UCAT Bus Fleet Electrification Study

FINAL REPORT

Ulster County, New York

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Introduction

As electric bus technology continues to improve year after year, transit agencies are increasingly looking towards a not-too-distant future in which full electric bus fleets is a reality. Whereas operating a reliable electric transit service, especially in an region with as diverse weather extremes as the northeast United States would seem impossible just a few years ago, research and development dollars by both the public and private sectors have advanced battery reliability and capacity and reduced vehicle cost to a point where it is not only feasibly, but tantalizingly within reach.

The Ulster County Department of the Environment and Ulster County Area Transit (UCAT) are responding to the new opportunities provided by improved technologies and have begun the planning process to prepare for an electric bus future. Through funding made available via the Volkswagen settlement under grant administration by NYSDERDA, Ulster County is in the process of purchasing three new *New Flyer* electric buses and installing three electric bus charging stations and associated supporting infrastructure at their main Kingston Garage within the next 12 months. This partnership also provides the County with an option to further expand the number of charging stations at the Kingston Garage to six.

The report intends to assist Ulster County and UCAT build on these initial fleet electrification efforts by analyzing the existing system's operations and providing some insights into routes that are suitable for electrification relative to the capabilities of the initial vehicles to be purchased. As transit operations are consistently changing in response to shifting demand and other considerations, this report will also provide tools which can be used by Ulster County and UCAT to evaluate route characteristics against available battery and infrastructure to determine whether a route is suitable for electrification at the time of implementation or if operational changes are required. This report will provide the framework for the ultimate goal of this study – to develop a phased implementation plan for the County towards full fleet electrification.

1 Existing Conditions & UCAT Operations

1.1 UCAT Fixed Route Characteristics

The following evaluation of suitability for implementation of electric buses within the UCAT system will utilize UCAT bus schedules and route alignments as they operated in late 2019. These schedules were selected to be representative of UCAT's typical, pre-COVID-19 service characteristics. Route alignments and operating characteristics have changed since fall 2019 and can be expected to further change periodically in response to shifting demands of the UCAT passengers. However, this report uses the fall 2019 service as the input for the analyses conducted in this report and will provide UCAT and the Ulster County (the County) with valuable insights that can be applied to future service conditions. Route maps and schedules used as the basis of this report are provided in Appendix A.

Each UCAT vehicle's daily schedule has been defined as "vehicle blocks" which include the full driver shift from the time the driver departs the Kingston Depot in the morning to the time it returns at the shift's conclusion. A description of each of the routes as modeled in this analysis and the corresponding vehicle blocks associated with each UCAT vehicle are as follows:

Blue Route

The Blue Route provides circulating bus service to passengers within Downtown Kingston. Beginning at Kingston Plaza, the route makes regular stops with approximately five minutes of travel time between stops. Service is provided to points of interest including SUNY Ulster, City Court, and Kingston Hospital. Each individual trip from Kingston Plaza and back is scheduled for a total of 55 minutes of travel time. The schedule provides for five minutes of layover/recovery time between trips. The vehicles assigned to the Blue Route have been assigned two Block IDs – 1001 and 1002. **Block 1001** covers the portion of the schedule from 6:30 AM to 2:30 PM when the bus returns to the depot. **Block 1002** begins at 2:30 PM until the end of service at 7:25 PM.

CL Route

One vehicle is assigned to provide service along the CL Route and is defined by **Block 1003.** This route travels between SUNY New Paltz and SUNY Ulster, with a trip time of approximately 45 minutes. The CL Route utilizes a transit hub at SUNY New Paltz which it shares with several other routes. Drivers are provided layover durations of between zero and 35 minutes between trips. The CL Route provides service between 7:45 AM and 4:55 PM

EU Route

The EU Route is one of the longer UCAT routes, providing service between Kingston and Ellenville via Route 209. Each one-way trip is scheduled for 60 minutes, with termini at Liberty Square in Ellenville, and Golden Hill in Kingston. Three vehicles provide service along the EU Route during a typical day, each being defined in this analysis by three Block IDs 1004, 1005, and 1018. **Block 1004** includes service between 6:15

AM to 4:45 PM beginning in Kingston and traveling northbound to Ellenville. **Block 1018** includes service between 6:20 AM and 4:45 PM, beginning in Ellenville and traveling southbound to Kingston. **Block 1005** includes service in both directions between 2:20 PM and 10:30 PM.

KPL Route

The KPL Route provides service between Kingston and the Poughkeepsie Metro North rail station. This service primary serves commuter passengers and is designed to be coordinated with the Metro North rail schedules at Poughkeepsie. The route primarily utilizes route 9W between Kingston and Poughkeepsie along which it can reach speeds of between 45 and 55 mph. Two vehicles are assigned to the KPL Route service throughout the day, defined as Block IDs 1007 and 1008 in this analysis. **Block 1007** defines KPL AM service between 5:10 AM and 1:45 PM and **Block 1008** defines PM service between 2:35 PM and 10:05 PM.

KS Route

Route KS operates between Kingston and Saugerties. It is one of UCAT's most popular route with high ridership, providing service to the mall and the Tech City development. Four vehicles are assigned to provide service along this route, defined as Block IDs 1006, 1009, 1016, 1017. **Block 1006 and 1016** define the AM service on this route, operating between 6:20 AM and 3:30 PM and 5:20 AM and 2:30 PM, respectively. **Block 1009 and 1017** define the PM service, operating between 3:20 PM and 10:45 PM and 1:30 PM and 10:15 PM respectively.

Route M

Route M provides circulator service at the mall. One vehicle provides this service over a ten-hour service day. The Route makes 12 stops along an approximately 60-minute loop, with between ten and fifteen minutes of schedule layover/recovery time between each trip. The route serves a total of 12 stops, beginning and ending within the Tech City development. The one vehicle assigned to this service is defined as **Block 1010** in this analysis, with a span of service from 6:20 AM to 5:10 PM each day.

Block ID 2001 defines the demand response service along Route M from 4:50 to 10:05pm each night.

Route NPL (New Paltz Loop)

The New Paltz Loop Route provides circulator service within the Town of New Paltz and serves as the campus shuttle for the SUNY New Paltz Campus. The Town of New Paltz is also a stakeholder in this route's operation. Two vehicles are assigned to this route, providing service between 7 AM and 7 PM each day. **Block 1012** defines the AM service on Route NPL, spanning between 7:20 AM and 3:40 PM. **Block 1013** defines the PM service spanning between 2:10 PM and 10:16 PM.

Red Route

The Red Route is a second circulator route in Downtown Kingston. This route serves 14 stops over the course of approximately 50-minute trip time, beginning and ending at Kingston Plaza. Two vehicles are assigned to the Red Route throughout its service day. **Block 1014** defines the route's AM operations, spanning 6:50 AM to 3:10 PM and **Block 1015** defines the PM operations between 2:50 PM and 7:00 PM

Route UPL

Route UPL is another commuter-centric bus route, providing connections between New Paltz and Poughkeepsie. This route is under contract with NYSDO to provide service to Metro North trains as an effort to reduce single occupancy vehicle trips and associated parking demands at the Poughkeepsie station. It also serves the transportation needs of the SUNY New Paltz campus. Five vehicles are assigned to provide service along this route each day. **Block 1021** and **Block 1022** define the AM service, spanning between 5:00 AM to 10:30 AM and 5:30 AM to 10:45 AM, respectively. **Block 1025** defines midday service, spanning 9:15 AM until 3:45 PM. **Block 1023** and **Block 1024** define the PM service, spanning between 2:45 PM to 10:30 PM and 4:15 PM to 8:30 PM, respectively.

Route W

Route W makes two trips per day serving New Paltz, Wallkill, and Plattekill. The route is scheduled to perform one trip in the morning and one in the evening. Each trip takes approximately 60 minutes to complete and begins and ends in New Paltz. One vehicle is assigned to each daily trip. **Block 2002** defines the route's AM service from 6:00 AM to 7:00 AM, and **Block 1011** defines the PM service from 6:00 PM to 7:00 PM.

Route X

One vehicle is assigned to Route X's service between New Paltz and Newburgh. It operates four trips per day with each two-way trip scheduled for as much as 120 minutes of travel time. The route operates one trip in the morning from New Paltz to Newburgh and back from 6:30am to 9:00 am. It then operates three trips in the afternoon between 1:00pm to 8:30pm. The operations of this vehicle is defined by **Block 2003**.

Yellow Route

The Yellow Route utilizes Route 9W and serves locations in Downtown Kingston. The Yellow Route operates as a circulator, beginning and ending at the Ulster County Department of Social Services and serves 12 total stops. The 12-hour span of service is divided into two shifts operated by two separate vehicles. **Block 1019** defines the AM service between 6:30 AM and 2:20 PM, and **Block 1020** defines the PM service between 2:30 PM and 7:20 PM.

Route Z

Route Z provides service between Kingston and Belleayre Mountain via Route 28. The route operates on relatively long running times, scheduled for an hour and fifteen minutes each way. There is a large elevation change between Kingston and Belleayre Mountains over each trip. Three vehicles are assigned to Route Z's service each day. Two vehicles are assigned to providing AM service between 5:50 AM and 10:50 AM. These are defined by **Block 1026** and **Block 1027**. One vehicle is assigned to the PM service between 2:20 PM and 8:10 PM. This service is defined by **Block 1028**.

The UCAT routes and the Blocks used in this analysis to define the operations of each is summarized in Table 1.

Table 1. Vehicle Block IDs Used to Define the Operating Day of Each Vehicle

Route	Block ID	Span of Service
Blue Route	1001	6:30 am – 2:30 pm
	1002	2:30 pm – 7:25 pm
CL Route	1003	7:45 am – 5:10 pm
EU Route	1004	6:15 am – 4:45 pm
	1005	3:45 pm – 10:30 pm
	1018	7:20 am – 4:45 pm
KPL Route	1007	5:45 am – 1:45 pm
	1008	3:45 pm – 10:05 pm
KS Route	1006	7:25 am – 3:30 pm
	1009	4:25 pm – 10:45 pm
	1016	6:15 am – 2:30 pm
	1017	3:25 pm – 10:15 pm
M Route	1010	6:36 am – 5:10 pm
	2001	5:00 pm – 10:33 pm
NPL Route	1012	8:05 am – 3:40 pm
	1013	2:50 pm – 10:16 pm
Red Route	1014	7:00 am – 3:10 pm
	1015	3:00 pm – 7:08 pm
UPL Route	1021	5:12 am – 10:28 am
	1022	5:42 am - 10:42 am
	1023	2:57 pm – 10:27 pm
	1024	4:27 pm – 8:32 pm
	1025	9:27 pm – 5:42 pm
W Route	1011	5:58 pm – 7:28 pm
	2002	6:00 am – 7:40 am
X Route	2003	1:00 pm – 8:54 pm
Yellow Route	1019	6:25 am – 2:30 pm
	1020	2:25 pm – 7:30 pm
Z Route	1026	7:15 am – 3:10 pm
	1027	6:15 am – 10:50 am
	1028	3:45 pm – 8:10 pm

The individual trips that comprise each of the vehicle blocks used throughout this analysis are provided in Appendix B.

1.2 Vehicle Block Characteristics

For each one-way vehicle trip within a schedule block the bus battery's state of charge (SOC) decline is calculated based on mileage traveled. If on-route chargers are installed at layover locations, some or all the scheduled layover time can be used to recharge the bus for the return trip. Table 2, below, summarizes the characteristics of the 31 vehicle blocks analyzed by total mileage from pull-out to pull-in at the depot, scheduled running time, and percentage of layover time built into the schedule. Most of the vehicle blocks consisted exclusively of a single route, which makes the analysis simpler to interpret. The main exceptions are several vehicle blocks that start and end with trips on Route R – because of this interline operation, Route R does not appear as the primary route on any vehicle blocks.

The distances operated by the vehicle blocks range from 41.4 miles to 261.3 miles, with an average of 129.1 miles. Vehicle blocks on routes CL, Z, X, and EU tend to operate the longest distances.

The time operated by the vehicle blocks ranged from 2.1 hours to 10.8 hours, with an average of 7.3 hours. These represent typical work shifts for drivers, but of course we should note that longer work shifts are inherently harder to electrify. Vehicle blocks on routes CL and EU tend to operate the longest shift times.

Table 2 also notes the amount of layover time provided relative to the shift time. Layover time becomes relevant when considering usage of on-route charging that would occur at layover points. These values range from no layover to 42.7%, with an average of 19.8%. Schedulers often aim for 20% layover as a typical value, and UCAT's schedules align with that. Routes M, UPL, NPL, and EU have relatively high layover times that may be supportive of on-route charging.

Table 2. Characteristics of UCAT scheduled vehicle blocks. Note that UCAT does not use block IDs; they were generated by the consultant team for reference.

Primary Route	Block ID	Miles	Hours	Layover Time
Blue	1001	56.5	8.3	19.00%
	1002	41.4	5.3	7.80%
CL	1003	213.6	10.6	21.30%
EU	1004	184.9	10.5	27.70%
	1005	186.6	8.2	23.50%
	1018	186.6	10.4	22.40%
KPL	1007	191.5	8.6	18.40%
	1008	157	7.5	18.90%
KS	1006	119.6	9.2	21.10%
	1009	90.6	7.4	15.30%
	1016	119.6	9.2	23.30%
	1017	90.6	7.9	13.70%
M	1010	100.5	10.8	26.00%
	2001	51	5.8	42.70%
NPL	1012	114.4	8.3	21.60%
	1013	95.6	8.1	30.00%

Primary Route	Block ID	Miles	Hours	Layover Time
Red	1014	84.2	8.3	24.00%
	1015	51.5	4.3	11.60%
UPL	1021	177.3	5.5	18.60%
	1022	129.6	5.2	30.80%
	1023	206.9	7.7	24.50%
	1024	90.4	4.3	33.50%
	1025	168.3	8.5	26.20%
W	1011	71.6	2.1	0.00%
	2002	70.1	2.3	0.00%
X	2003	186.2	8.2	21.70%
Yellow	1019	90.4	8.3	25.30%
	1020	65.5	5.3	14.30%
Z	1026	261.3	9.3	16.10%
	1027	171.4	5.7	5.90%
	1028	176.8	5.8	8.60%

1.3 General UCAT System Fleet Characteristics and Performance

The current UCAT fleet of fixed-route vehicles is quite diverse. It includes 31 vehicles of various sizes, models, and fuel types. As of 2018, only 20 vehicles were needed to operate UCAT's maximum fixed-route service, which leaves a healthy number of spare vehicles. UCAT's mixed fleet has developed in part due to the convenience of partnering with other agencies' purchases rather than conducting separate procurements. Most peer agencies prefer to use a more consistent vehicle fleet, which will be easier to maintain. It is hoped that this fleet electrification plan will allow UCAT to develop a more streamlined fleet.

The summary of the current UCAT fleet by vehicle size and by fuel type is shown in Figure 1 below. There are 11 larger buses sized 35 and 40 ft. These generally see higher levels of utilization, and they are also older on average than the rest of the fleet. There are 14 smaller buses sized 29 or 30 ft, and also six cutaway vehicles sized 23 to 26 ft. (Note that currently the electric bus market does not include established options for this smallest size category, so they will be excluded from fleet electrification analysis.) One-fifth of the fleet uses gasoline – these are the smaller cutaway-style vehicles. The remainder of the buses are primarily diesel, though several are diesel-electric hybrids delivered in 2010.

Figure 1. Breakdown of UCAT's Active Bus fleet by Size and by Propulsion Fuel Type

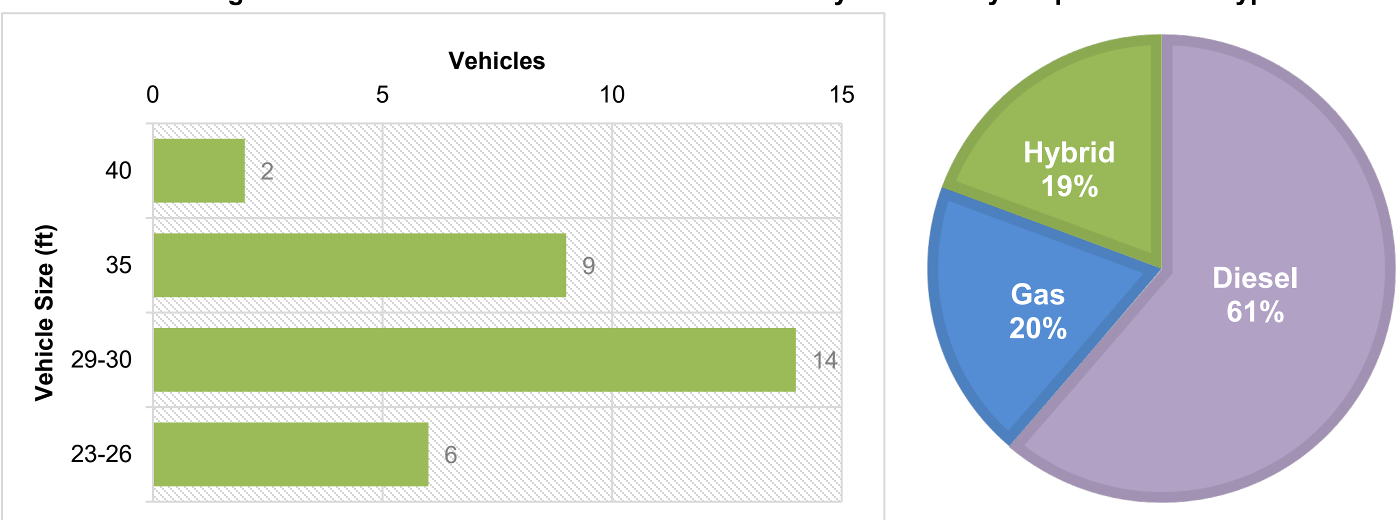
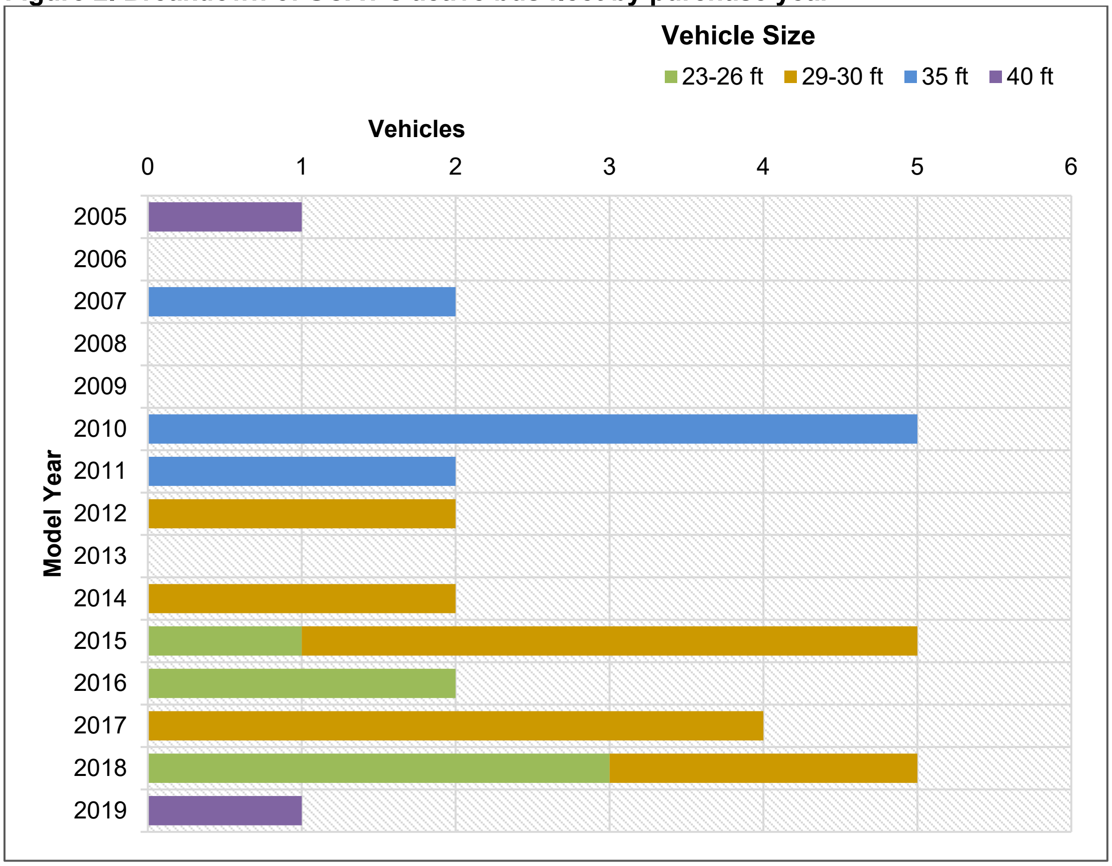


Figure 2 illustrates the breakdown of the UCAT fleet by model year. This shows a relatively consistent distribution, though the larger vehicles tend to be older and the smaller vehicles tend to be newer. The average age of the vehicles is between 6 and 7 years.

