet, regardless of whether the buses are actually placed into service. This data will also be analyzed to determine the overall utilization rate of the BEBs when available.
4. Maintenance Costs: The maintenance cost analysis will compare maintenance activities, time, and cost for the BEBs against the CNG fleet, regardless of whether the maintenance activity is covered by warranty.

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

Vehicle Data

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

Table 30 - Vehicle Data Elements

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

Charging Data

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

Table 31 - Charging Data Elements

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

CNG Fleet Data

The following table outlines the data used for comparison to CNG buses that is needed to assess the impact that the BEBs have on operational performance and reliability and operations and maintenance costs.

Table 32 - CNG Fleet Data Elements

Data Element	Source	Format	Frequency
Mileage by Bus or Fleet	Transfort	Database or Log, usually MS Excel	Monthly
Fuel Consumption by Bus or Fleet	Transfort	Database or Log, usually MS Excel	Monthly
Fuel Costs by Bus or Fleet	Transfort	Database or Log, usually MS Excel	Monthly
Maintenance Required – For each	Transfort	Database or	Monthly

maintenance event, the following should be provided: • Maintenance description • Type of Maintenance (scheduled/unscheduled) • Open date • Close date • Parts used • Parts cost • Labor hours • Labor cost • Odometer • Road call required? • Warranty?		Log, usually MS Excel	
Historical Depot Utility Costs	Transfort	Utility Bills	One time report (already provided to CTE)

A cloud-based central project file repository (DropBox or other) may be used to share and preserve operations and maintenance data. Reports and source data shall be prepared for internal distribution and may be shared with the FTA, if requested by Transfort. Transfort may also choose to publish this information publicly as well.

14 Cutaway Fleet Evaluation

Transfort currently operates seven (7) cutaway vehicles in paratransit and contracted fixed route service. Transfort's paratransit fleet is comprised of four (4) Ford E450 Startrans Senator cutaways (12 passenger) that are fueled by LPG. Two (2) of the cutaways are model year 2019 and the other two (2) are model year 2020. Two (2) cutaways operate in peak paratransit service each day. The vehicles travel on average approximately 100 miles per day (approximately 70 miles in revenue service and approximately 30 miles in deadhead). A maximum daily mileage in operation was not available at this time. In addition, Fort Collins contracts with an operator for fixed route service using three (3) Ford F550 Startrans Senator cutaways (25 passenger) fueled by LPG. Two (2) of the vehicles operate in peak service. A review of the block data indicates that they operate Monday through Friday for approximately 12 hours covering a distance of approximately 178 miles. A summary of the vehicle profiles is included in **Table 33**.

Table 33 - Cutaway Vehicle Summary

Model	Model Year	Qty	Service Type	Fuel Type	Passenger Capacity	Average Daily Mileage (mi)	Max Daily Duration (hr)
Ford F450 Startrans Senator	2019	2	Paratransit	LPG	21	100	To be determined
Ford F450 Startrans Senator	2020	2	Paratransit	LPG	21	100	To be determined
Ford F450 Startrans Senator	2021	3	Fixed Route (contracted)	LPG	25	178	12

Transfort plans to operate their cutaway vehicles in service for a minimum of ten (10) years. As such, the first paratransit cutaways are not scheduled for replacement until 2029 and the contracted service cutaways until 2031.

Electric Vehicle Research

Many of the cutaways, small buses, and vans discussed below are based on Ford or other OEM chassis but include third-party electric drivetrains and passenger bodies. Some of the vehicles included are built entirely by a single OEM. The listed vehicles are not a complete inventory of available makes and models but do represent promising battery-electric alternatives Transfort's future needs.

Based on the current operational profile of Transfort's paratransit fleet, it appears there are suitable replacements currently on the market; however, replacements for the contracted fixed route service are less certain. Key implications of this vehicle research are:

- Most available battery-electric alternative vehicles are built on factory cab/chassis platforms and involve third-party electrification repowers. These vehicles are typically Transit/Sprinter-type vans or cutaways and are not Altoona-tested, which precludes them from purchase with FTA funds.
- As of December 2022, only two (2) Altoona-tested ADA-accessible battery-electric light-duty transit cutaways exist: GreenPower EV Star and the Forest River Bus Ford E-450 Cutaway Shuttle Bus. Additional OEMs have indicated the intent to have their vehicles tested Altoona tested or are currently in the process.
- Battery-electric light-duty transit vehicles are typically significantly more costly than their fossil-fueled counterparts. Converting the paratransit fleet and support vehicle fleet to battery-electric alternatives will require more funding than fossil fuel capital replacement plans prescribe and/or creative financing.
- The battery-electric light-duty transit vehicle market is rapidly evolving. Vehicle classes that do not currently have battery-electric alternatives will likely see multiple new models brought to market in the next few years.