Figure 2. Breakdown of UCAT's active bus fleet by purchase year



Subsequent sections of this memorandum will evaluate the current UCAT fleet based on several performance metrics. We will compare current the fleet's performance with projected performance of electric buses on the same metrics.

- First, we will consider the **cost of ownership** on a per-mile basis and an annual basis. This evaluation will incorporate purchase costs, maintenance costs, and fuel costs (inclusive of both diesel and electricity.)
- Next, we will consider the **social costs** associated with UCAT's buses on an annual basis. This evaluation will incorporate CO_2 and equivalent greenhouse gas emissions, NO_x emissions, particulate matter emissions, and noise impacts measured in financial terms.
- We will also separately report the estimated annual **metric tons of CO_2 equivalent emissions**, under three different stages of UCAT's electrification plans.

1.4 Lifetime Cost of Ownership

The total cost of ownership for UCAT's existing fleet is estimated considering three categories of costs: purchase prices, maintenance costs, and fuel costs over a vehicle's useful life. While there may be other costs associated with the vehicles, these are considered the key factors for the purpose of comparison with electric buses. The calculations add up these costs over each year of a vehicle's expected life. Future costs are also adjusted to reflect 1.8% annual inflation and a 3% discount rate on future costs.

Because UCAT has a mixed vehicle fleet, different assumptions are needed for different vehicle types. First, the expected useful life is different for different vehicles: based on FTA guidance, we assume that 35-ft and 40-ft vehicles will have a 12-year expected life, 30-ft vehicles will have a 10-year expected life, and 25 ft vehicles will have a 5-year expected life.

Average bus purchase prices for each combination of vehicle size and propulsion were identified from UCAT's 2019-20 vehicle inventory. These values were then converted into 2020 dollars. Results ranged from $124,700 for a 25 ft gas vehicle to $658,300 for a 35 ft hybrid.

Bus maintenance costs were estimated based on 2018-19 AssetWorks maintenance data for each vehicle. The data were differentiated by vehicle size and propulsion, yielding values ranging from $0.21 to $0.54 per mile. Applying these rates with the 2019 average bus mileage of 32,208, this yields annual maintenance costs ranging from $6,300 to $16,300 per bus in 2020.

Finally, fuel costs were calculated. The current price of diesel was $2.199 per gallon based on UCAT's 2019 purchases, and in future years this follows a trend projected by the US Energy Information Administration. The current price of gasoline was $2.212 per gallon based on UCAT's 2019 purchases, and in future years this follows a trend projected by the US Energy Information Administration. Fuel usage rates were differentiated by vehicle size and propulsion using averages of 2018-19 UCAT vehicle statistics. The resulting rates ranged from 6.9 mpg to 9.7 mpg. Applying these rates and rates with the 2019 average bus mileage of 32,208, this yields annual fuel costs ranging from $7,300 to $10,200 per bus in 2020.

These costs were combined into a weighted average that reflects UCAT's fleet breakdown between different vehicle types, with the results summarized in Table 3. In total, 64% of the cost of ownership comes from bus purchases, 20% comes from bus maintenance, and 16% comes from bus fueling.

Table 3. Summary of cost of ownership for an average UCAT bus (weighted average of vehicle types)

	Cost per Mile	Cost per Year
Purchase cost	$1.04	$33,400
Maintenance cost	$0.32	$10,400
Fuel cost	$0.27	$8,700
Total	**$1.63**	**$52,500**

A more detailed breakdown of costs by vehicle type is provided in Table 4.

Table 4. Breakdown of cost of ownership by UCAT vehicle types

Vehicle Type	Cost per Mile			Cost per Year		
	Purchase cost	Fuel cost	Maintenance cost	Purchase cost	Fuel cost	Maintenance cost
25ft Gas	$0.74	$0.25	$0.20	$23,784	$7,933	$6,312
30ft Diesel	$0.89	$0.25	$0.33	$28,638	$8,094	$10,496
35ft Diesel	$1.05	$0.30	$0.32	$33,809	$9,768	$10,166
40ft Diesel	$1.13	$0.31	$0.31	$36,458	$10,024	$9,836
35ft Hybrid	$1.70	$0.31	$0.43	$54,858	$10,104	$13,981
40ft Hybrid	$1.47	$0.26	$0.51	$47,241	$8,465	$16,307

Next, we will calculate the lifetime cost of ownership for **electric buses** for the purpose of comparison.

The purchase price for a 35 ft electric bus was known based on UCAT's recent New Flyer procurement. This price was $808,542.

Bus maintenance costs were estimated by making the conservative assumption that half of manufacturer claimed savings will occur; this was based on a review of research and peer agency experience. Specifically, we applied a 9.25% reduction to UCAT's observed diesel bus maintenance cost per mile. Using this rate with the 2019 average bus mileage of 32,208, this yields an annual maintenance cost of $9,200 per electric bus in 2020.

Finally, electricity costs were estimated. These costs were generated under three scenarios that represent Year 1 (garage charging only), Year 5 (garage charging and one on-route location), and Year 10+ (garage charging and four on-route locations). Under each scenario, Sage Engineering calculated bus electricity costs based on charging requirements and the electrical rate structures. Over time, the amount of on-route charging and energy consumption per bus increases, as longer vehicle blocks are being electrified. Additionally, an extra $1.50 per MWh is added for Renewable Energy Credits. Combining the projected energy costs under our three scenarios, we estimate that the annual electricity cost to power electric buses could range from $12,800 to $30,600 per electric bus.

Table 5 summarizes the cost the cost of ownership of electric buses under our three scenarios. In total, 63%-75% of the cost of ownership comes from bus purchases, 9%-10% comes from bus maintenance, and 14%-29% comes from electricity.

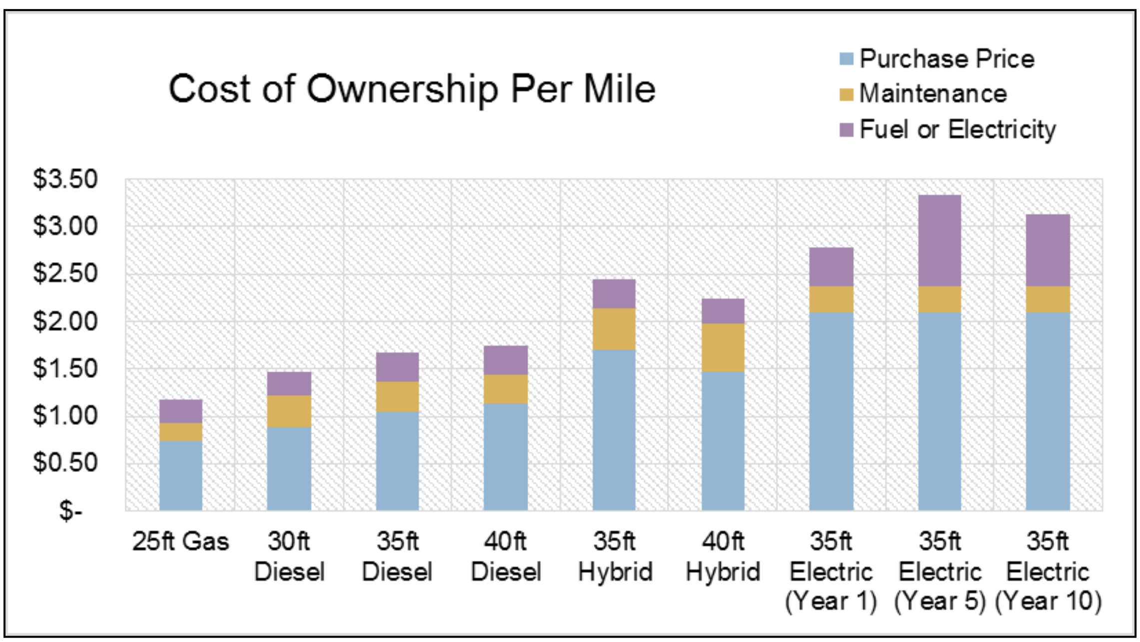
Table 5. Breakdown of cost of ownership for electric buses under three scenarios

Scenario	Cost per Mile			Cost per Year		
	Purchase cost	Electricity cost	Maintenance cost	Purchase cost	Electricity cost	Maintenance cost
Year 1 (Garage Charging Only)	$2.09	$0.40	$0.29	$67,379	$12,753	$9,226
Year 5 (Garage Charging and One On-Route Location)	$2.09	$0.95	$0.29	$67,379	$30,603	$9,226
Year 10+ (Garage Charging and Four On-Route Locations)	$2.09	$0.75	$0.29	$67,379	$24,100	$9,226

Finally, the graph below compares the estimated cost of ownership per mile for all of the vehicle types we analyzed. This indicates that electric buses have a higher cost of ownership compared with UCAT's existing vehicle types – about 13% to 36% greater than the cost of ownership for UCAT's most expensive vehicle type. The following factors influence this result:

- The electric buses have a higher purchase price compared with UCAT's current vehicles. UCAT's current vehicles tend to have relatively low purchase prices, thanks to UCAT's procurement strategies. However, we should note that electric bus prices are projected to converge with diesel/hybrid bus prices over the coming decade.
- The maintenance costs shown may be an underestimate, as they do not include salaries and fringe benefits. The relative maintenance savings from electric buses could be greater with these factors included.
- Electricity costs are expected to grow considerably in future years. UCAT might be able reduce these costs if a more favorable rate structure could be established.

Figure 3. Comparison of cost of ownership between UCAT's current vehicle types and electric buses



1.5 Social Costs of Current UCAT Fleet

While the estimate of cost of ownership focuses on direct costs to UCAT, operating a bus fleet also generates social costs that are important to evaluate. These social costs are evaluated based on three key pollutants emitted, CO2, NOx, and particulate matter, as well as noise. These calculations are based upon the miles traveled and gallons of fuel estimated in the previous section. As before, the calculations vary based on vehicle size and propulsion within UCAT's mixed fleet.

The emissions of CO2 and equivalent greenhouse gases are estimated in terms of the kg emitted per mile traveled or per gallon of fuel. These masses were generated using 2018 USEPA Emission Factors for Greenhouse Gas Inventories as well as the Comparison of Modern CNG, Diesel and Diesel Hybrid-Electric Transit Buses. Then the social cost of the emissions was calculated using a rate of $42 per ton from the US EPA's fact sheet.

The emissions of NOx are estimated using statistics from the US Environmental Protection Agency, the California Air Resources Board, and the Environmental and Energy Study Institute. The social costs of the resulting emissions were calculated using a rate of $8,335 per ton as determined by the US EPA.

The emissions of particulate matter are calculated from US Environmental Protection Agency sources including the Diesel Emissions Quantifier. The resulting emissions were assigned a social cost based on the rate of $971.77 per kg specific to Ulster County.

Finally, noise costs were estimated based on research in the Victoria Transport Policy Institute's Transportation Cost and Benefit Analysis Part II. We applied an average of their urban and rural noise rates for diesel buses, and also included a reduction for UCAT's quieter hybrid vehicles.

These costs were combined into a weighted average that reflects UCAT's fleet breakdown between different vehicle types. The results are shown in Table 6. In total, 24% of the social costs come from CO2 and equivalent greenhouse gases, 43% come from NOx emissions, 13% come from particulate matter emissions, and 20% comes from noise.

Table 6. Summary of social costs for an average UCAT bus (weighted average of vehicle types)

	Social Cost per Year
CO_2e Emissions	$1,700
NO_x Emissions	$3,100
PM Emissions	$900
Noise	$1,400
Total	**$7,100**

A detailed breakdown of costs by vehicle type is provided in Table 7 below.

Table 7. Breakdown of annual social costs associated with UCAT's vehicle types

Vehicle Type	Social Cost per Year			
	CO_2e Cost	NO_x Cost	PM Cost	Noise Cost
25ft Gas	$1,356	$2,213	$803	$1,288
30ft Diesel	$1,760	$4,924	$813	$1,610
35ft Diesel	$2,123	$4,924	$981	$1,610
40ft Diesel	$2,179	$4,924	$1,006	$1,610
35ft Hybrid	$1,699	$2,782	$981	$1,417
40ft Hybrid	$1,743	$2,782	$1,006	$1,417

Next, the performance metrics of UCAT's bus fleet will be compared against potential scenarios utilizing electric buses. This is relatively straightforward, as UCAT will be purchasing Renewable Energy Credits that offset emissions from electricity generation. The only social cost, therefore, will be the noise generated by electric buses. Using figures from the Victoria Transport Policy Institute's Transportation Cost and Benefit Analysis Part II, we estimate that electric buses will generate $966 in annual social costs from noise.

This indicates that electric buses would reduce social costs by 86% compared with UCAT's current fleet. The estimated annual social costs saved per bus would be approximately $6,200.

2 Technical Feasibility Analysis for Fleet Electrification

At the time of this report, UCAT has purchased three, new 35-foot New Flyer Xcelsior Charge electric buses. Additionally, UCAT has purchased and will installed three 150kW High Power bus charging stations and dispensers to be installed at the Kingston Storage and Maintenance facility. These vehicles and equipment are part of a pilot program in furtherance of a goal for full electrification of the UCAT bus fleet. Ulster County and UCAT also has the option to purchase an additional four electric buses and three additional power cabinets under these same programs over the next five years.

Route characteristics between fixed routes within the system are diverse, including circulators within Downtown Kingston, never traveling too far from the depot, and routes that experience large elevation changes and long trip times between Kingston and the Bellayre Mountains. To start on the path towards full fleet electrification, existing route operations are evaluated relative to battery capacities and pragmatic operational considerations to determine those most suitable for implementation of electric bus service. The evaluation then provides insight into vehicle, technology, and infrastructure needs to support a phased implementation of full electric bus service within UCAT's service area.

2.1 Schedule Modeling Results

The modeling and analysis conducted for this report analyzed the suitability of vehicle block electrification under three different charging infrastructure scenarios – depot-based charging only, depot-based charging with four on-route chargers installed a strategic locations at shared layover hubs, and depot-based charging with on-route chargers installed at every layover location for each route. For scenarios that include on-route charging, the state of charge (SOC) increases are included in the model at the appropriate locations. Ultimately, this allows for the determination as to whether the simulated SOC performance of each vehicle block would reflect successful electrification or would fail by falling below a minimum acceptable SOC to maintain reliable operations.

2.2 Conservative Technology Assumptions

The first electric buses purchased by UCAT will be of the *New Flyer Xcelsior Charge* model. These buses have a nominal battery capacity of 388 kWh. Unfortunately, this battery is not compatible with on-route fast charging at 450 kW. The 388 kWh buses will be appropriate for garage-based charging, but our analysis will consider a different battery offering when evaluating on-route charging. For on-route charging, we will assume a 320 kWh battery, which is the largest *New Flyer* offering that is compatible with fast charging. The assumption in the analysis contained herein is that Ulster County and UCAT will seek to purchase buses compatible with on-route fast charging when considering future purchases.

For this analysis, adjustments are applied to generate a battery capacity that reflects adverse real-world conditions and account of natural degradation of battery capacity over its useful life. These adjustments are referred to in this document as "**conservative technology assumptions**." The intent of modeling battery performance under these assumptions is to provide a determination as to which routes will be suitable for implementation and of which UCAT can be confident will operate reliably from the first day of operation to the last day before the battery is replaced.