The information gathered for this assessment is from a combination of manufacturer and dealer marketing materials and press releases, test results, and direct correspondence.[4] Range figures, in particular, should be viewed skeptically and assumed to be optimistic. Average battery-electric vehicle costs and operational ranges published by the OEMs are included in **Table 34** and details are included in **Appendix B.**

Table 34 - Battery-Electric Cutaway Vehicle Availability Summary

Vehicle Type	Number of Models Assessed	Number of Models Altoona Tested	Advertised Operational Range (miles)	Cost Range
Cutaways & Small Buses	20	2	70-170	~$170,000 - $330,000

Review of the data on available battery-electric cutaway options, indicates that there are several models that may meet paratransit service requirements today; however, there do not appear to be any models currently available that would meet the service needs for the contracted service on a one to one replacement basis. As noted previously, the cost of battery-electric cutaway vehicles is significantly higher than traditional fossil-fueled options today. Even if all vehicles could be replaced one-to-one with a battery-electric cutaway, the expected cost to replace the seven (7) vehicles in cutaway service with a battery-electric alternative today is at an estimated $1.75M assuming an average cost of approximately $250,000 per vehicle. For comparison, Transfort paid approximately $723,000 for the purchase of the current seven (7) cutaways between 2019 and 2021. This more than doubles the cost of each vehicle purchased. Due to the rapid advancement in battery-electric cutaway technology and competition in the market, it is recommended that Transfort reevaluate replacement of the cutaway vehicles with battery-electric alternatives during the next replacement cycle which is expected to begin in approximately 2028 (with vehicles

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

replaced in 2029). It is expected that by 2028, vehicles will exist that will exceed Transfort's cutaway service requirements and may be closer to the cost of replacement of a traditional fossil-fuel vehicle.

Charging Infrastructure Options

Electric Vehicle Supply Equipment (EVSE) is the equipment used to deliver electrical energy from an electricity source to an EV. ESVE communicates with the EV to ensure that an appropriate and safe flow of electricity is supplied. EVSE for EV is classified into several categories by the rate at which the batteries are charged. The types of EVSE applicable to Transfort's cutaway fleet include Level 2 chargers and DC fast chargers. Level 2 provides AC electricity to the vehicle, with the vehicle's onboard equipment converting AC to the DC needed to charge the batteries. DC fast charging provides DC electricity directly to the vehicle. Charging times range from 20 hours or more to less than 30 minutes, depending on the type of EVSE, the battery's capacity, state of charge, and the vehicle's acceptance rate or charging speed. A single 150 kW charger with multiple dispensers would support the charging needs of all of the paratransit vehicles. A second 150 kW charger could support the charging of the contract vehicles if they are stored at the Transfort TMF or future North Maintenance Facility. It is possible that future battery-electric cutaways may be able to support charging on-route (either with overhead pantograph or with inductive charging) although this is currently not available. Costs for installing an additional 150 kW charger to support the paratransit cutaways were included in the infrastructure costs for the proposed new north facility. Transfort may consider using Level 2 charging for the cutaway vehicles especially if used in conjunction with other light duty support vehicles, as the cost of charging installation is considerably lower.

15 References

Alternative Fuel Life-Cycle Environmental and Economic Transportation Tool (AFLEET), Argonne National Laboratory, https://afleet-web.es.anl.gov/home, 2019

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Long Beach Transit Battery Electric Bus Progress Report; Data Period Focus: Jan 2019 through Jun 2019, Leslie Eudy and Matthew Jeffers, US DOE NREL, January 2020

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Foothill Transit Agency Battery Electric Bus Progress Report – Data Period Focus Jul 2019 through Dec 2019, Leslie Eudy and Matthew Jeffers, US DOE NREL, March 2020

Long-Range, Low-Cost Electric Vehicles Enabled by Robust Energy Storage, Energy and Sustainability, Volume 2, US Department of Energy, 9 September 2015

Social Cost of Carbon, Methane, and Nitrous Oxide: Technical Support Document, United States Government Interagency Working Group on the Social Cost of Greenhouse Gases, February 2021

Appendix A

Single Line Electrical Diagrams for On-Route Charging

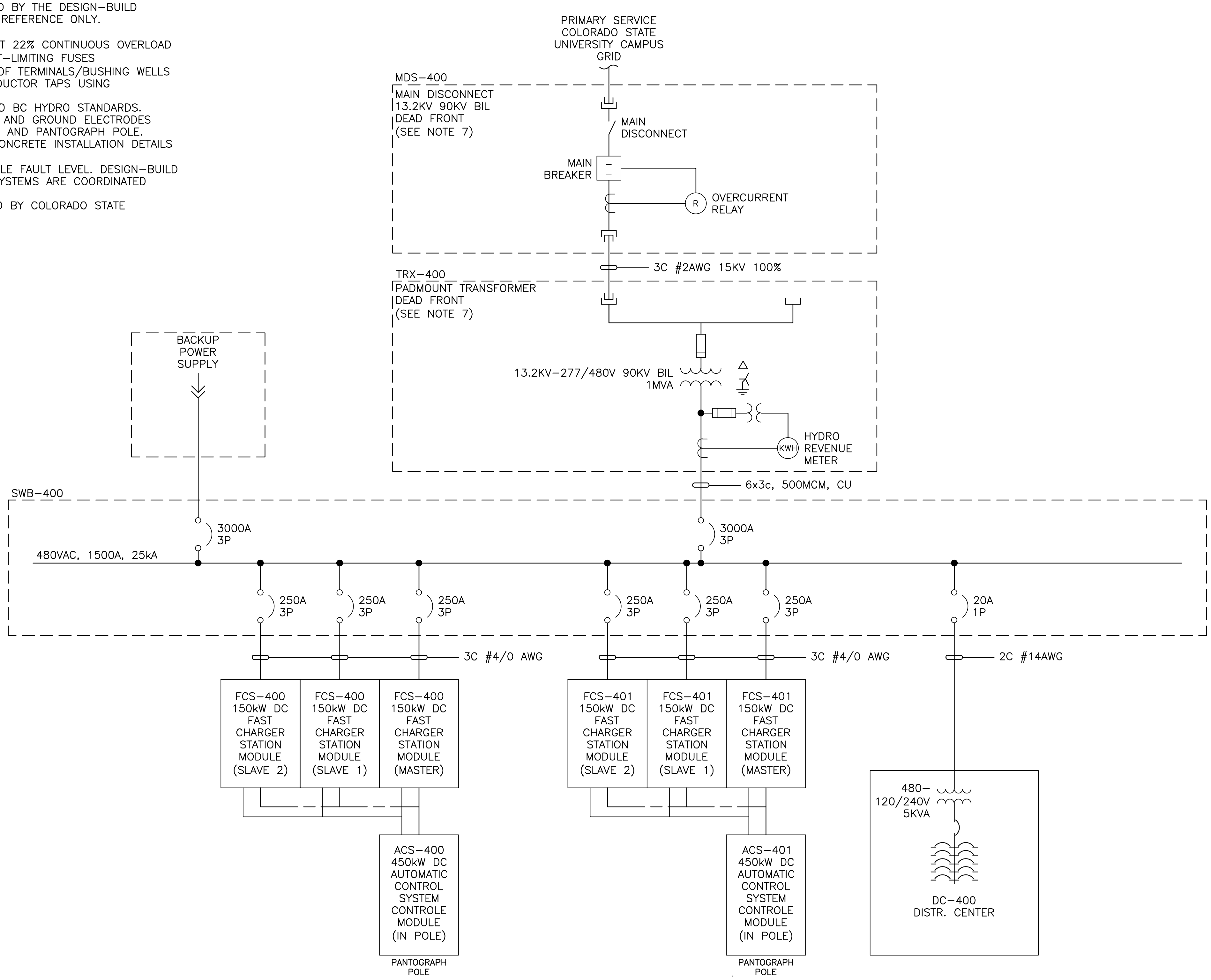
NOTES :