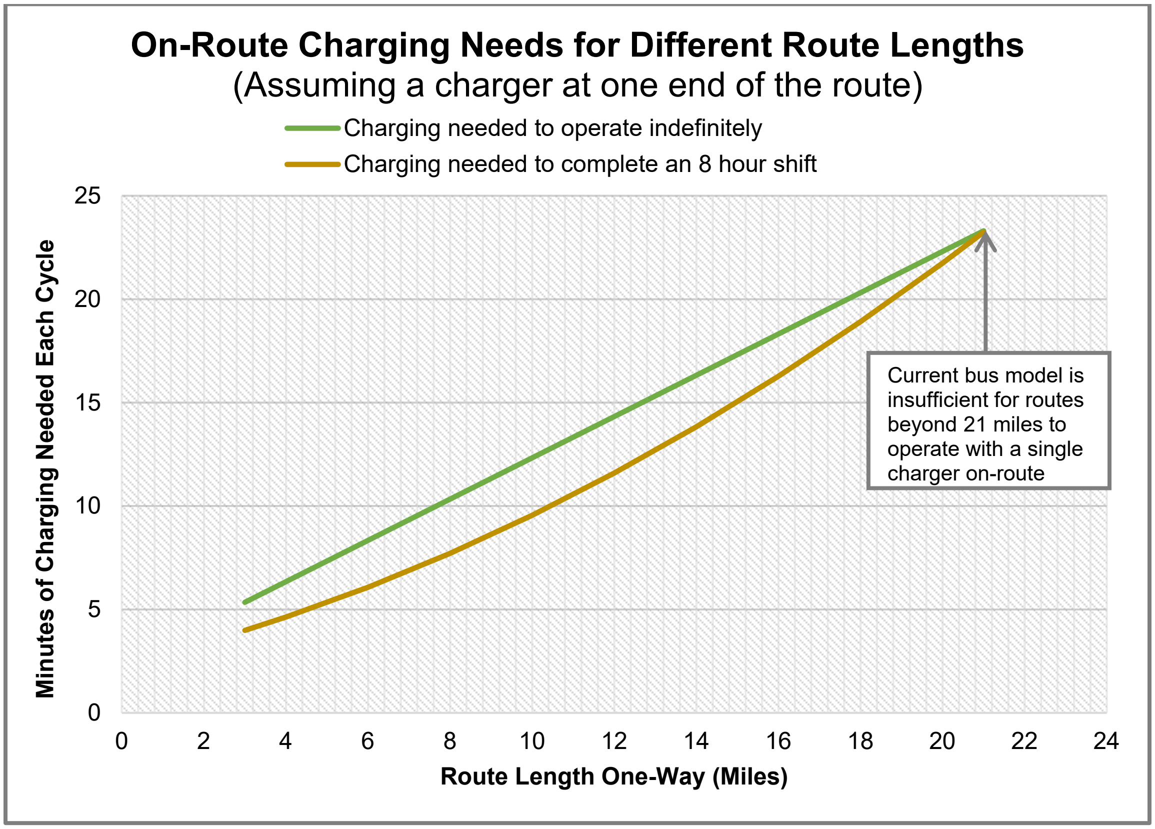
First, battery capacity is reduced 20% to account for the usability range (because the highest and lowest ends of the battery capacity are not usable). Another 20% is discounted to account for end-of-life capacity degradation. This yields an adjusted capacity of 205-248 kWh. A minimum reserve state of charge is then set at 20% or 41-50 kWh. This analysis assumes that buses consume this capacity at a rate of 3.18 kWh/mi, which was selected to be inclusive of wintertime conditions and is based on real-world performance metrics from the Chicago Transit Authority. This value also accounts for the use of on-board diesel-powered heaters to offset demands on the battery.

Buses that use garage-based charging under conservative technology assumptions are assumed to start the day with a fully charged battery. Based on the adjusted battery capacity assumptions and the consumption rate, **the effective range is calculated as 62.4 miles**. This is only 32% of the manufacturer's advertised range of 195 miles. As such, vehicle blocks that are less than or equal to a total of 62.4 miles in length can be reliably operated using UCAT's electric buses, even in adverse operating conditions, with depot-based charging only.

Calculation of the effective range of bus routes/vehicle blocks that utilize on-route charging becomes more complex. Theoretically, with enough on-route charging locations and enough charge time provided in the schedule at layovers, the range can be effectively unlimited.

If a bus in our model has a layover at a location where an on-route charger is provided, we presume that the bus utilizes that charger as follows: Buses are assumed to start the day with a 90% SOC, reflecting a modest amount of charging at the garage. Actual layover time is estimated to be 85% of the scheduled layover time to account for deviations from schedule due to road conditions and other factors. A discount of two minutes is applied to the remaining layover time to account for connecting and disconnecting the charger. The remaining layover time is allocated to bus charging. The graph shown in Figure 3 shows the charging time needed on bus routes relative to trip lengths assuming a 450 kW on-route charger is available on one end of the route.

Figure 4. Charging time required to operate bus routes with a 450 kW on-route charger at layovers



Each of the UCAT system's vehicle blocks were modeled under the three scenarios considered. Table 8 summarizes the results under the conservative technology assumptions. The first was to determine what blocks are suitable for electrification with garage charging only. Only 13% of vehicle blocks meet the requirements for this operation; the remainder would see their SOC fall to an unacceptable level to maintain reliable operation. The one route that could be fully electrified using only using garage charging is the Blue Route.

The second test was to determine which blocks could be electrified if on-route chargers were provided at four, strategically chosen locations: Kingston Plaza, Tech City, SUNY New Paltz, and Poughkeepsie. Under this scenario 61% of the UCAT vehicle blocks could be electrified, including the entire service day of Routes KS, M, NPL, Red and Yellow.

Finally, a relatively "extreme" scenario is included that tests maximum deployment of on-route charging (i.e. an on-route charger located at every layover location). Even with this high-density of charging infrastructure, 23% of the UCAT vehicle blocks analyzed would not be suitable for electrification using current battery technology. The most challenging routes to electrify include KPL, UPL, W and Z. Routes that fail to meet suitability under this scenario indicate the travel distance is too great and/or the layover time between trips in too short to be electrified.

Table 8. Summary of what UCAT vehicle blocks would be suitable to electrify under different scenarios using conservative technology assumptions

			Block is Suitable to Electrify Using…		
Primary Route	Block ID	Span of Service	Garage Charging Only	Garage Charging and Four On-Route Layovers	Garage Charging and On-Route Charging at all Layovers
Blue Route	1001	6:30 AM – 2:30 PM	Yes	Yes	Yes
	1002	2:30 PM – 7:25 PM	Yes	Yes	Yes
CL Route	1003	7:45 AM – 5:10 PM	No	No	Yes
EU Route	1004	6:15 AM – 4:45 PM	No	Yes	Yes
	1005	3:45 PM – 10:30 PM	No	No	Yes
	1018	7:20 AM – 4:45 PM	No	Yes	Yes
KPL Route	1007	5:45 AM – 1:45 PM	No	No	No
	1008	3:45 PM – 10:05 PM	No	Yes	Yes
KS Route	1006	7:25 AM – 3:30 PM	No	Yes	Yes
	1009	4:25 PM – 10:45 PM	No	Yes	Yes
	1016	6:15 AM – 2:30 PM	No	Yes	Yes
	1017	3:25 PM – 10:15 PM	No	Yes	Yes
M Route	1010	6:35 AM – 5:10 PM	No	Yes	Yes
	2001	5:00 PM – 10:33 PM	Yes	Yes	Yes
NPL Route	1012	8:05 AM – 3:40 PM	No	Yes	Yes
	1013	2:50 PM – 10:16 PM	No	Yes	Yes
Red Route	1014	7:00 AM – 3:10 PM	No	Yes	Yes
	1015	3:00 PM – 7:08 PM	Yes	Yes	Yes
UPL Route	1021	5:12 AM – 10:28 AM	No	No	No
	1022	5:42 AM – 10:42 AM	No	No	Yes
	1023	2:57 PM – 10:27 PM	No	No	Yes
	1024	4:27 PM – 8:32 PM	No	Yes	Yes
	1025	9:27 PM – 4:42 PM	No	Yes	Yes
W Route	1011	5:58 PM – 7:28 PM	No	No	No
	2002	6:00 AM – 7:40 AM	No	No	No
X Route	2003	1:00 PM – 8:54 PM	No	No	Yes
Yellow Route	1019	6:25 AM – 2:30 PM	No	Yes	Yes
	1020	2:25 PM – 7:30 PM	No	Yes	Yes
Z Route	1026	7:15 AM – 3:10 PM	No	No	No
	1027	6:15 AM – 10:50 AM	No	No	No
	1028	3:45 PM – 8:10 PM	No	No	No

It should be noted that reasons a vehicle block that fail to meet the suitability for electrification under these scenarios could be due their operating characteristics such as one-way trip length and allocated layover time. Adjusting schedules or route alignments to reduce trip travel distances or to increase layover time between trips could be non-capital changes that can increase the suitable blocks under each scenario. To electrify the most difficult portions of the current service, additional strategies will need to be considered such as considering different equipment with longer effective ranges or segmenting routes with long tips lengths.

2.3 Optimistic Technology Assumptions

While the conservative technology assumptions used in the previous analysis provide a reliable basis to plan for adverse conditions and to account for end-of-useful-life battery capacities, they do not necessarily reflect typical conditions. For example, battery capacity degradation will not be a major factor upon initial delivery and roll-out of the vehicles. Battery performance will also likely be significantly better during non-winter months and in good weather. To reflect somewhat these conditions, we also modeled performance under "**optimistic technology assumptions**." These assumptions are different from the conservative assumptions in two significant ways - (1) no battery capacity reduction is assumed for natural degradation over their useful life and (2) buses using on-route charging are assumed to start the day with 100% SOC. These changes will reflect performance that can be expected in the first years after buses are delivered, assuming good garage-based charging practices. The "optimistic technology assumptions" could be a reasonable basis for planning the first few years of UCAT's electric bus transition.

These changes to assumptions increase the effective battery range using garage-based charging only from 62.4 miles to **81.9 miles**. This still represents a conservative estimate and well below the manufacturer claim of 195 miles. Similarly, for on-route charging, the optimistic assumptions increase the theoretical longest trip that could be operated. The longest trip that could successfully use on-route charging under the optimistic technology assumptions would be 32 miles, better than the conservative estimate of 21 miles.

Table 6 on the next page shows the results of schedule modeling for three potential scenarios under our conservative technology assumptions. Under the scenario with garage charging only, only 23% of vehicle blocks would meet the requirements for electrification; the remainder would see their SOC fall to level below that determined to be necessary to provide reliable service. Two routes would be compatible for electrification of their entire service days - the Blue Route and Route W.

Similarly, we again modeled these operating conditions under the scenario with on-route chargers provided at four locations: Kingston Plaza, Tech City, SUNY New Paltz, and Poughkeepsie. This scenario could accommodate 77% of bus service, including the entirety of Routes CL, KS, M, NPL, Red and Yellow.

Finally, Table 9 also shows the extreme scenario that tests maximum deployment of on-route charging by assuming that on-route chargers are available at every layover location. Like what was found under conservative technology assumptions, this finds that some service (16% of blocks) still cannot be electrified. The most challenging routes to electrify include KPL and Z. These vehicle blocks travel too great a distance with too little layover time to be electrified with current technology.

Table 9. Summary of what UCAT vehicle blocks would be suitable to electrify under different scenarios using optimistic technology assumptions

			Block is Suitable to Electrify Using…		
Primary Route	Block ID	Span of Service	Garage Charging Only	Garage Charging and Four On-Route Layovers	Garage Charging and On-Route Charging at all Layovers
Blue Route	1001	6:30 AM – 2:30 PM	Yes	Yes	Yes
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KPL Route	1007	5:45 AM – 1:45 PM	No	No	No
	1008	3:45 PM – 10:05 PM	No	Yes	Yes
KS Route	1006	7:25 AM – 3:30 PM	No	Yes	Yes
	1009	4:25 PM – 10:45 PM	No	Yes	Yes
	1016	6:15 AM – 2:30 PM	No	Yes	Yes
	1017	3:25 PM – 10:15 PM	No	Yes	Yes
M Route	1010	6:35 AM – 5:10 PM	No	Yes	Yes
	2001	5:00 PM – 10:33 PM	Yes	Yes	Yes
NPL Route	1012	8:05 AM – 3:40 PM	No	Yes	Yes
	1013	2:50 PM – 10:16 PM	No	Yes	Yes
Red Route	1014	7:00 AM – 3:10 PM	No	Yes	Yes
	1015	3:00 PM – 7:08 PM	Yes	Yes	Yes
UPL Route	1021	5:12 AM – 10:28 AM	No	No	No
	1022	5:42 AM – 10:42 AM	No	Yes	Yes
	1023	2:57 PM – 10:27 PM	No	Yes	Yes
	1024	4:27 PM – 8:32 PM	No	Yes	Yes
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W Route	1011	5:58 PM – 7:28 PM	Yes	Yes	Yes
	2002	6:00 AM – 7:40 AM	Yes	Yes	Yes
X Route	2003	1:00 PM – 8:54 PM	No	No	Yes
Yellow Route	1019	6:25 AM – 2:30 PM	No	Yes	Yes
	1020	2:25 PM – 7:30 PM	Yes	Yes	Yes
Z Route	1026	7:15 AM – 3:10 PM	No	No	No
	1027	6:15 AM – 10:50 AM	No	No	No
	1028	3:45 PM – 8:10 PM	No	No	No

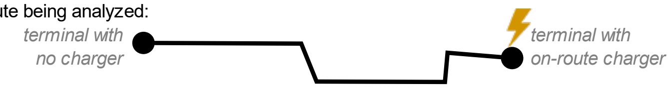
The preceding analysis is based on the UCAT operations, route alignments, and schedules as they existed in winter 2019 – spring 2020. It is typical for transit routes to change and schedule modified regularly in response to changing customer demands or conditions in the field. UCAT is no exception to this reality and in fact UCAT route alignments and schedules have changed since the completion of this analysis. In recognition of this reality a simple spreadsheet tool was developed to allow Ulster County and UCAT to evaluate future route characteristics and available technologies to determine their suitability for electrification.

Figure 5. Summary of what UCAT vehicle blocks would be suitable to electrify under different scenarios using optimistic technology assumptions

Estimating Requirements for On-Route Charging

Developed by Sam Schwartz Consulting for UCAT 10/5/20
This spreadsheet tests the charging requirements of an example bus route with an on-route charger at one end.
This represents a simplified analysis that does not account for factors such as deadhead/pull trips, interlines, etc.

Diagram of route being analyzed:



Yellow cells are inputs
Green cells are results

Predefined Scenarios

Conservative Technology Assumptions *(select one)*

Vehicle Characteristics

3.18	kWh/mi burn rate
388	battery nominal kWh
248	battery adjusted kWh
223	starting state of charge (kWh)
50	minimum reserve state of charge (kWh)

On-Route Charger Characteristics

450	kW Fast charger

Route Characteristics

15	mi one way
30	mi round trip
12	mph *(average operating speed)*
75	min one way
150	min round trip time
20%	recovery time
180	min full cycle time

Requirements to Operate Indefinitely

95	kWh burned per cycle
✓ 1.0	does SOC remain above minimum?
12.7	min charging needed per cycle
17.3	min layover at charger needed per cycle

Requirements to Complete 8 hr Shift

8	hr shift length to evaluate
2.7	cycles per shift
95	kWh burned per cycle
78	extra kWh available
29	extra kWh per cycle
8.8	min charging needed per cycle
12.7	min layover at charger needed per cycle

The spreadsheet tool developed has been provided as an electronic attachment to this report. A static image of the inputs and interface is provided in Figure 4. Cells highlighted in yellow indicate user inputs, and green highlighted cells are output results from the model. The user begins by selecting either "Conservative Technology Assumptions" or "Optimistic Technology Assumptions" as defined in the discussion above. The user can then input various battery characteristics, route characteristics, and whether an on route fast charger is available and at what power. The spreadsheet will then conduct the calculations to determine whether or not the bus State of Charge (SOC) remain above the minimum defined to ensure reliable operation and will report the minimum amount of layover time required to charge the bus at the end of the trip to provide sufficient charge to operate until the next charge opportunity.

3 Infrastructure Improvements Supporting Electrification

The electrical system at UCAT's main Kingston Depot was originally constructed only anticipating transit vehicles would operate using diesel fuel or gasoline. Except those facilities built in the past few years, nearly every transit storage and maintenance facility has an electrical system designed to support traditional bus operations. Electrical systems and supply sufficient to support full electrification of a bus fleet was never anticipated during design or construction.

The existing maximum load drawn by UCAT's main facility, with the existing diesel fleet, is 80KVA according to the utility. The existing utility transformer on site is a 300KVA transformer.

UCAT recently purchased three electric buses and chargers as part of the UCAT Electric Bus Charging Infrastructure Phase I project. With each bus charger drawing the equivalent of 150KVA, this indicates operation of three electric buses at the existing facility will require a larger transformer and an upgraded service into the building.

The Phase I project includes an upgraded electrical service. The utility will upgrade their transformer to support the new service. The electrical upgrades in this project would support the 'garage only charging' scenario illustrated by Table 4.

Looking at Table 4, one can see that adding on route chargers more than triples the number of routes suitable for electrification. Likewise, the number of electric buses needed for those routes would also significantly increase.

It is important to note that once UCAT elects on-route charging, the three chargers now being installed under Phase 1 would not be sufficient to charge the fleet size required to operate under that scenario. UCAT is already looking towards this future with preliminary plans for a larger service that could simultaneously charge ten buses.

3.1 UCAT Facility Improvements

The Electric Bus Charging Infrastructure Phase I project is in progress at the time of this study. It includes capacity improvements to the electrical system as part of the project. For this work the utility (Central Hudson) will upgrade their transformer at the Transit Center to a 750KVA unit. This study assumes this work will be completed, and this upgraded electrical system forms the base case.

UCAT purchased three electric buses and three chargers. Each charger will be equipped with one dispenser, which connects the charger to the bus. This arrangement constitutes the Year 1 scenario of buses and chargers that the electrical infrastructure must support.

A review of UCAT's present route schedules reveals that the chargers do not have to operate simultaneously when recharging the buses. This means charger operation can be managed to minimize electrical demand costs. This management of charger operation plays a key role in the cost of electricity to power the electric buses, as demand costs can become a significant part of the electric utility bill.

In many facilities, staff are as yet unaware how management of electrical loads can significantly reduce operational costs simply because it has not impacted operations to any great extent. With electric bus charging, however, awareness and education will be essential to economical operations.

With proper management of charger operation, UCAT can limit the kilowatt demand to less than 250KW and still operate three chargers. The upgraded service and transformer will, however, have enough capacity to run all three Year 1 chargers at the same time should operations dictate.

In Year 5, UCAT anticipates a total of seven electric buses. Of these, four would be upgraded buses with fast charge capability. UCAT anticipates purchasing two chargers for these buses, and these chargers would come equipped with three dispensers each. Sequential charging operations would allow two chargers to serve six buses.

Another review of UCAT's present route schedules reveals that even with seven electric buses, chargers can still operate sequentially (or one charger at a given time). Basically, a charging plan only needs to exploit the gaps in the route schedules when the buses are not running. These gaps are long enough and frequent enough to allow fully charging buses without interfering with route schedules.

While it will take more careful scheduling to create a charging plan to ensure buses are fully charged to complete their routes, the charge plan would still have significant flexibility to meet the variations that always arise in daily operations. Again, managing the charging plan will have a significant impact on minimizing the overall electric costs associated with bus operation.

It should be noted however, that the present service upgrade and 750KVA transformer would not have capacity to simultaneously operate all five chargers. This is of no concern, though, because with seven electric buses, the present (or similar) route schedule, and the existence of non-electric vehicles in the fleet the need to charge even four electric buses at the same time should never arise.

In turn, this highlights the impact of the charging plan upon the capital costs of implementing electrification of the bus fleet. If UCAT elects that operations dictate the electrical system must support all chargers operating at once, then another electrical upgrade will be needed before Year 5. Alternatively, if UCAT elects to manage charging operations to suit bus routes – which is entirely feasible with relatively few restrictions – then the capital cost of upgrading the electrical system and transformer can be put off or even avoided altogether.

In Year 10, UCAT anticipates operating twenty-four electric vehicles. Under this scenario twenty-one vehicles are fast charge, with the original garage-only charge buses rounding out the fleet. UCAT anticipates servicing these vehicles through seven chargers. Four of the chargers would be compatible with the fast charge buses. Each of these chargers would have three dispensers each, creating a total of twelve charging locations. The remaining three chargers would the original chargers installed in Year 1 under the pilot program.