1. DESIGN IS BASED ON 450kW DC FAST CHARGING PANTOGRAPH SYSTEM.
2. ALL CABLING WIRING AND GROUNDING TO BE SIZED BY THE DESIGN–BUILD CONTRACTOR, CABLE SIZES AND MATERIAL IS FOR REFERENCE ONLY.
3. INSTALL PADMOUNT TRANSFORMER :
   - 3.1. FR3 LIQUID–FILLED, 55°/75°C RATED TO PERMIT 22% CONTINUOUS OVERLOAD
   - 3.2. C/W LIQUID–IMMERSED BAYONET AND CURRENT–LIMITING FUSES
   - 3.3. DEAD FRONT CONSTRUCTION C/W DUAL SETS OF TERMINALS/BUSHING WELLS ON PRIMARY TO ALLOW FUTURE PRIMARY CONDUCTOR TAPS USING DEAD–BREAK ELBOWS.
4. INSTALL DEAD FRONT PADMOUNT SERVICE KIOSK TO BC HYDRO STANDARDS.
5. PROVIDE ALL UNDERGROUND CONDUITS, BOLLARDS AND GROUND ELECTRODES FOR HYDRO KIOSK, PADMOUNT TRANSFORMER, FCS AND PANTOGRAPH POLE. REFER TO CIVIL DRAWINGS FOR CAST–IN–PLACE CONCRETE INSTALLATION DETAILS (PADS, DUCT BANKS AND FCS FOUNDATIONS).
6. FCS, MODULES RATED FOR MAXIMUM 25kA AVAILABLE FAULT LEVEL. DESIGN–BUILD CONTRACTOR TO ENSURE THAT THE PROTECTION SYSTEMS ARE COORDINATED ACCORDINGLY.
7. PRIMARY 13.2kV VOLTAGE LEVEL TO BE CONFIRMED BY COLORADO STATE UNIVERSITY.

LEGEND :

——— AC CABLE

— — — DC CABLE



ROLE	NAME	SIGNATURE	DATE
DRAFTSPERSON		NR	
DESIGNER		NR	
CHECKER			
DES. COORD.			
RESP. ENG.			
LEAD DISC. ENG.			
ENG. MANAGER			
PROJ. MANAGER			

DRAWING APPROVAL STATUS:

No.	DESCRIPTION	BY	CHK'D	DATE

REVISIONS

HATCH

CITY OF FORT COLLINS

FOOTHILLS CAMPUS TRANSIT CENTER
FAST CHARGING SYSTEM
SINGLE LINE DIAGRAM

SCALE: NTS | DWG No. | REV: B

SHEET SIZE: A3

$TIME$ $USERNAME$ $DATE$ $FILE$

NOTES :

1. DESIGN IS BASED ON 450kW DC FAST CHARGING PANTOGRAPH SYSTEM.
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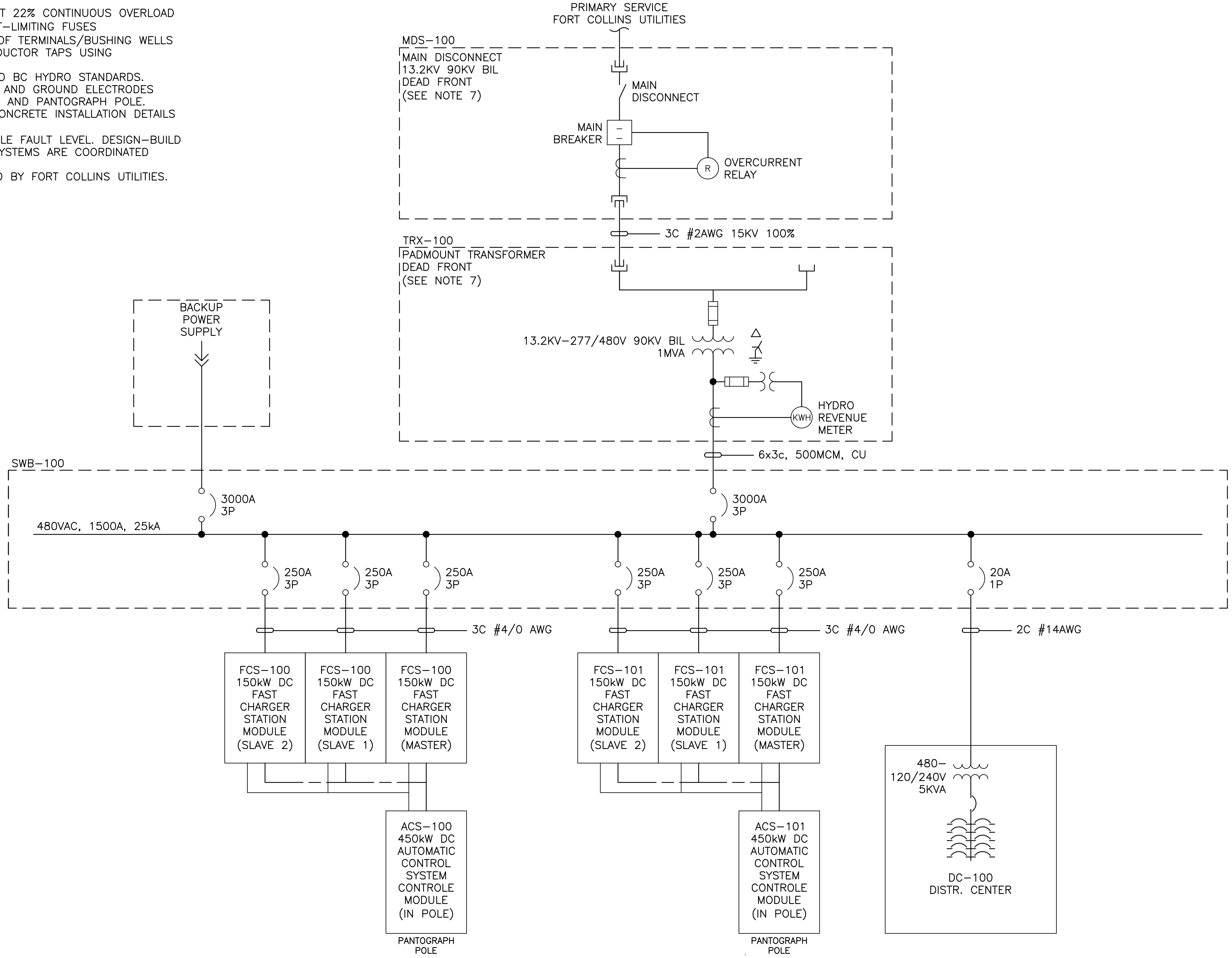
   - 3.3. DEAD FRONT CONSTRUCTION C/W DUAL SETS OF TERMINALS/BUSHING WELLS ON PRIMARY TO ALLOW FUTURE PRIMARY CONDUCTOR TAPS USING DEAD–BREAK ELBOWS.
4. INSTALL DEAD FRONT PADMOUNT SERVICE KIOSK TO BC HYDRO STANDARDS.
5. PROVIDE ALL UNDERGROUND CONDUITS, BOLLARDS AND GROUND ELECTRODES FOR HYDRO KIOSK, PADMOUNT TRANSFORMER, FCS AND PANTOGRAPH POLE. REFER TO CIVIL DRAWINGS FOR CAST–IN–PLACE CONCRETE INSTALLATION DETAILS (PADS, DUCT BANKS AND FCS FOUNDATIONS).
6. FCS, MODULES RATED FOR MAXIMUM 25kA AVAILABLE FAULT LEVEL. DESIGN–BUILD CONTRACTOR TO ENSURE THAT THE PROTECTION SYSTEMS ARE COORDINATED ACCORDINGLY.
7. PRIMARY 13.2kV VOLTAGE LEVEL TO BE CONFIRMED BY FORT COLLINS UTILITIES.