With the growth in electric buses and chargers, the crucial nature of the charge plan becomes readily apparent. Given the route schedule in ten years' time is similar to the current schedule, the 750KVA transformer and matching electric service would be fully capable of charging the full fleet.

This conclusion is based upon:

- a 'smart' charging plan that manages charger operation, and
- on route charging providing a portion of the energy needs for the electric buses.

In Year 10 it would be possible to fully charge the electric bus fleet with a charge plan that would require simultaneous operation of only two chargers. Unusual or unexpected conditions might require rare operation of three chargers together. Note that even with three chargers and the existing building operating together, the total load comes to no more than 550KVA. This is well within the capacity of the 750KVA transformer upgrade planned as part of the Year 1/pilot program. No capital investment would be needed for the transformer or electric service. The utility would still own the transformer and be responsible for its maintenance.

If, however, UCAT elected to install capacity to operate all chargers and the building at the same time, then the transformer and electrical system must have a capacity of at least 1,150 KVA. This would require capital investment to support this load. Notably, it would also trigger requirements with the utility regarding the type of service and the type of equipment UCAT would be obligate to purchase.

Once a customer's electric load exceeds 900KW (or about 1,100 amps), the utility requires the customer to change to primary metering. This means, in turn, that the customer must purchase equipment to accept service from the utility at a voltage level of 13,200 volts. This equipment includes a 13,200-volt service switch/disconnect and a transformer to convert the utility voltage from 13,200 volts to the 480 volts used in the Transit Center. Ulster County would own this new equipment and would be responsible for its maintenance and repair.

These two scenarios starkly illustrate how the operation of the chargers – not the quantity of chargers alone – drives the capital costs associated with bus electrification. Meshing charging times with route schedules yields both minimal operational costs and minimal capital costs.

UCAT is presently exploring the feasibility of a 2,000KVA, 2,000-amp 480-volt electric service. It is suggested that expanding the electric service to this extent may not be necessary. The costs associated with this expansion could instead be re-purposed into purchasing electric buses and chargers. Re-purposing of these funds would directly further the goals of fleet electrification. To verify this suggestion, it is recommended that some preliminary charge plans be developed using route schedules. In addition, these charge plans should be subjected to sensitivity tests to determine how changes in critical variables force changes in the number of buses that must be charged at the same time.

UCAT anticipates constructing a storage facility at a location separate from the existing bus garage. The scenarios outlined for the existing garage apply equally to the storage location in terms of charger management, electricity costs, and capital costs for electrical equipment to support charging operations.

3.2 On-Route Improvements

To accomplish the route service levels indicated in Tables 8 and 9 indicated by the on route charging scenarios, installing chargers at the main UCAT facility alone will not be sufficient. Remote or stand-alone charging stations will have to be installed at layover locations to recharge the buses, so they have enough power to continue to operate until the next charging opportunity.

The utility will require UCAT to establish each of these charging stations as a new electric service, with its own meter and its own financial account. Given a fast charger is rated at 450KW (or about 550 amps) and the nature of the utility electrical connection required, these accounts will very likely be established as commercial accounts at standard commercial rates for metering, energy delivery, and energy supply.

The remote chargers will have to be located where the utility has the capacity to supply the power the chargers will consume. When the remote chargers are laid out in the community, the utility should be closely involved to ensure that these locations are compatible with their power distribution. In the more remote areas of the county the utility may not have the infrastructure that matches the type and form of power required by the chargers.

3.3 Related Considerations

Presently nearly all the energy for the UCAT fleet is delivered by fuel truck to tanks at the UCAT facility. With the electrification of the fleet, all that energy formerly delivered by truck now must be delivered through electrical lines connected to the facility and to remote stations. It is certain that UCAT closely monitors fuel deliveries and fuel use, not only as a budget item but also as an indicator of fleet maintenance.

Similarly, UCAT must be prepared to devote attention to its increased electrical energy use. Significant savings in electrical costs can be obtained just through conscientious monitoring of energy use, scheduling times of use, and acting promptly to trends indicated by accurate tracking.

This level of effort will require some measure of staff education to obtain a confident understanding of electrical terms, utility tariffs, and electrical energy purchasing. For the quantities of electrical energy UCAT will be purchasing, close monitoring of electric energy use by a competent staff member will result in cost avoidances and savings many times the cost of the training.

With competent training, a staff member will need tools to monitor, and as necessary, control the flow of electrical energy for UCAT's benefit. This would involve using software programs, energy management systems, metering installations, and receiving support from UCAT's Information Technologies group.

Installing electric bus chargers will place the UCAT bus facility service on an hourly pricing rate structure, unless Ulster County strikes a separate agreement with an energy supplier. This means the price for electrical energy could vary by the hour, with 8,760 different prices over the course of a year, one for each hour. Hourly pricing has the disadvantage that the variation in the cost of electricity is not within the customer's control. Hourly pricing has the advantage, though, that prices are almost always low during later evening and overnight hours – precisely the time when a majority of bus charging will occur. This illustrates why monitoring electric use is so very important, because a well-informed customer will manage electrical loads towards hours that have low-electrical prices.

Taking service at primary voltage means UCAT will have to budget for maintenance contracts for the equipment that operates at 13,200 volts. Because this equipment requires specific training and specialized equipment, it is likely most cost effective to purchase these services.

As UCAT converts to electrified operations, consideration must be given how the transit system will maintain operations during a power outage. A permanently installed generator sized to charge all buses would be a costly capital investment, with accordingly significant annual maintenance costs. With a managed charge plan, the size and costs of a permanently installed generator could be meaningfully reduced. Operation plans must be prepared for a county-wide outage, an outage at only the main UCAT facility, outages at remote charging stations, and combinations thereof.

Some consideration should be given for security at the remote charging stations, in consideration for the safety of employees and to prevent vandalism of equipment. Routinely they will only be attended for limited times during the day or week. Any issues UCAT has experienced with their bus shelters could be readily expected to occur with chargers in the same locations.

All the considerations mentioned for electric service to the existing facility become similar considerations in the planning and design of a new facility.

4 Cost and Operational Impacts of Electrification

4.1 Social Cost Impacts

The annual greenhouse gas reductions that would occur can be projected under future fleet electrification scenarios. Using the emissions rates described in the section "Social Costs of Current UCAT Fleet," we found that the average UCAT bus emits 37.4 tonnes of CO_2 and equivalent greenhouse gases (CO_2e) annually. This means that UCAT's total fleet emits about 1,160 tonnes of CO_2e annually. The table below summarizes how these emissions would be reduced with different levels of electric bus deployment in the future.

Table 10. Projected reductions in CO2e emissions under future fleet electrification scenarios

Scenario	Fossil Fuel Buses	CO_2e Emissions Reduced (tonnes)	CO_2e Emissions Reduced (percent)
Year 0 (Existing conditions)	31	0	0%
Year 1 (Garage Charging Only)	28	112	10%
Year 5 (Garage Charging and One On-Route Location)	24	262	23%
Year 10+ (Garage Charging and Four On-Route Locations)	7	898	77%

This shows that even in the first year of electric bus deployment, one-tenth of CO_2e emissions from buses could be eliminated. By 2030 three-quarters most of UCAT's emissions could be eliminated, and with additional changes to schedules full decarbonization could be feasible. This would represent important progress towards state and county climate goals.

4.2 Additional Support Systems and Maintenance Needs

The introduction of new vehicle types and new technologies into the UCAT vehicle fleet will induce new demands for support staff and systems. Longstanding maintenance training programs and institutional knowledge regarding the maintenance and repair of diesel buses must be supplemented with input from external experts and the crafting of new programs and procedures. Additionally, as the performance and effective capacity of bus batteries can vary unpredictably with weather conditions and degrade over the useful life of the vehicles, asset management systems should be upgraded to monitor and report on vehicle performance over time.

New Flyer provides on-site training for maintenance personnel on new vehicles as part of the purchase contact. Broken into 13 different modules, the on-site training program will provide UCAT maintenance staff with the skills necessary to troubleshoot problems, conduct daily and regular maintenance, routine inspections, and performing major repairs on the new vehicles. *New Flyer* estimates the duration of recommended training program modules to total 136 hours.

These training sessions are usually provided by the OEMs while the buses are under warranty. Taking advantage of training offered during this time could provide UCAT with hands-on training at lower risk as any accidental damage may be covered by the manufacturer warranty.

Despite training offered by the manufacturer, there may be a need to hire additional specialty staff or for existing staff to acquire supplemental, ongoing specialized training. High Voltage Mechanics and training for safe operation around high voltage will be necessary to avoid and identify new potential hazards and dangers. This training can extend to include not only those mechanics working directly on the new buses and charging equipment but also those working in the general vicinity of maintenance areas.

5 Implementation Plan and Recommendations

The Ulster County Department of the Environment and Ulster County Area Transit (UCAT), hereafter collectively the County, retained the services of Creighton Manning Engineering, Sam Schwartz Consulting, and Sage Associates (hereafter the Creighton Manning Engineering team) to conduct a feasibility assessment for the implementation of electric buses within the UCAT service area. The previous report developed for this study – *UCAT Bus Fleet Electrification – Existing Conditions & Technical Feasibility* – focused on how to best deploy the three electric buses already procured by the County, and on how best to phase in implementation of electric buses throughout the as much of the entirety of the UCAT service as possible area over 5- and 10-year planning horizons. Using the operational details of UCAT bus service, including spans of service and trip lengths, it was determined that, provided enough electric buses are acquired, most of UCAT's service can be electrified using currently available electric bus and electric bus charging technology.

In consultation with the County, reasonable assumptions for the quantities and types of electric buses to be procured and put into revenue service over the 5- and 10-year planning horizons have been developed and outlined herein. Effective implementation of these new vehicles into revenue service will require charging infrastructure to be installed at the UCAT storage and maintenance facilities as well as the installation of on-route fast-charging stations (and associated infrastructure) at layover locations to provide additional charging opportunities for buses to allow for completion of their entire service day without returning to the UCAT garage. Finally, implementation of electric buses will require changes to UCAT's daily operations to accommodate the charging needs of buses, resulting in additional demands on facility personnel as well as additional utility costs.

This report will present recommendations for the implementation of electric buses within the UCAT service area over the next 10 years. The Creighton Manning Engineering team also developed conceptual designs for on-route charging stations that can be used by UCAT in order to determine effective locations for future installation of fast-charging infrastructure.

5.1 Horizon Planning Year Assumptions

To develop recommendations for implementation of electric buses within the UCAT service area, the Creighton Manning Engineering team proposed a set of assumptions for the number of electric buses in operation and the operating characteristics of the future electric bus fleet and associated infrastructure in 'Year Zero,' 'Year Five', and 'Year 10' horizons. These included the number of electric vehicles assumed to be in service, the quantities and locations of on-route charging equipment, and other operating characteristics assumed to be in place over three different planning horizon years. These assumptions were necessary as UCAT operations, route structures, and schedules have changed and will continue to change between the issuance of this project's final report and the final implementation horizon planning year.

All assumptions were developed to be independent of individual fixed routes and operational schedules which may change significantly over time. As such, the outputs of this study and recommendations contained herein are intended to be used by UCAT and other New York State transit agencies guidance as to how best to deploy available capital, material, and personnel resources upon reaching milestones along the path towards full electric bus fleet implementation.

The set of assumptions utilized for developing the UCAT Plan and recommendations for each of the horizon planning years are as follows:

Horizon Planning Year	Year 0	Year 5	Year 10+
Number of Electric Vehicles	3	7	20 - 25
Battery Capacity	388 kWh (garage only)	388 kWh (garage only) 320 kWh (on-route)	388 kWh (garage only) 320 kWh (on-route)
Effective Travel Distance before Charge	81.9 miles	81.9 miles (new) 62.4 miles (original)	62.4 – 81.9 miles (Garage) Unlimited (On Route)
Number of Dispensers at Garage	3	9	24 12 @ UCAT 12 @ Storage Garage
Buses per Power Cabinet	3	3	3
Garage Charging Locations	UCAT (3 @ 150KW)	UCAT (3 @ 150 KW) New Paltz (1 @ 150 KW)	UCAT (4 @ 150KW) Storage Garage (6 @ 150 KW)
On Route Charging Locations	None	Kingston Plaza (2 @ 450 KW)	4 @ 450KW
Blocks/Veh/Day (Single/Multiple)	Single	Single	Multiple
Fast Charging (>150 kW) Compatible Vehicles	No	3x No 4x Yes	Yes (new buses)
Charge Methodology (Time of Day)	Day or Night	Day or Night	Day or Night
Charge Sequence	Sequential Only	Sequential Only	Simultaneous as Needed

The horizon years and assumptions outlined for each were selected based on a combination of imminent vehicle and equipment procurements, procurement options for additional vehicles and equipment available to Ulster County and UCAT to be executed at their discretion, and the findings of the *Existing Conditions and Technical Feasibility Assessment* submitted recently to the County as part of this study. This previous report found that, as per the Fall 2019 operating characteristics of UCAT service, there are several vehicle blocks (defined as the entire shift of a single vehicle from pull-in to pull-out) that could be electrified in the short- to medium-term using only garage-based charging, and a that a majority of the UCAT service could be electrified in the long-term with future capital investment of additional vehicles, charging locations, and layover-based on-route chargers installed at shared layover hubs within the service area.

These assumptions establish the base upon which the Creighton Manning Engineering team has developed its implementation plan and recommendations support the UCAT bus fleet electrification initiative. These have also been used to determine the equipment and service delivery upgrades necessary at the garage, capital and operating costs, and operational changes needed to support fleet electrification at each phase of the implementation timeline.

5.1.1 Number of Vehicles

The assumption for the number of vehicles in revenue service in the “Year Zero” horizon planning year was set at three to account for the three electric vehicles already procured by UCAT and the County. These will be procured from New Flyer and will include three 35-foot X*celsior CHARGE* model buses. The specifications for these vehicles are included in Appendix A. This first batch of vehicles will be compatible with depot-based 150kW charging technology, and not compatible with 450 kW fast-charging. As per findings of the previous report issued during this study, these vehicles will be suitable for implementation on UCAT bus routes centered around Downtown Kingston and will be capable of serving the full span of service of vehicle blocks on those routes without recharge before returning to the garage at the end of the driver’s shift.

When planning for the subsequent procurement round of electric buses, it is recommended that the County only consider vehicle models that are compatible with 450kW fast-charging technology. This technology will allow for rapid battery charging while in service via infrastructure typically installed at bus layover locations. This rapid charging capability will provide the charge necessary to electrify many UCAT route blocks which would otherwise have too long a span of service to be electrified using garage-charging-compatible vehicles only. The previous report found that with enough fast-charging capable buses, and with fast-chargers installed at four layover locations shared by several routes, it would be possible to electrify the majority of UCAT’s bus routes without substantial operational changes.

An assumption for the Year 5 horizon planning year was set at the procurement of an addition four fast-charging equipped vehicles (bringing the total in-service to seven). The number of vehicles assumed to be procured by the Year 10 horizon planning year was set at up to 25, enough to electrify all routes that were found to be suitable for electrification under the assumption these would be fast-charging compatible vehicles and with fast-charging infrastructure installed at major layover hubs within the UCAT area.

5.1.2 Types of Vehicles, Battery Capacities, and Effective Travel Distances

The first three electric vehicles to be procured by UCAT will be 35-foot New Flyers capable of depot-based 150kW charging only. These will be delivered with advertised battery capacities of 388 kWh. As per the previous report, it is recommended that UCAT consider this battery capacity to equate to an effective range of 81.9 miles per charge when new, decreasing to 62.4 miles per charge as the batteries reach the end of their useful life. These recommended effective ranges are lower than those advertised by the manufacturers, as they account for actual battery performance documented by other transit agencies in the United States in similar weather conditions as Ulster County and provide a factor of safety or charge buffer so UCAT can be confident that the chances of a bus running out of charge in the middle of their service day has been minimized to the extent possible.

Fast charging equipped electric buses available from New Flyer come equipped with battery capacities of 320 kWh. While these vehicles would provide a proportionally lower effective range per charge, the ability to charge in the middle of their service day can extend their effective range to be effectively unlimited assuming schedules are designed around ensuring charging opportunities at layovers and sufficient charging infrastructure is installed.

5.1.3 Number of Dispensers at Garage and Buses per Power Cabinet

The County has indicated that the first procurement round for furnishing electric buses and charging equipment will include the procurement of three ABB HVC-C UL 150 kW depot charging cabinet, each capable of supporting three charge dispensing stations. However, in the initial rollout, each cabinet will support one charge dispensing station. Future expansions of on-site infrastructure will include the addition of six charge stations to provide the maximum number of dispensers (total of nine). The electrical infrastructure upgrades to be completed at the facility would support the future installation of a fourth charging cabinet capable of supporting a further three charge stations for a total of twelve. The specifications of the vehicle charging equipment to be installed at the Kingston facility is included in Appendix B. These cabinets are designed to provide sequential charging to up to three buses. The County has developed preliminary plans for the placement of the cabinet and dispensers within the existing UCAT storage and maintenance facility. Plans are also in place to upgrade on-site transformers and other electric service delivery infrastructure at the facility to accommodate this charger cabinet. This work is preliminarily scheduled for the Spring of 2021.

Planning towards the Year 5 horizon year, it is assumed UCAT will have a total of seven in-service electric buses. As will be demonstrated in this report, it will be possible to charge all seven of these buses using the same single cabinet and three dispenser stations if so desired, never requiring more than one bus to be charged at any time. However, acquisition and installation of a second cabinet and dispenser stations would provide some redundancy for charge equipment and greater flexibility as to when UCAT personnel can charge bus batteries.

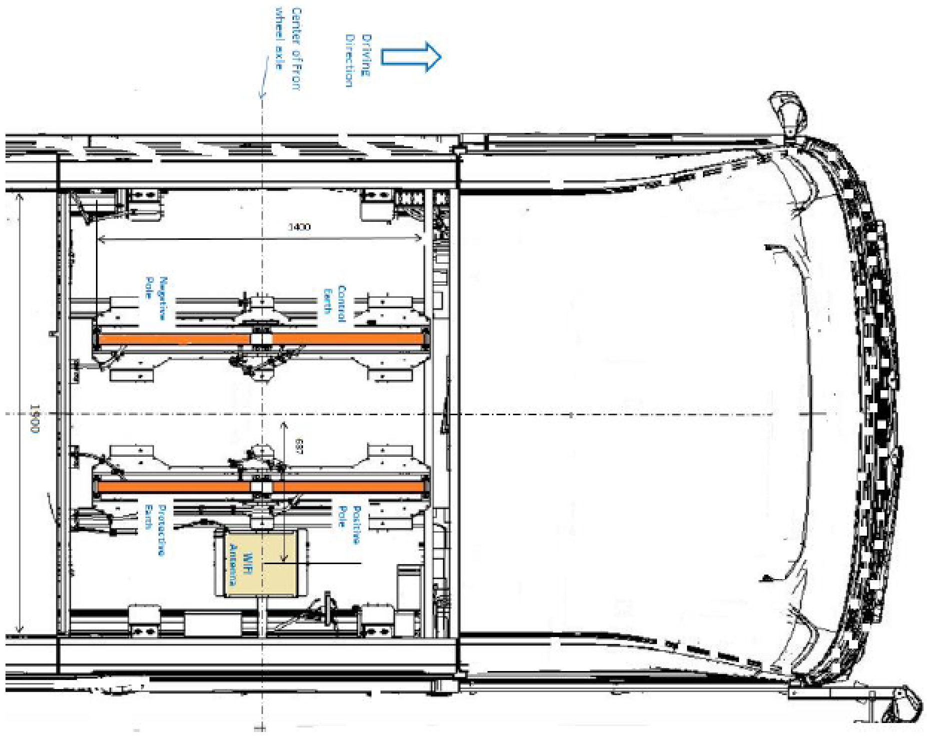
The County is currently in the process of considering alternatives for a new, supplemental bus storage and maintenance facility within Ulster County to accommodate future UCAT growth. It is recommended UCAT consider implementation of electric vehicle charging equipment within the plans for that future facility and accommodate the future charging needs of the full electric fleet.

5.1.4 On-Route Chargers & Locations

To date, the County has not yet selected the specific make and model of on-route charging equipment or vendors to best serve the County needs. This selection would likely be subject to a future review of available technology and a Request for Proposal process. Based on currently available technology, the Creighton Manning Engineering team has identified that 450 kW fast-chargers are necessary to achieve the charging capacity and charging speed to sufficiently charge buses during reasonable layover times and keep buses in service throughout their service day. For the purposes of this report, the Creighton Manning Engineering team assumes the use of the OPPCharge Pantograph charging technology, the specifications of this technology are detailed in a white paper included in Appendix C. The OPPCharge fast-charger technology utilizes a pantograph connection to charge buses via a set of conductive rails on the roof of the vehicles. These are illustrated in Figure 1.

This model and type of fast-charger was selected as it has been installed elsewhere by ABB, the vendor of the depot-based charging equipment to be installed at the existing UCAT facility, as well as by New Flyer, the manufacturer of the buses to be procured in the first round of electric vehicle purchases. This experience of success elsewhere provides a level of confidence that it could be similarly successful for implementation in Ulster County and would be compatible with other equipment purchased for this effort. The technology has been implemented successfully in other cities in the United States, including in New York City, and abroad, including in the United Kingdom and Luxemburg, and it satisfies the planning specifications identified over the course of this study.

Figure 6. OPPCharge Capable Conductive Rails Installed on the Top of Electric Buses[1]



To reduce total capital costs associated with installation of these chargers, it is recommended they be installed at communal layover hubs shared by several routes, all of which can take advantage of the same charging equipment. It was determined in the previous study that installation of fast-chargers at four layover locations could satisfy the charging needs of almost all of the current UCAT bus routes (assuming sufficient vehicles are procured to provide the service). The layover locations which would provide the greatest utility to the greatest number of UCAT bus routes include the following:

- Kingston Plaza
- New Paltz
- Tech City
- Poughkeepsie Transit Hub (outside Ulster County boundaries)

For the Year 5 horizon planning year, it is recommended that installation of two fast chargers at Kingston Plaza is prioritized due to the large number of UCAT routes which use the Kingston Plaza parking lots for layover. Only one fast-charger would be required to support the four fast-charging capable vehicles assumed to be in-service, but two would be needed to support future service levels. Installation of fast chargers at this location would provide UCAT with several options of suitable routes and vehicle blocks

[1] *OPPCharge Common Interface for Automated Charging of Hybrid Electric and Electric Commercial Vehicles – 2nd Edition* – April, 2019

for the deployment of their fast-charging capable vehicles assumed to be acquired. Recommendations for possible locations, site treatments, and cost estimates for the installation of fast chargers at Kingston Plaza are provided in this report.

This study finds that only one fast charger would be required at the other three layover locations based on current service. However, recommendations on the specific locations for installation of chargers at the New Paltz, Tech City, or Poughkeepsie Transit Hub locations has not been included in this report.

6 Facility Infrastructure Needs

UCAT has purchased three 35-foot New Flyer Xcelsior CHARGE buses. Additionally, UCAT has purchased and will install three ABB 150kW High Power Bus Charging cabinet with three dispensers at the Kingston Storage and Maintenance facility. These vehicles and equipment are part of a pilot program in furtherance of a goal for full electrification of the UCAT bus fleet.

In parallel with the purchase of the buses and chargers, UCAT is also upgrading the electric service to the facility. The utility, Central Hudson, will upgrade their transformer upgrade from 300KVA capacity to 750KVA capacity. The transformer will supply new service equipment, consisting of an outdoor switchboard rated 480-volt, 1,600-amp, three phase, 4 wire configuration. The switchboard will re-feed the existing building and supply the three chargers purchased under the pilot program. Capacity and terminations will exist to supply a fourth charger, to connect a future solar array system, and to connect a future generator.

These recommendations assume that the electrical upgrade will be in place for the expansion of the electric bus fleet in the Year 5 and Year 10 horizon planning years. This electrical upgrade will have the capacity to supply the bus electrification plan as outlined through Year 10. This conclusion is based upon the assumption that UCAT will adopt an efficient charge plan and that the four chargers will serve one dispenser/depot box (i.e., charging one bus) at a time.

The 750KVA transformer provided by Central Hudson virtually matches the load imposed by simultaneous operation of four chargers plus the load of the building itself. It appears possible to develop charge plans that will require only two chargers operating simultaneously. This means both the transformer and the switchgear have the spare capacity to provide UCAT with considerable operational flexibility should it be necessary to operate more than two chargers at once.

6.1 Existing Electric Service Delivery and On-Site Equipment

6.1.1 Pilot Program Upgrades

For the purposes of the recommendations contained in this report, it is assumed that the upgraded transformer, switchgear, chargers, and dispensers previously mentioned are installed. Also, it is assumed the spare conduits needed to install a future fourth charger are likewise installed. These have been confirmed by UCAT and County personnel.

To support the installation of the three purchased chargers and the additional future charger, no significant changes appear necessary to the building distribution system. The addition of one electrical panel inside the Bus Storage Area (Room 122) could be considered to support the sixteen 120-volt branch circuit loads for the dispensers.

6.1.2 Standby Power to Recharge Buses During Utility Outages

Presently, the existing electrical system at UCAT's main Kingston facility includes a 500KW/625KVA standby diesel generator. Reports indicate the current load on the generator is less than 50 amps, which is a relatively light load. The full output of the generator is not available to the facility because the generator output breaker is only rated 350 amps.

During discussions for the development of this report, the question of powering an electric bus fleet during a utility power outage arose several times. As part of the discussion, it was discussed what capacity generator would be needed and whether the existing generator could serve that purpose.

Further investigation is required, but it may be possible for the existing generator to support operations during a power outage, especially if UCAT operations are conducted on some form of reduced schedule. The existing generator output breaker and feeder to the building would have to be upgraded. The existing conduit between the generator and the building could be reused. The conduit and feeder would have to be extended from the existing electric room to the transfer switch contained in the new outdoor switchgear. This would require an additional underground conduit run from the building to the switchgear for this feeder extension. However, should this be possible then UCAT would avoid the costs of installing a new generator or avoid the costs of relocating the existing one.

6.2 UCAT Charge Plans

As UCAT transitions to greater numbers of electric buses in service, the energy that was formerly provided by diesel fuel for combustion engine vehicles now must be provided to the electric buses by the utility and through the building electrical distribution system. A charge plan becomes the method by which the:

- time required to charge a bus is integrated into daily operations,
- electric buses in the fleet are placed on the maximum number of suitable vehicle-blocks daily,
- determination is made if existing electric system capacities can meet charging requirements,
- impact of electricity costs related to bus operations is kept to a minimum,
- how a fleet operator integrates a growing number of electric buses into an existing fleet.

A practical observation illustrates, in part, the need for a charge plan. Refueling a diesel bus requires only a few minutes to fill the tank. Recharging an electric bus utilizing the depot-based 150 kW chargers will take from 60 to 75 minutes depending upon the extent of battery depletion. This means operators or facility personnel must build that extra time into a plan or into a schedule to assure buses are ready to depart to meet route schedules and to obtain the full benefits of operating an electric bus fleet.

The follow examples of charge plans are diagrammatic and depict high-level perspectives. Even so they provide examples of how electric buses introduce new factors into fleet operations, how these factors evolve as the electric fleet grows, and how planning enables a fleet operator to address these factors adeptly and efficiently.

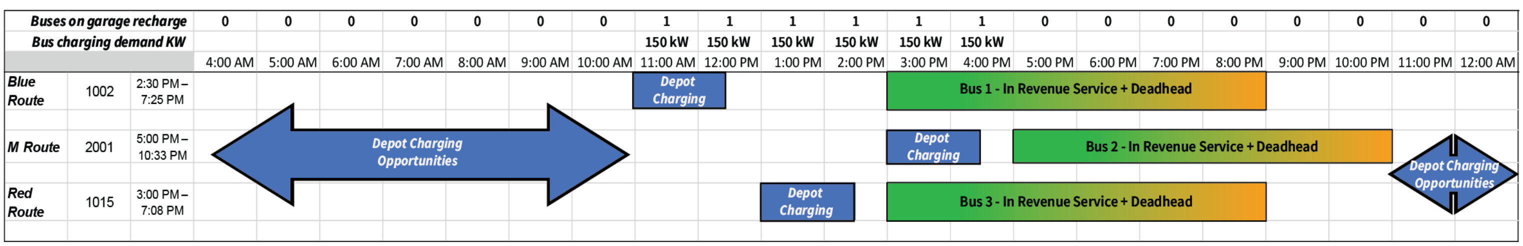
6.2.1 Year Zero Charge Plan

The pilot electrification program includes three buses and three chargers. All charging will be performed at the garage. For the few numbers of vehicles anticipated, developing a charge plan is relatively straightforward as the demands on the facility are relatively light. Such a plan can be used to readily provide examples to illustrate different types of charge plans.

As charge plans are developed in support of future fleet demands, it is noted that it is not necessary for a bus to be charged immediately before leaving on a route or immediately upon returning from a route. Charging times can occur hours before a bus leaves or hours after a bus returns, with the batteries capable of retaining the charge.

Figure 2 illustrates the possibilities for charge methodology for the planned electric bus implementation upon receipt of the first three electric buses. The span of service plus deadhead time for the routes selected are represented by the green-to-orange gradient bars. Recharge times have been selected for these routes during the midday period, when the facility would be most well-staffed. As shown, these buses can be fully charged during normal business hours, and no two busses would need to be charged simultaneously, which could affect the rate charged by the utility. This example could be referred to as a 'sequential' charge plan.

Figure 7. Sequential Charge Plan for Year Zero Horizon Planning Year



As indicated by the blue, double-headed arrows, UCAT's fleet manager and facility staff will have the flexibility to charge these buses at any point before or after their service days. This will provide UCAT with considerable flexibility for scheduling charge times as they are most convenient and ensure that no two buses need to charge simultaneously.

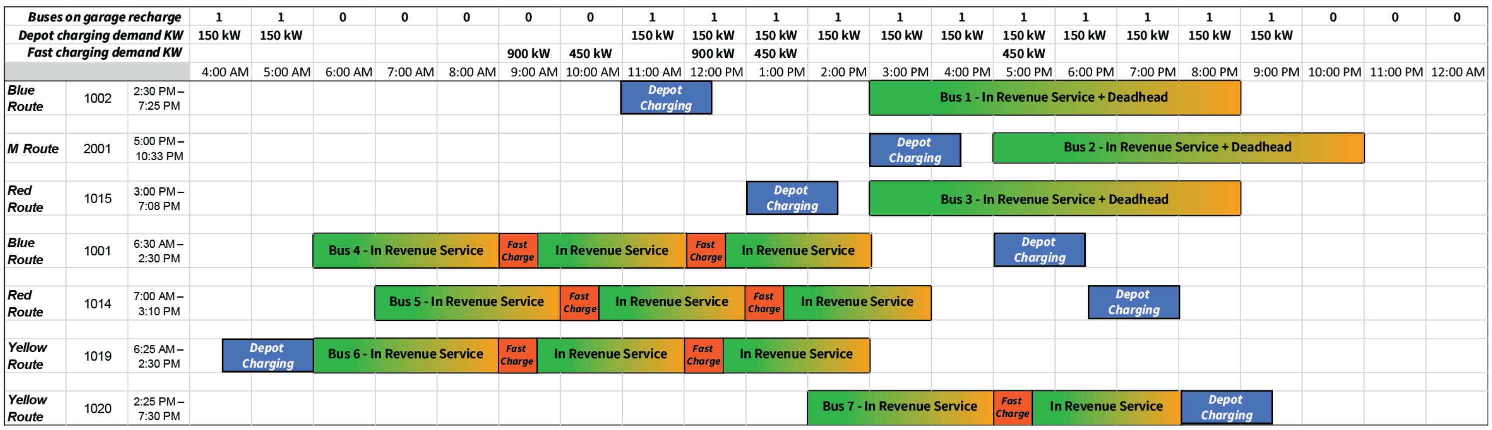
Alternatively, the fleet manager could decide to charge all buses at the same time, or a 'simultaneous' charge plan. This would provide facility personnel with a more convenient schedule but would result in additional simultaneous power demands on the facility, possibly resulting in additional demand charges from the facility. These demand charges could have significant cost implications to fleet operations, as well be discussed later in this report.

6.2.2 Five Year Horizon Planning Year Charge Plans

In the Year Five horizon planning year it is assumed UCAT will purchase an additional four, fast-charging compatible electric buses to further expand the electric bus fleet from the original three. The original three buses will continue to be charged at the garage only. The additional fast charging equipped buses will charge both at the garage as well as during specific layovers during their service day. The times at which the buses will need to charge on-route will be largely dictated by their state-of-charge at the end of each trip and their daily operating schedule. However, even with seven buses in need of daily charging at the existing UCAT facility, the agency and facility staff will still be afforded a high degree of flexibility.

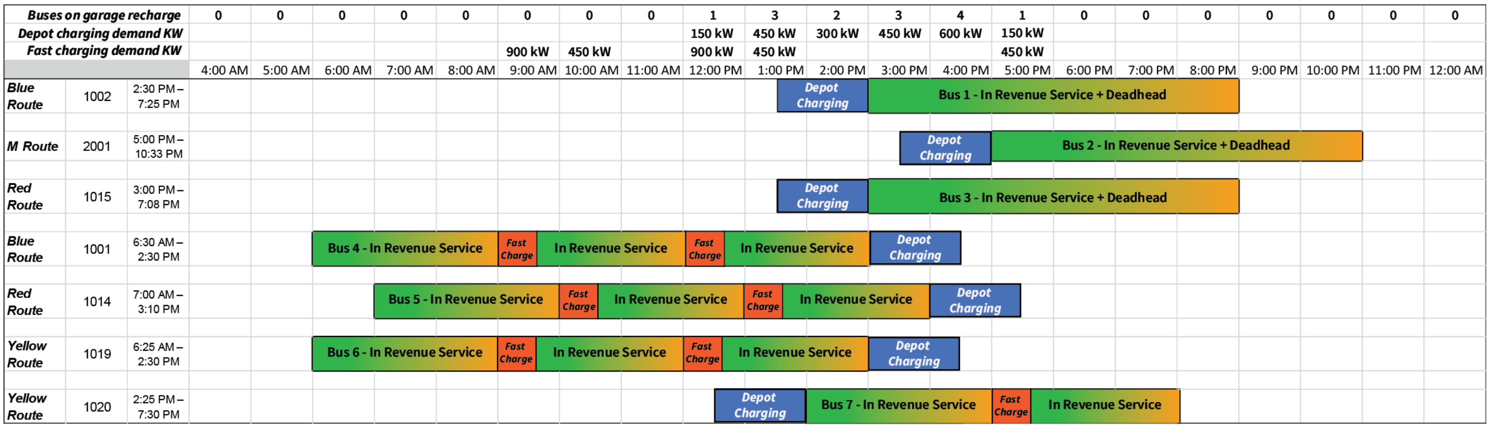
With the expanded electric bus fleet, it will likely be possible to devise a sequential charge plan for garage charging during which no two buses will need to charge at the same time. Further, as shown, this sequential charge plan can be accomplished utilizing only a single charge cabinet with the three charge dispensers currently planning for implementation and the existing facility. An example of a possible charge plan arrangement to accomplish this is illustrated in Figure 3.

Figure 8. Potential Sequential Charge Plan to Accommodate the Year 5 Horizon Planning Year Scenario



As with the Year Zero charge plan, it is also possible to arrange the charge plan for greater convenience for the facility staff. Figure 3 illustrates a possible charge scenario in which a fleet manager could elect to perform all bus charging at the garage during first shift operations, either immediately before a bus departs or immediately after a bus returns to the garage. While this is more than feasible from a capacity perspective, it could require up to four buses to be charging simultaneously. This would require a second charge cabinet to be installed with an additional three charge dispenser stations at the facility and could result in significant surcharges to utility expenditures. An example of a possible simultaneous charge plan is illustrated in Figure 4.

Figure 9. Potential Simultaneous Charge Plan to Accommodate the Year 5 Horizon Planning Year Scenario



The fast-charging intervals to occur at the Kingston Plaza layover area are illustrated as red boxes within the charge plan of Buses 4, 5, and 6. In the figures above, these are represented by blocks of approximately 25 minutes in demonstration. However, actual charge times for these buses at these locations could vary between five and 35 minutes, depending on usage, weather conditions, battery age, and other factors.