LEGEND :

AC CABLE (solid line)
DC CABLE (dashed line)



ROLE	NAME	SIGNATURE	DATE
DRAFTSPERSON		NR	
DESIGNER		NR	
CHECKER			
DES. COORD.			
RESP. ENG.			
LEAD DISC. ENG.			
ENG. MANAGER			
PROJ. MANAGER			

DRAWING APPROVAL STATUS:

No.	DESCRIPTION	BY	CHK'D	DATE

REVISIONS

HATCH

CITY OF FORT COLLINS

DOWNTOWN TRANSIT CENTER
FAST CHARGING SYSTEM
SINGLE LINE DIAGRAM

SCALE	DWG No.	REV
NTS		B

SHEET SIZE: A3

$TIME$
$USERNAME$
$DATE$
$FILE$

NOTES :

1. DESIGN IS BASED ON 450kW DC FAST CHARGING PANTOGRAPH SYSTEM.
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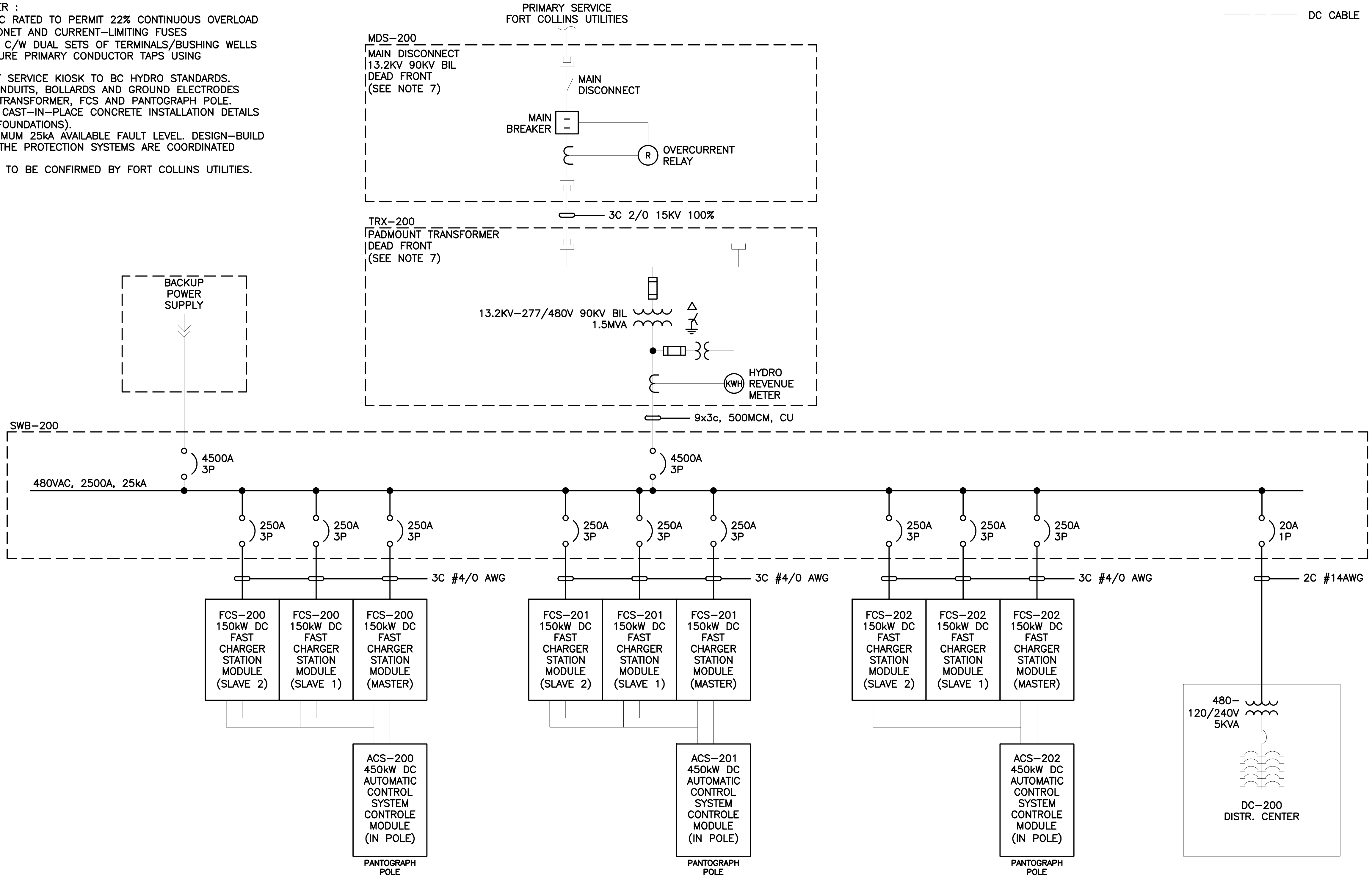
7. PRIMARY 13.2kV VOLTAGE LEVEL TO BE CONFIRMED BY FORT COLLINS UTILITIES.

LEGEND :

——— AC CABLE

– – – DC CABLE



ROLE	NAME	SIGNATURE	DATE
DRAFTSPERSON		NR	
DESIGNER		NR	
CHECKER			
DES. COORD.			
RESP. ENG.			
LEAD DISC. ENG.			
ENG. MANAGER			
PROJ. MANAGER			

DRAWING APPROVAL STATUS:

No.	DESCRIPTION	BY	CHK'D	DATE

REVISIONS

HATCH

CITY OF FORT COLLINS

SOUTH TRANSIT CENTER
FAST CHARGING SYSTEM
SINGLE LINE DIAGRAM

SCALE	DWG No.	REV
NTS		B

SHEET SIZE: A3

$TIMES$ $USERNAMES$ $DATES$ $FILES$

1	2	3	4

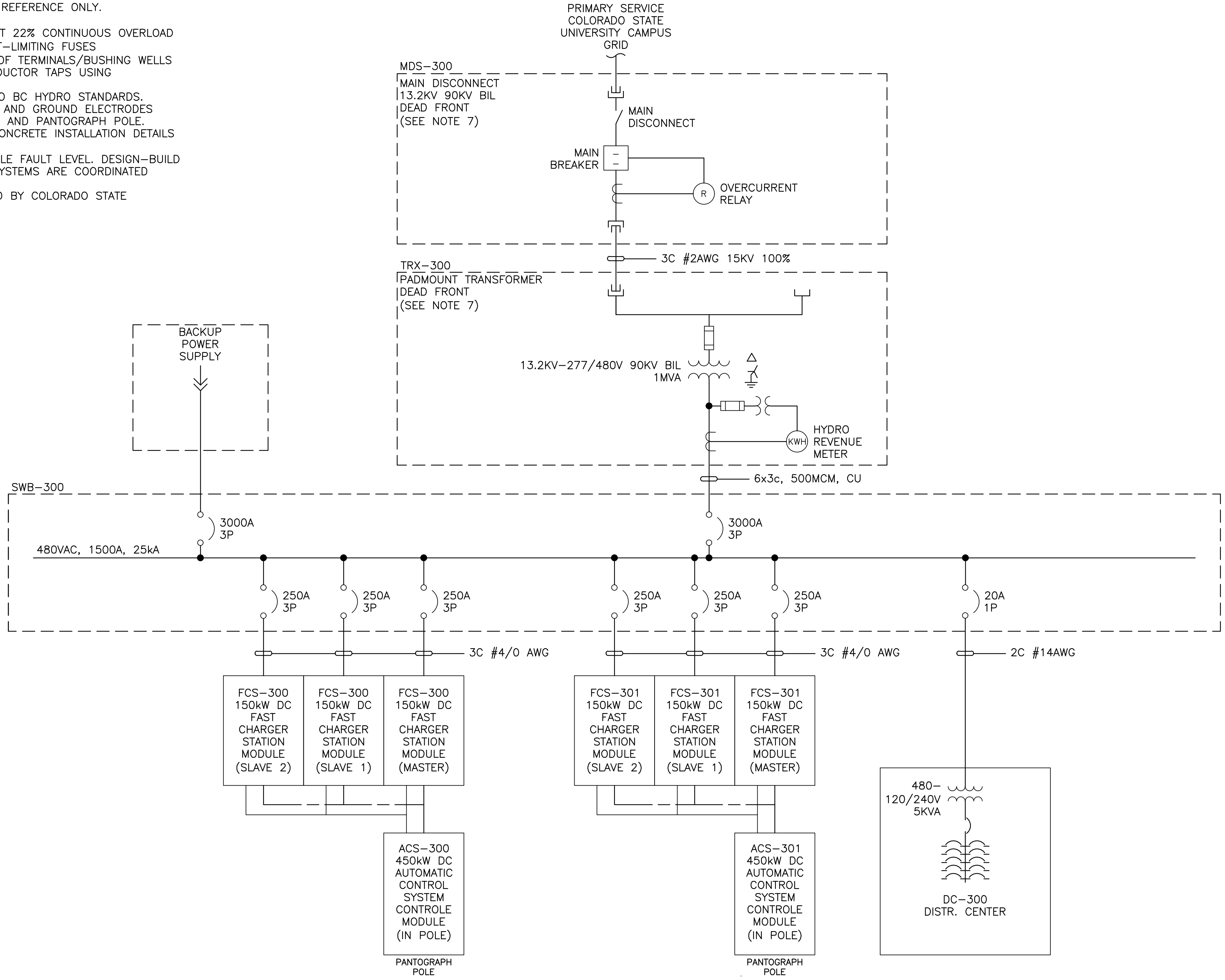
NOTES :

1. DESIGN IS BASED ON 450kW DC FAST CHARGING PANTOGRAPH SYSTEM.
2. ALL CABLING WIRING AND GROUNDING TO BE SIZED BY THE DESIGN–BUILD CONTRACTOR, CABLE SIZES AND MATERIAL IS FOR REFERENCE ONLY.
3. INSTALL PADMOUNT TRANSFORMER :
   - 3.1. FR3 LIQUID–FILLED, 55°/75°C RATED TO PERMIT 22% CONTINUOUS OVERLOAD
   - 3.2. C/W LIQUID–IMMERSED BAYONET AND CURRENT–LIMITING FUSES
   - 3.3. DEAD FRONT CONSTRUCTION C/W DUAL SETS OF TERMINALS/BUSHING WELLS ON PRIMARY TO ALLOW FUTURE PRIMARY CONDUCTOR TAPS USING DEAD–BREAK ELBOWS.
4. INSTALL DEAD FRONT PADMOUNT SERVICE KIOSK TO BC HYDRO STANDARDS.
5. PROVIDE ALL UNDERGROUND CONDUITS, BOLLARDS AND GROUND ELECTRODES FOR HYDRO KIOSK, PADMOUNT TRANSFORMER, FCS AND PANTOGRAPH POLE. REFER TO CIVIL DRAWINGS FOR CAST–IN–PLACE CONCRETE INSTALLATION DETAILS (PADS, DUCT BANKS AND FCS FOUNDATIONS).
6. FCS, MODULES RATED FOR MAXIMUM 25kA AVAILABLE FAULT LEVEL. DESIGN–BUILD CONTRACTOR TO ENSURE THAT THE PROTECTION SYSTEMS ARE COORDINATED ACCORDINGLY.
7. PRIMARY 13.2kV VOLTAGE LEVEL TO BE CONFIRMED BY COLORADO STATE UNIVERSITY.