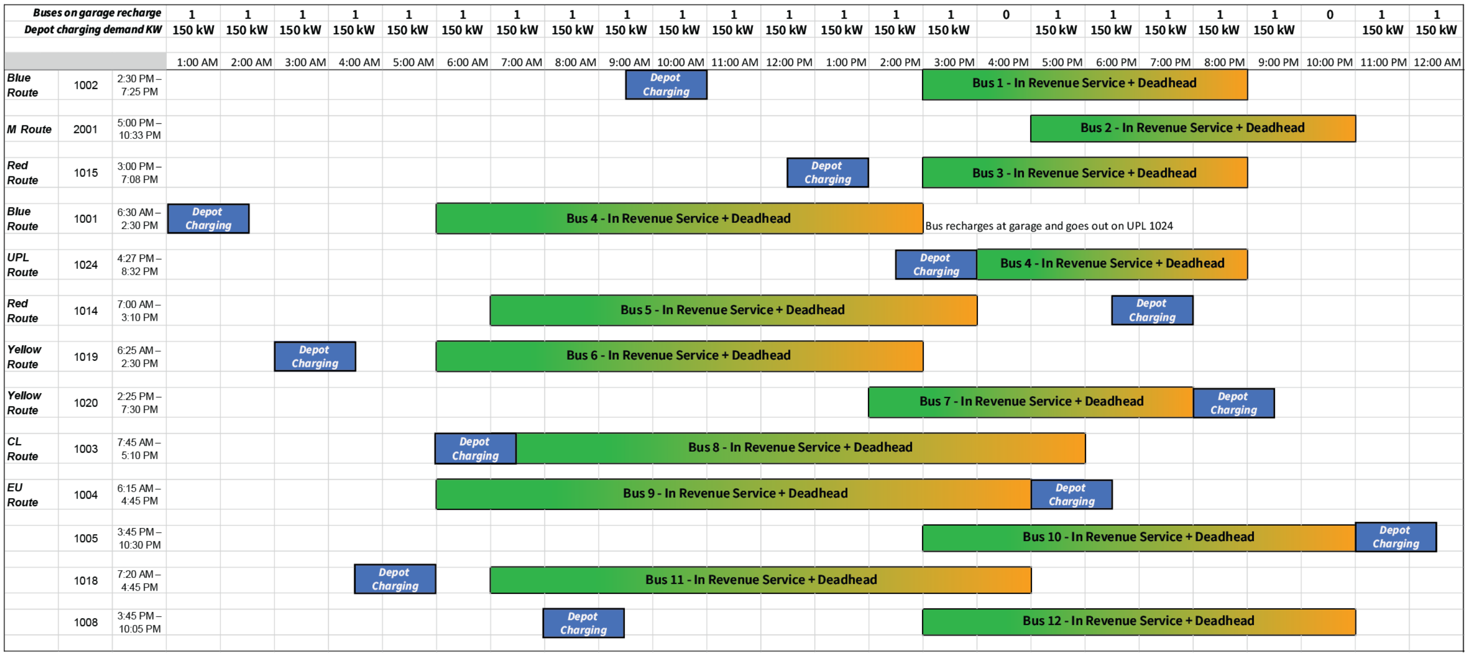
It should be noted that these fast-charge times as shown in the figures above are only conceptual and illustrative. As noted earlier, actual charge intervals within the buses' service days will be dictated by actual schedules upon implementation and the state of charge of the buses. Clearly, bus operators will have less flexibility as to when and where on-route charging can occur. Schedules will need to be developed to ensure on-route charging infrastructure is not overwhelmed by simultaneously occurring charge demands of several buses. Schedule planners should also plan on including some buffer time on top of the typical recovery time to accommodate for road delays or other factors when considering operational changes for these new demands.

6.2.3 Ten Year Horizon Planning Year Charge Plans

In Year 10 it is assumed UCAT will have approximately 24 electric buses in service, which will permit electrification of almost the entirety of the service. UCAT is currently in the process of identifying, planning, and constructing a second bus facility within Ulster County to accommodate operational needs and growing service. It can be assumed that this new facility will be operational before the ten-year horizon planning year.

For the purposes of this study, it is difficult to predict how many electric buses will be stored, charged, and maintain at either of the two facilities. Further, it is likely that UCAT's bus routes, spans of service, and route schedules will change significantly in the coming 10 years. As such, it may not be useful to develop a charge plan for the planned 24 bus condition. However, it should be noted that even with 12 electric buses operating out of a single UCAT facility, it is hypothetically possible to develop a charge plan in which no two buses would ever need to charge simultaneously, as illustrated in Figure 4.

Figure 10. Hypothetical Charge Plan for Sequential Charging of 12 Buses at a Single Facility



This hypothetical exercise should provide a level of confidence that the future demands of electric bus charging on UCAT facilities will are manageable, even with the additional of a larger electric fleet. If UCAT operates and staffs a 24-hour facility, it is more than reasonable to assume that the amount of electric charging cabinets and charge dispenser stations can be minimized. It should be noted that an on-route charge plan developed for operations in the Year Ten horizon planning year is, by necessity, a highly conceptual effort. This plan assumed modest technical developments in battery kilowatt-hour/kilogram density. This led to the assumption that longer vehicle blocks would require two charges via on-route charges installed at layover locations and shorter routes only one.

It is expected that battery improvements will surpass these conservative assumptions over the next the years. These assumptions, though, were helpful in establishing boundary conditions for developing an example charge plan. Depending on the assignment of electric buses between the two UCAT facilities in the future, installing a second charge cabinet, providing a total of six charging stations, can provide both the charge capacity and redundancy to satisfy the charge needs of an electric bus fleet large enough to serve the needs of Ulster County.

6.3 Impact of Charge Plan on Facility Needs

The traditional view holds that as the number of electrified buses in a fleet grows the capacity of the electrical system must follow. This is likely true in a fair number of situations. A well-managed charge plan allows a fleet operator to depart from the traditional view and avoid significant capital cost – yet maintain full operations.

6.3.1 Efficient Charge Plans Conserve Capital

The benefit of a well-managed charge plan can be seen by a comparison of Figure 2 and Figure 5. This comparison is summarized by the table below:

Scenario	# of Buses	Graphic	Total Electrical Load
Year 0	3	Figure 2	Existing Building Load + One Bus Charger
Year 10	12	Figure 5	Existing Building Load + One Bus Charger

The number of electric buses charged at the garage increased by a factor of four, yet it is possible that the total electrical load can remain constant depending on the charge plan methodology adopted. This comparison clearly conveys the benefits of an efficient charge plan. The fleet expansion does not necessarily trigger any capital improvements or costs.

If the fleet operators adopt a plan of charging all buses immediately before starting their routes in the Year 10 horizon planning year scenario, additional charging equipment will be required. For the current UCAT facility, such an operation would exceed the capacity of the utility transformer and an additional two charge cabinets will need to be purchased and installed. Additionally, it is likely that further site work would be required, such as installing a trench across the parking lot from the outdoor switchgear to the building to connect the two new charge cabinets.

6.4 Costs of Bus Charging

When a bus fleet transitions from diesel combustion engines to battery-based operations, the ‘fuel’ to operate the bus fleet also transitions to the electricity drawn from the utility. This introduces complexities into bus fleet operations because the sale of electricity (the ‘fuel’) is subject to terms and conditions set by the utility and the Public Service Commission.

These terms and conditions for electricity purchase are known as rate structures or tariffs. While a fleet operator may be able to competitively bid or negotiate diesel fuel costs with suppliers, the terms of a utility rate structure are non-negotiable. This presents an advantage that the ‘fuel’ costs are public, fixed, and well established, which in turn simplifies budgeting and planning. This presents a disadvantage by virtually eliminating any flexibility in the terms and conditions under which fleet ‘fuel’ is purchased.

Fortunately, these rate structures – despite their rigidity – often provide a means for a fleet operator to control costs particularly for fleet operators who plan well and monitor electrical usage closely.

6.4.1 Components of Electric Utility Bills

A commercial electric utility bill is composed of six main components:

- Cost of energy, in dollars per kilowatt-hour (commodity cost)
- Cost to ship the electricity over the utility’s power lines, in dollars per kilowatt-hour (delivery cost)
- Demand cost, in dollars per kilowatt; measured as the peak reading during the month.
- Monthly charges, in dollars (example: customer service charge)
- Adjustments - typically based upon the kilowatt hours consumed.

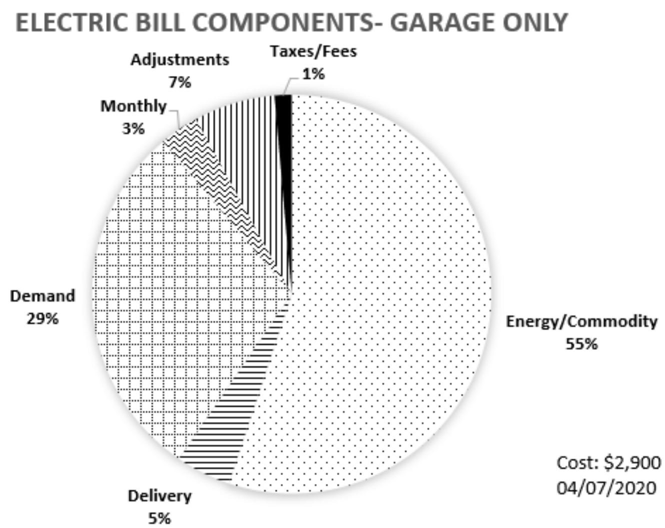
- Taxes and fees.

When operating a bus fleet with diesel fuel, the costs are sensitive only to the quantities used. In other words, the more gallons used the higher the costs. There are no additional costs if a large quantity of diesel fuel is used on a particular hour or even a particular day.

When operating a bus fleet with electric vehicles, the costs are sensitive to both the quantity of electricity used and also to how it is used. The sensitivity related to 'how' is triggered by the rate structure under which the power is purchased. This will be illustrated via the following example scenarios:

For the existing UCAT facility, the six cost components of the utility bill allocate as follows using the April 7, 2020 electricity bill for the source data:

Figure 11. Existing Allocation and Costs of Power Delivery to the Primary UCAT Facility



This bill shows the operation of the garage without any electric vehicles.

6.4.2 Effects of Adding Electrical Vehicle Charging, Performed Efficiently

When adding electric vehicles to the bus fleet, the cost of that energy naturally is reflected in the utility bill. The additional electricity is reflected in the bill by – as noted – the amount that was consumed and how it was consumed.

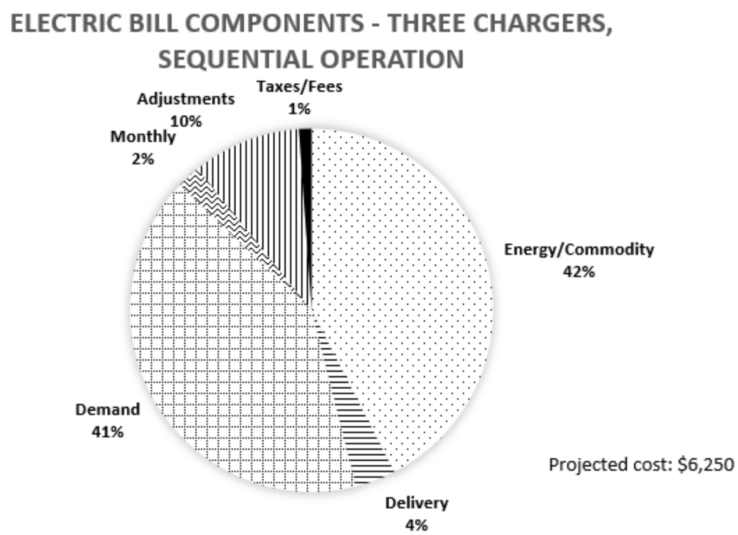
Electric vehicles when charging appear as significant 'blocks' of electric load to the utility. When a vehicle or bus is connected to a charger, today's chargers apply their full capacity to charging the battery. Once the battery approaches full charge only then does the charger begin to taper off. This operation causes the electricity drawn from the utility to rise immediately in a step fashion; there is no ramping up or gradual increase in electrical load.

In this next example, the costs of three electric buses were added to the garage utility bill above. These costs were based upon the energy an electric bus requires to navigate its route, how long it takes to charge a bus, and how many chargers operated at one time.

It was assumed for this case that UCAT created (as we would expect) an efficient charge plan so that only one charger operated at any one time. All three buses still received a full charge to be ready for the next day's run. Limiting charging to one charger at a time placed no restrictions at all on UCAT's route schedules or bus operations.

With this approach, the components of the electric bill allocate as follows:

Figure 12. Anticipated Allocation and Costs of Power Delivery to UCAT Facility upon Implementation of Three Electric Bus Chargers utilizing Sequential Charge Operation



Note the increase in the total cost, but also the increase in the portion of the bill that relates to demand.

The increase in the demand portion is driven by the 'block' load that the utility measures when a charger operates. Once the utility measures that block load, it refers back to the rate structure for the calculation to include that block load. That calculation results in the demand costs becoming a larger portion of the bill. The same rate structure and unit costs in the first garage-only example were used to calculate the projected costs and allocations for this example.

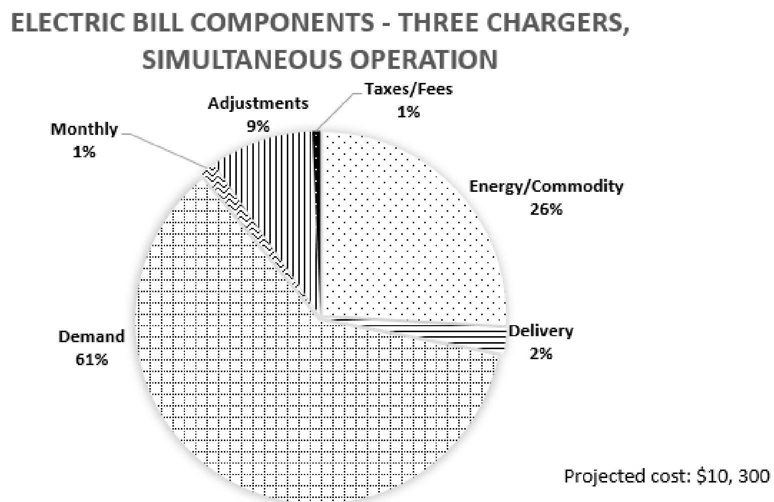
6.4.3 Effects of Adding Electrical Vehicle Charging, Performed Without a Charge Plan

The next chart demonstrates how a fleet operator affects operating costs by choice alone. In this example the number of electric buses is the same – three. However, the fleet operator has no charge plan and decides to charge all three buses at the same time, even though it is not necessary to do so.

This case exemplifies it is not only how many electric vehicles are in the fleet, but that the choices in designing a charge plan directly affect operating costs. In this case and in the previous case, exactly the same result occurs: three fully charged buses ready for the next day's routes. The major difference is the choice the fleet operator made in how to charge the buses.

In this third approach, the components of the electric bill allocate as follows:

Figure 13. Anticipated Allocation and Costs of Power Delivery to UCAT Facility upon Implementation of Three Electric Bus Chargers utilizing Simultaneous Charge Operation



Note the increase in the demand portion of the bill, but also note the significant increase in the total cost. These changes are solely driven by the fleet operator's choice to run all the chargers at the same time. The extra cost provides no advantage or value to the fleet's operations.

Again, the increase in the demand portion is driven by the 'block' load that the utility measures when a charger operates. In this example however, the utility measures not one block but instead measures three charger blocks. As before, the utility references the rate structure to calculate the bill with the above results. The same rate structure and unit costs in the first garage-only example were used to calculate the projected costs and allocations for this example.

The fleet operator's lack of a charge plan cost the organization approximately $4,000. This cost could have been avoided had they employed an efficient charge plan as was shown in the second example.

These examples demonstrate that while the tariffs and rate structures are rigidly defined, a fleet operator can minimize operating costs simply by designing and implementing an efficient charge plan.

6.4.4 Expanding the Electric Vehicle Fleet with an Efficient Charge Plan

As the number of electric vehicles in a fleet grows, it is a necessary consequence that increased costs will reflect accordingly in the utility electric bill. The concepts demonstrated in the three examples above still apply and become even more important as the fleet expands:

- an efficient charge plan, closely monitored, will minimize costs as the fleet grows, and
- the lack of a charge plan or a poorly designed plan results in unnecessary costs that provide no value to the operating organization.

6.4.5 Charger Networking, Control, and Management

To execute an efficient charge plan – particularly with a larger fleet – it will be necessary to communicate, control, and manage the chargers. Typically, such control of equipment permanently attached to the building is done through an energy management system (EMS) or building management system (BMS). These systems also follow generic or common communications standards which make them compatible with many pieces of equipment.

A modest control system is incorporated into the chargers through the dispensers. The charger when connected to three dispensers will sequence through the dispensers, one at a time. This allows a fleet operator to plug in three buses at the end of a workday, and effectively walk away knowing all three buses will be charged by the following morning. However, this modest control system does not permit an efficient charging plan where more than one charger is used.

The chargers purchased as part of the pilot program list a network connection as "GSM/3G modem | 10/100 base-T Ethernet". Manufacturers typically provide limited and basic information through this connection as part of the charger purchase. To gain access to full information regarding charger operation and statistics, manufacturers usually require a subscription service to a web or cloud site where the data resides. The subscription service may be required by the manufacturer as part of a warranty or service agreement. Again, the amount of control the manufacturer allows to the user through this interface will vary between specific manufacturers.

In the least sophisticated and least expensive case, the existing building management system could provide a simple contact to the charger. The contact would serve as an 'enable' signal to the charger. This would allow the owner to schedule charger operations like the basic 'timer' function available in any building management system. The connection would have to be coordinated with the charger manufacturer to determine how to interface the contact to provide the control signal to the charger's control inputs.

More advanced controls may be available through programming the charger itself or though the manufacturer's web access portal. Either of these approaches are more sophisticated than the simple contact approach. Programming the charger will require staff member training, documentation of how the chargers are programmed, and a tracking mechanism to ensure chargers are programmed properly. Managing through the manufacturer's portal will require monthly or annual subscriptions to maintain the needed access to the chargers.

6.4.6 Anticipating Electric Rate Structure Changes as the Electric Vehicle Fleet Expands

Electric rates structures define limits and characteristics for each tariff or rate structure. The utility examines the quantity of electricity used by a customer and the patterns of that use, and then determines which rate structure applies. This determination is important, because the rate structure terms control how a customer is billed and the various unit costs that make up the bill.

Utilities monitor customers' bills to ensure the proper rate structure is applied to those bills. Significant changes in a customer's electric use can activate a rate change for the customer. Rate changes do not always result in a favorable change to less expensive power. Bus chargers are a large enough load that customers should be aware of potential rate changes and impacts on their electrical costs.

The examples given for charge plans show a well-managed plan reduces and controls costs. Such a plan will also minimize the possibilities that bus chargers will force an unfavorable shift to a more expensive rate structure.

Should UCAT's electric use expand beyond the terms of their present rate structure, that would initiate a required electric service upgrade. UCAT would have to take service at medium voltage levels, purchase a medium voltage switch, and purchase a transformer to accept service at that level.

Fortunately, the installation of the three chargers included in the pilot program will not cause a rate change especially when operated under an efficient charge plan. Should UCAT install a total of five bus chargers care should be taken to operate under a conservative charge plan that limits the simultaneous operation to no more than four chargers.

Utilities are developing rate structures explicitly for customers with electric vehicles and chargers. Most of this activity is now on the residential level but commercial rates structures for vehicle charging are emerging. As utilities advance their vehicle charging rate submissions to the Public Service Commission, the best result would be obtained where large users of electric vehicles can collaborate with the utility in the rate development.

Any new rate structures should focus on the unique aspects of charging electric vehicles. In this fashion, the need for a new and distinct rate structure can be justified to the Public Service Commission.

For example, a reliable and repeatable load pattern is preferred by utilities over a sporadic and chaotic load pattern - especially for a larger load presented by several vehicle chargers connected through a single meter. An electric vehicle fleet operator, of course, runs its vehicles on a predictable schedule, which in turn means the electrical load to recharge the vehicles will be reasonably repeatable and predictable as well. The rate structure design also may include a requirement that the fleet operator has the chargers connected through a limiting control system in exchange for a unique pricing structure that reduces fleet operating costs.

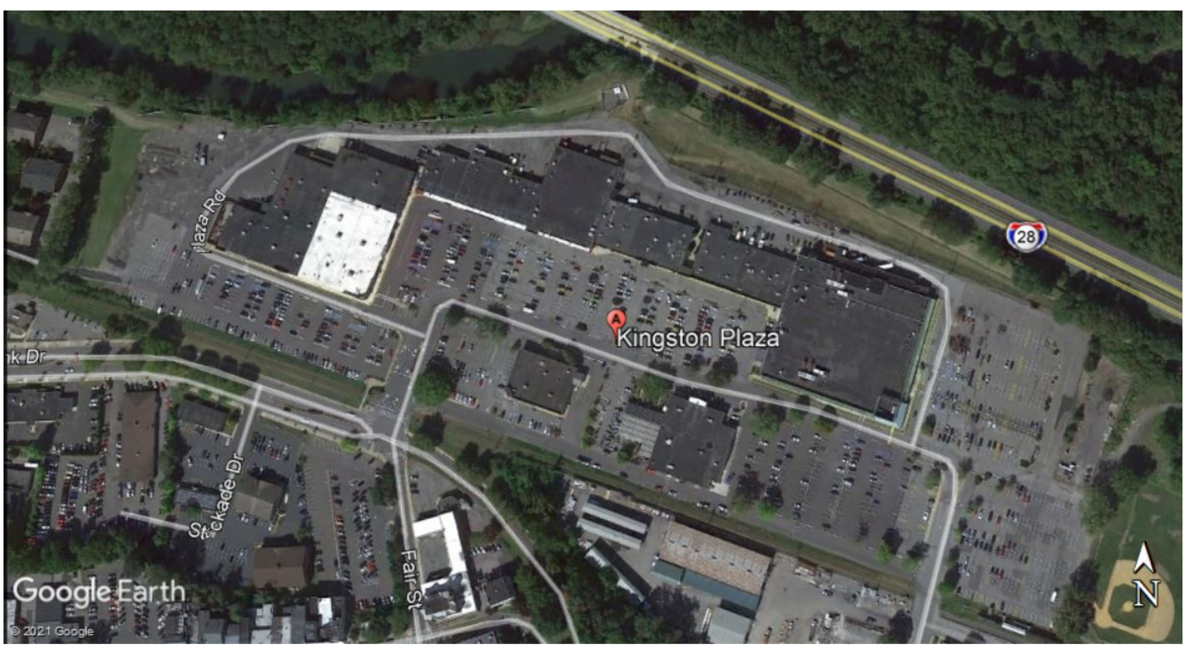
7 Conceptual Design for On-Route Charging Locations

Installation of fast chargers and purchase of an additional four fast-charging compatible buses in the year five horizon planning year will allow UCAT to electrify several vehicle blocks. These blocks will need to be supplemented by the installation of fast chargers at the Kingston Plaza layover area. The Creighton Manning Engineering team developed several potential concept design alternatives for the arrangement and installation of fast charging stations at the Kingston Plaza layover. The alternatives include both those with and without accommodations for passenger loading and unloading activities at the charging location as well as bus stop passenger amenities. Designs that included pedestrian activity at the charging location are compliant with current Americans with Disabilities Act (ADA) requirements for transit stops. These are presented as concepts for future consideration by UCAT and the County as potential arrangements and charging locations at Kingston Plaza. While comparative advantages of disadvantages for each design have been considered from the perspective of UCAT bus operations, negotiations and site agreements with the Kingston Plaza property owners have not been conducted to date.

7.1 Site Selection and Overall Layout

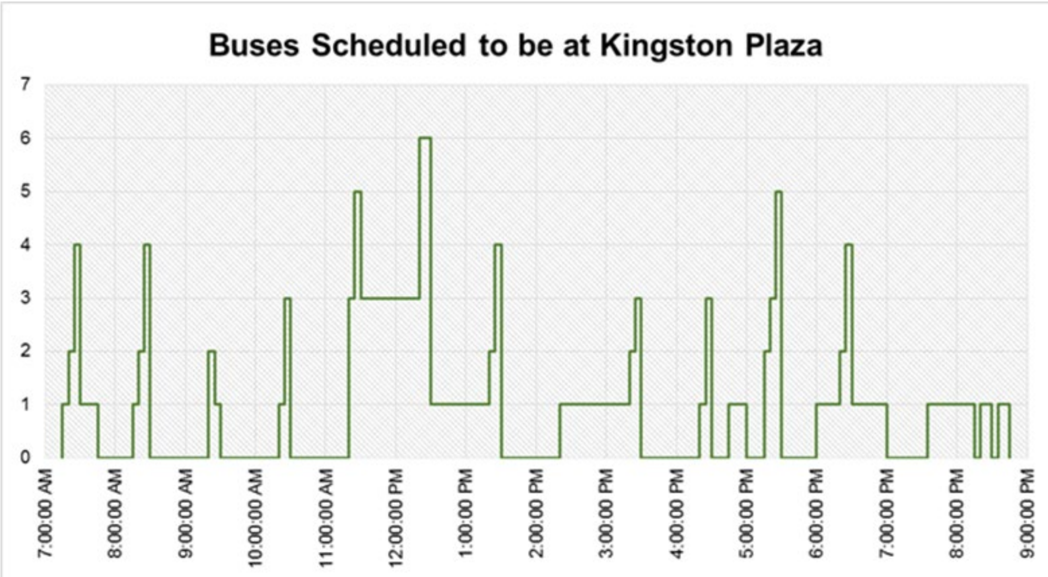
The Kingston Plaza lot location was selected for the placement of the initial fast charging stations as it serves as the terminal stop and layover area for several existing UCAT bus stops. The existing terminal pick-up and drop-off location is located on the east side of the plaza, in front of Hannaford Supermarket and Advanced Auto Parts. The overall site layout of Kingston Plaza is shown in Figure 14.

Figure 14. Existing Aerial View of Kingston Plaza, Ulster County, NY



The existing bus stop has high daily ridership volumes and the surrounding parking lots are used as a layover location by several existing bus routes. The concept design figures were produced with the assumption of maximum number of 6 buses could be using the charging stations or queued to charge upon electrification of the full UCAT fleet. The results of the accumulation analysis of existing UCAT operations at Kingston Plaza is illustrated in Figure 15.

Figure 15. Existing UCAT Bus Layover Weekday Vehicle Accumulation at Kingston Plaza



Securing lease agreements, easements, or other forms of contracts with the property owner at this stage to accommodate the future charging needs of UCAT will facilitate the phased implementation of electric bus service over the coming decade. The sites within Kingston Plaza that were considered for installation of fast charging equipment are also in relatively close proximity to overhead power infrastructure which appears to be sufficient to accommodate power demands of the charging equipment. The close proximity of overhead power infrastructure will reduce the ultimate capital costs of construction and increase the efficiency of power delivery.

7.2 Overhead Pantograph Bus Charging Infrastructure

The OPPCharge pantograph fast-charging technology and associated vehicle interface for the charging of the commercial electric vehicles were selected as the basis of the station design which would partially or fully charge UCAT electric buses in short periods of time (up to approximately 15 minutes per bus)[2,3]. The interface is compliant with ISO/IEC 15118 requirements which is the international standards of digital

[2] Mobile Source Group (2020), "Technical Guidelines for Electric Public Light Buses (Fast Charging Type) and the Associated Charging Facilities" Retrieved from: https://www.epd.gov.hk/epd/sites/default/files/epd/english/environmentinhk/air/guide_ref/files/Technical_Guidelines_for_e-PLB_and_Charging_Facilities_October_2020.pdf

[3] OppCharge (2019), Common Interface For Automated Charging of Hybrid Electric Commercial Vehicles" Retrieved from: https://www.oppcharge.org/dok/OPPCharge%20Specification%202nd%20edition%2020190421.pdf

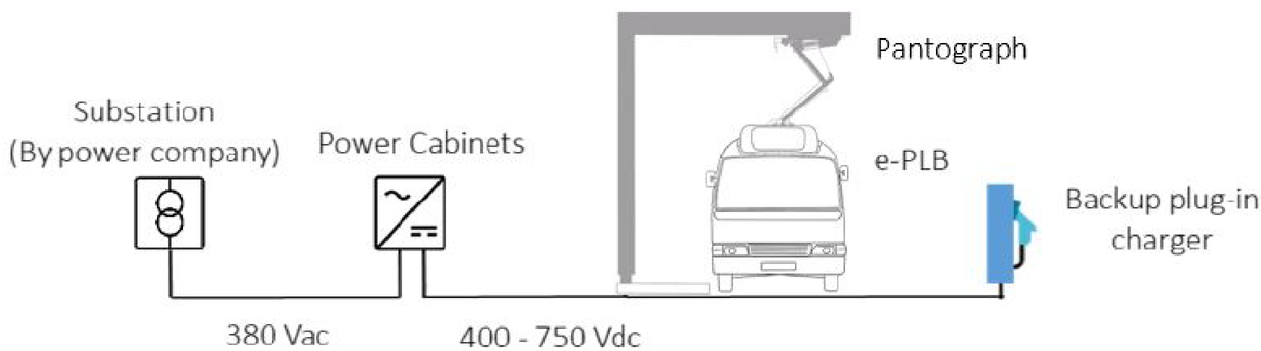
communication protocol that charging stations should follow to recharge electric vehicle high-voltage batteries.

The OPPcharge system requires the following components to operate:

- DC Electric Vehicle Conductive Charging System: Conductive rails/poles fixed on vehicle roof.
- Automatic Connecting System (ACS): Pole mounted connection device called pantograph charger.
- Optional Plug-in Quick Charger

The relationship between these components is illustrated in Figure 16.

Figure 16. OPPCharge Pantograph Fast-Charging Equipment Schematic1

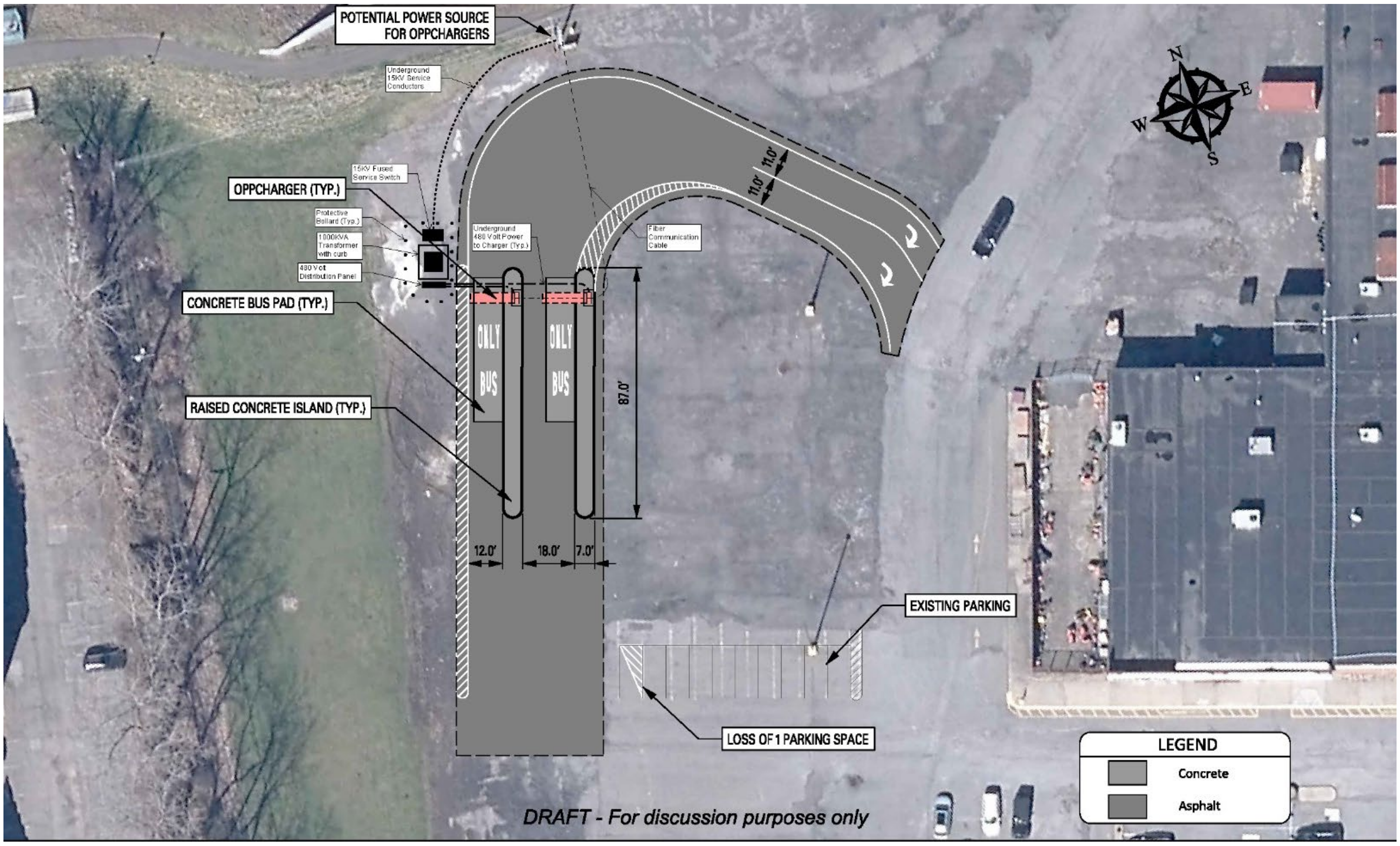


Creighton Manning Engineering developed conceptual design alternatives for the fast charging stations to accommodate the anticipated electrification of UCAT bus operations. The full concept design figures and estimates are attached to the end of this report. A preliminary construction cost estimate for concept design alternatives are included in the appendices of this report. Conceptual construction cost estimates include site and electrical work for each alternative, but not the cost of the pantograph chargers themselves.

7.3 Concept 1 West

The northwest corner of Kingston Plaza was selected for this alternative as the area seems to be less utilized, less frequented by mall customers, and of lower demand for surface parking by patrons as compared to the remainder of the lot. This alternative includes the proposed fast-charging stations to be placed at the existing gravel area currently with little to no designated parking within its limits. Two fast-charging stations would be arranged parallel to each other and aligned north-south along the western edge of the property. This would allow for two buses to charge simultaneously, and an additional four buses (two in each lane) to queue. The conceptual layout for this arrangement is shown in Figure 17 and included in the appendices of this report.

Figure 17. Kingston Plaza Fast Charger Implementation – Concept 1 West



In this concept alternative, buses would unload passengers at the existing terminal bus stop, navigate through the Kingston Plaza parking lot, approach the chargers from the south, and exit along the north to either complete their layover activity or return to the terminal pick-up stop to begin their subsequent trip. The location of the OPPCharge pantographs are shown in red in the figure above. Power delivery would occur from the existing overhead power lines which run along the northern property line of Kingston Plaza, approximately 90 feet to the north of the proposed charge infrastructure.

The site work involved in this concept design alternative would include construction of raised concrete islands, concrete pavement for bus drive lanes, full depth pavement reconstruction and striping in addition to the electrical work associated with the OppCharge equipment installation. Each of the two combinations of raised curb, concrete bus islands, and pantograph charge equipment would be identical to each other. The tangent section of raised islands would be 80 feet long; therefore, this alternative could facilitate up to four 40-foot long buses in the charging station area at a time due to space limitations and bus turn movements into the facility.

It is assumed that this alternative would have the least impact on the existing parking lot operations and surface parking supply of the shopping center. However, it is likely least convenient for bus operations. No bus passenger activity is envisioned to occur in this alternative and vehicles would need to navigate between the terminal bus stop and charge stations.

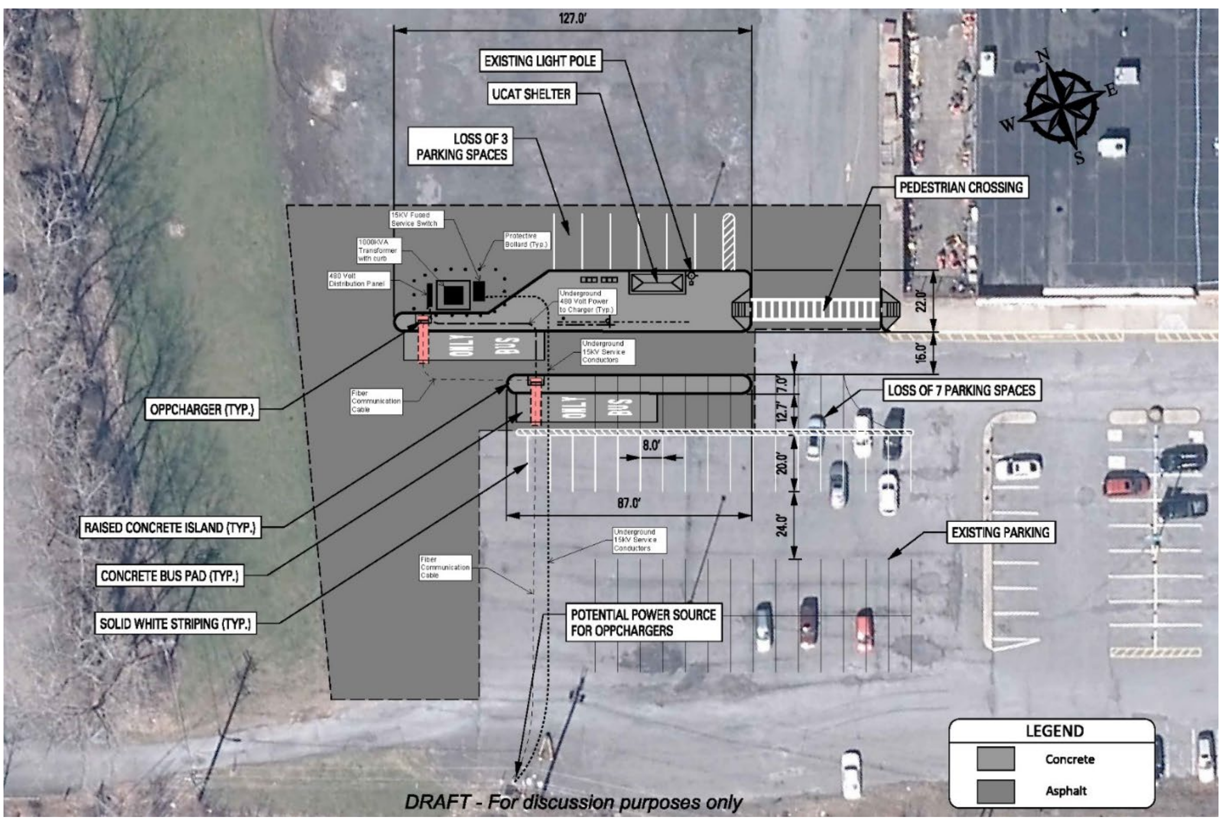
7.4 Concept 2 West

Concept 2 West is located towards the southwest corner of Kingston Plaza, just south of the area envisioned for use in Concept Alternative 1. This concept design was developed to incorporate passenger activity and amenities with the bus charging operations. Concept 2 West is shown in Figure 18.