LEGEND :

AC CABLE

DC CABLE



A

B

C

ROLE	NAME	SIGNATURE	DATE
DRAFTSPERSON		NR	
DESIGNER		NR	
CHECKER			
DES. COORD.			
RESP. ENG.			
LEAD DISC. ENG.			
ENG. MANAGER			
PROJ. MANAGER			

DRAWING APPROVAL STATUS:

No.	DESCRIPTION	BY	CHK'D	DATE

REVISIONS

HATCH

CITY OF FORT COLLINS

COLORADO STATE UNIVERSITY TRANSIT CENTER
FAST CHARGING SYSTEM
SINGLE LINE DIAGRAM

SCALE	DWG No.	REV
NTS		B

SHEET SIZE: A3

$TIME$
$USERNAME$
$DATE$
$FILE$

Appendix B

Cutaway Research

OEM	Model/Platform	Battery Nameplate Capacity (kWh)	Advertised Range (miles)	Altoona Tested (Y/N)	Cost	Source
Arboc	24' Freedom Charge	160	250	N	Not Available	https://arbocsv.com/models/freedom-gm-chassis/
Zeus Electric Chassis	Z-19 Electric Chassis	105	150	N	$200,000	https://zeuselectricchassis.com/
Zeus Electric Chassis	Z-19 Electric Chassis	210	150	N	$230,000	https://zeuselectricchassis.com/
Phoenix Motorcars	Zeus 400 Shuttle Bus	63	70	N	$250,000 - $300,000	https://www.phoenixmotorcars.com/products/
Phoenix Motorcars	Zeus 400 Shuttle Bus	94	100	N	$250,000 - $300,000	https://www.phoenixmotorcars.com/products/
Phoenix Motorcars	Zeus 400 Shuttle Bus	125	130	N	$250,000 - $300,000	https://www.phoenixmotorcars.com/products/
Phoenix Motorcars	Zeus 400 Shuttle Bus	156	160	N	$250,000 - $300,000	https://www.phoenixmotorcars.com/products/
GreenPower Bus	25' EV Star and EV Star+	118	150	Y (EV Star)	$173,000 - $326,000	https://greenpowermotor.com/gp-products/ev-star/
Lightning eMotors	Transit 350HD Cargo Van	80	140	N	Not Available	https://lightningemotors.com/lightningelectric-ford-transit-cargo/
Lightning eMotors	Transit 350HD Cargo Van	120	170	N	Not Available	https://lightningemotors.com/lightningelectric-ford-transit-cargo/
Lightning eMotors	20' E-450	125	130	N	Not Available	https://lightningemotors.com/lightningelectric-e450-cutaway/
Lightning eMotors	20' E-450	157	160	N	Not Available	https://lightningemotors.com/lightningelectric-e450-cutaway/
Lightning eMotors	Ford F-550	128	100	N	Not Available	https://lightningemotors.com/lightningelectric-f550/
Endera	23 to 28' B- Series Ford E-450 Chassis	129	130	N	Not Available	https://www.enderamotors.com/endera-b-series
Optimal EV	26.5' Optimal E-450	113	125	N	Not Available	https://insideevs.com/news/459330/optimalev-200-e1-chassis-ford-e450-cutaway/
Motiv	23' to 26' inches Ford E-450	127	105	N	$230,000	https://www.motivps.com/products/epic-e450/
Motiv	Ford F-53	127	105	N	$230,000	https://www.motivps.com/products/epic-f53/#:~:text=127%20kWh%20total%20capacity
Alpha Mobility	Model-G Shuttle Bus	108	100 - 125	N	Not Available	https://californiahvip.org/vehicles/alpha-mobility-model-g-shuttle-bus/
Alpha Mobility	Model-G Shuttle Bus	144	100-125	N	Not Available	https://californiahvip.org/vehicles/alpha-mobility-model-g-shuttle-bus/
Forest River Bus	E450 EV	100 - 157	80 - 170	Y	Not Available	https://www.bestbussales.com/buses-by-mfr/forest-river/index.html