In this concept the terminal bus stop activity would be relocated to the concrete islands shared with overhead charging infrastructure. Two raised curb islands would be placed parallel to each other and aligned east to west. Wider raised concrete island would provide the potential to accommodate a bus route sign, a bus shelter, and other bus stop passenger amenities such as benches, bike racks, lighting, trash cans, and others. Painted crosswalks and ADA-complaint curb ramps could be provided to provide designated pedestrian crossings between the passenger areas and the shopping areas. Buses would take Plaza Road, continue on to the parking isle into the charging stations. Vehicular circulation through the charging stations would be one-way and counterclockwise. Buses would utilize the existing parking isles to get back on Plaza Road to exit Kingston Plaza after being charged.

This concept alternative is also located in a relatively less-used portion of the Kingston Plaza parking lot. It has been arranged to reduce impacts to existing surface parking supply and so as to not impeded vehicular circulation and access by patrons and delivery vehicles.

Figure 18. Kingston Plaza Fast Charger Implementation – Concept 2 West

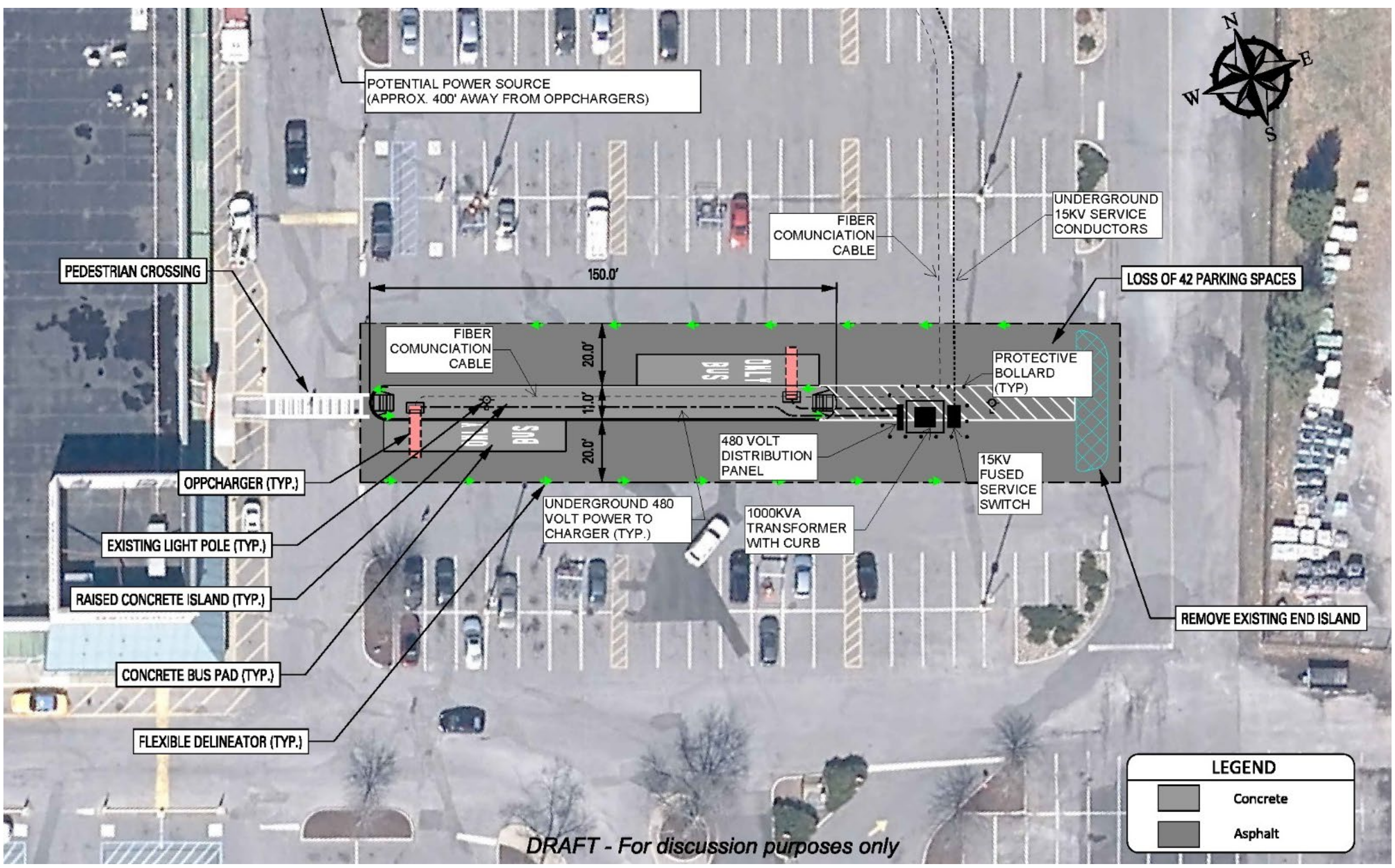


Proposed site work would include construction of raised curb islands, concrete pavement for bus drive lanes, full depth pavement reconstruction and striping in addition to the electrical work associated with the OppCharge equipment installation. Utility poles is located approximately 170 ft south of the proposed location and aligned along the southern property line, parallel to the train tracks at this location, can potentially be used as the power source south of the chargers. Each raised island would contain one pantograph charger, allowing up to two buses to be charged simultaneously. The tangent sections of raised islands would be 120 ft and 80 feet long facilitating up to five 40 ft long buses in the charging station area at a time due to space limitations and bus turn movements into the facility.

7.5 Concept 1 East

Concept 1 East was developed to locate the charging equipment and passenger activity closer to the existing terminal bus stop adjacent to the Hannaford Supermarket, the main ridership generator of this stop. This alternative combines the charging and passenger loading and unloading activities within the same area, although those two functions could be separated easily as well. Concept 1 East is shown in Figure 19.

Figure 19. Kingston Plaza Fast Charger Implementation – Concept 1 East



It is assumed that the existing bus stop would be relocated to and consolidated with the proposed charging station island. Different than the other two alternatives this option includes a single 150 feet long raised curb island with 2 pantograph chargers on each end. An 11-foot wide center island could be aligned east to west along the parking lot and placed along an existing row of parking spaces, allowing for the accommodation of passenger activity and bus route signs while meeting current ADA compliance standards. Located adjacent to the supermarket, painted crosswalks could be installed to provide designated crossing locations between the island and the supermarket. In the example illustrated, buses could utilize both sides of the raised island, either entering the charge locations from the west or the east.

This concept alternative is the most convenient of the three presented for bus operations, providing close charge proximity to the main ridership generators of Kingston Plaza and high visibility of the transit stop and infrastructure. However, it would likely also be viewed as most impactful to existing parking lot operations and surface parking supply, with a loss of up to 42 parking spaces. It should be noted that this concept design could be shifted north or south within this segment of the lot if determine to be more desirable by either UCAT or the property owner.

The site work included with this concept alternative design includes construction of a single raised curb island, concrete pavement for bus drive lanes, milling and paving of the station area and striping in addition to the electrical work associated with the pantograph charging equipment installation. Some raised concrete islands may need to be removed to facilitate bus maneuvers into and out of the charging locations.

Proximate electric utility poles to be used as the power source are located approximately 275 ft north of the chargers. One pantograph pole on each side of the island would allow up to two buses to be charged simultaneously. This alternative could facilitate up to 6 40 ft long buses in the charging station area at a time.

Template Concept Alternatives for Use Elsewhere

Fast charging installations at Kingston Plaza represent those recommended to be included in the Year Five Horizon Planning year to facilitate the first implementation of fast-charging compatible electric buses in UCAT's service. As per the assumptions of this study, fast charging equipment installed at the other three layover locations identified (New Platz, Tech City, and the Poughkeepsie Transit Hub) would not be phased in until the most distant horizon planning year.

Specific alternatives at these layover locations have not been identified in this study as the circumstances of land availability, required vehicle charge capacity, available vehicle and charging equipment technology, and future partnerships with local interests and/or other municipalities may impact these decisions greatly.

However, building on the concept plans developed for pantograph fast-charging equipment installations presented above, the Creighton Manning Engineering team developed some template implementation design alternatives. These have been developed to provide the County with general geometric, material, equipment, and service delivery needs for the fast charging installation to be used in the planning an decision making process to locate appropriate and feasible locations for charge activities in the future.

One template provides an example of a single aisle charging arrangement, including a concrete bus pad, raised concrete island (which could be substituted for an existing sidewalk or curb if space permits), the pantograph fast-charging equipment, and associated equipment required for electric service delivery. The second template expands on the first by allocating a wider passenger area (either as standalone raised concrete island or designated space on existing sidewalk) to provide additional bus stop amenities such as bus shelters, bus stop signs, and other street furniture. These two templates are shown in Figures 20 and 21, respectively.

Figure 20. Template Concept Design of Single Aisle, Curbside Fast-Charging Station with Associated Equipment

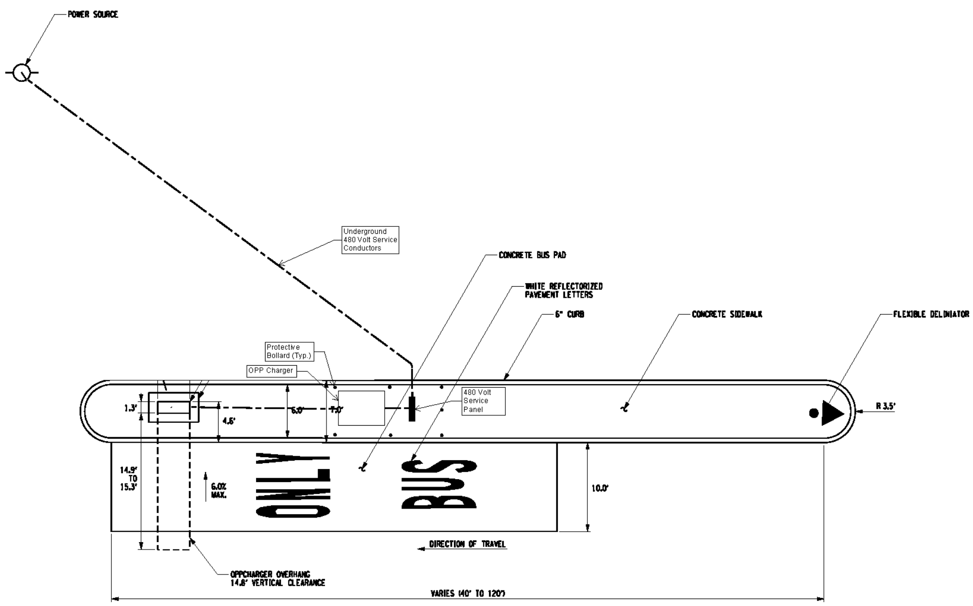


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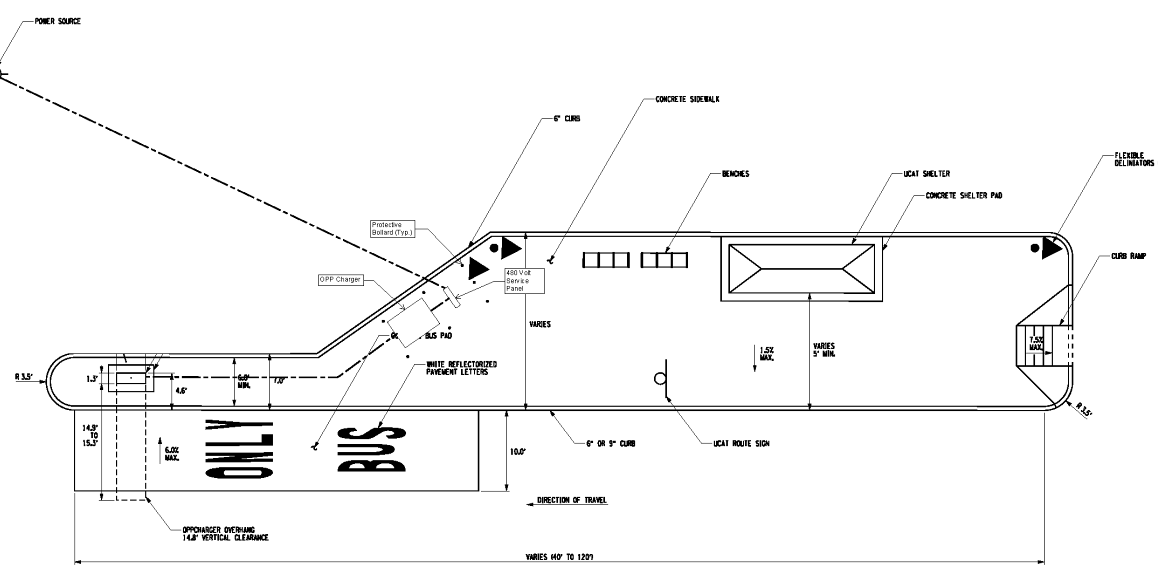
Figure 21. Template Concept Design of Single Aisle, Curbside Fast-Charging Station, Associated Equipment, and Bus Stop Passenger Amenities



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8 Framework of Study for Use by Other Agencies

Any transit agency that is considering adopting electric buses, like UCAT has undertaken in this study, should undergo an evaluation process that includes several key steps. These include evaluating schedule compatibility, developing solutions to electrify more difficult service, evaluating facility impacts, and preparing cost projections. This section is accompanied by two sketch-level planning tools to support schedule compatibility analysis and cost comparisons.

The following list of steps is not exhaustive, but it summarizes the most critical planning topics. Other topics that might inform fleet electrification include social equity prioritization, simulation of detailed garage charging strategies, resiliency evaluation, and year-by-year fleet planning.

1. **Evaluate the compatibility of your schedules to be operated using electric buses.**

   The first analysis step is to model the state of charge (SOC) of electric buses if they were to operate existing bus schedules. This is best evaluated at the level of the vehicle block, or the daily schedule of every trip assigned to a single bus. A vehicle block is considered incompatible for electrification if its modeled SOC falls below a minimum acceptable level.

   A simplified approach to schedule modeling can be applied using the associated spreadsheet “Estimation Tools”. This tests compatibility for a single bus route, based on typical assumptions about how trips are scheduled. It can test how much on-route charging time might be needed for different block lengths. While it is a useful tool for estimation, we should note that it does not account for the impacts of deadheads and interlines.

   Often this type of analysis will show that a portion of existing bus service can be electrified as-is, only using charging at garages. These routes or blocks may be the best fit for an initial pilot project.

2. **Develop potential solutions to electrify service that is initially not compatible.**

   Typically, some scheduled bus service will be difficult to electrify without changes. Modeling may show the battery SOC falling to an unacceptable level, due to some combination of the distance traveled being too long and the opportunities for on-route charging being too limited. It can be valuable to study this service closely to understand the barriers to electrification.

   The characteristics of the service that was incompatible for electrification may be suggestive of potential solutions. If multiple incompatible routes share layovers at the same location, perhaps that location would be a candidate for an on-route charger. If some of the incompatible vehicle blocks travel very long distances, perhaps the blocks could be split in two or a larger battery could be considered to improve compatibility.

   In the case of UCAT, we tested multiple solutions that included garage charging alone, four on-route chargers, and unlimited on-route chargers. With detailed schedule modeling, an agency can predict what portion of service would become compatible under various interventions.

3. Consider what upgrades to your storage facilities may be needed and how garage operations will change.

Charging electric buses at garages will require updates to the spatial layout to accommodate charging equipment. Garage charging typically requires space near the bus storage area for charger cabinets and dispensers. This equipment has the potential to displace bus storage space, which can be a significant impact if storage space is already limited. Developing a garage charging strategy early on can be helpful to avoid the need to replace or reconfigure the charging system later in the electrification process.

Planning for garage operations is just as important as the garage infrastructure. Should buses charge immediately upon arriving to the garage, overnight, or when they are about to leave the garage? For larger garages, charging management systems can automate these charging processes so buses charge at the optimal times. For smaller garages, a charging plan (such as what was developed for UCAT earlier in this report) can ensure that charging occurs at the most efficient times that will not exacerbate electricity costs.

4. Complete projections of how operating and capital costs may change under potential electrification strategies.

When considering major changes such as converting to an electric bus fleet, it is important to have an understanding of the likely financial impacts. The spreadsheet "Estimation Tools" includes a cost estimation tab that can help develop basic cost comparisons between diesel buses and electric buses. It includes calculations to quantify the annual cost of ownership, including the cost of a bus purchase, diesel fuel, electricity, maintenance, social costs from emissions, and social costs from noise. As with the route evaluation tab, we encourage users to update the input values to reflect the distinct characteristics of their transit agency.

Cost projections can be especially valuable when an agency is considering tradeoffs between different electrification strategies: for example, the tradeoff between adding more on-route chargers and splitting apart long vehicle blocks to increase compatibility. More sophisticated cost analysis can compare additional cost categories, including charger costs and schedule change costs. Deeper analysis of the electricity rate structure can also be invaluable to understand how time of day and peak demand impact electricity costs.

These four steps represent a core framework for fleet electrification planning. For larger agencies and situations needing more tailored analysis, it may be appropriate to consider a more rigorous analysis with greater detail. However, for smaller agencies with constrained budgets, sketch planning tools may be sufficient for identifying a suitable strategy to launch an electric bus program.

9 Conclusion

The results of the *Existing Conditions & Technical Feasibility Assessment* revealed that implementation of electric bus service on the majority of UCAT's bus routes would be feasible. The exceptions to this were bus routes that made particularly long one-way trips and/or were not provided sufficient layover time at the end of trips to provide opportunity for sufficient recharge to conduct their return trip – operational issues that could be rectified by changing schedules or splitting routes into two if so desired. The previous report also found that there were several existing bus vehicle blocks, particularly those centered within Downtown Kingston, that would be well suited for implementation of electric bus service using the three electric buses already procured by the County.

The purchase of the first three depot-based charging vehicles and the charge cabinets and dispensers already planned for installation at UCAT's main facility will provide an excellent start to UCAT's electric bus service. As shown in this report, the facility is more than capable of accommodating the charge needs of these first three buses, and UCAT facility personnel will have a high degree of flexibility as to when buses can be charged.

This study aimed to provide the County with a roadmap towards the next round of procurement for electric buses and charging equipment. Procurement of fast-charging compatible vehicles and the installation of fast-charging equipment at Kingston Plaza will provide the County with the most flexibility as to the number of different vehicle blocks that could be electrified. However, beyond the purchase of buses, there is significant capital investment, operational and personnel adjustments, and other logistical changes that will be necessary as the County's electric bus fleet gets incrementally larger over the next five to ten years and beyond.

The timing of UCAT's plans to construct and open a second bus storage and maintenance facility within Ulster County is particularly well timed to supplement the needs of a growing electric bus fleet. As shown in developed charge plans, as the electric bus fleet grows, depot charging can be spread over the two facilities to reduce the capital investment required at each and spreading temporal power demand over several facilities to reduce impacts to operational costs.

Based on all findings resulting from assessments and analyses conducted over the course of this study, the Creighton Manning Engineering team finds that while proactive steps are required as identified throughout this report, no fatal flaws current exist that would prevent the County from achieving a fully electric fixed route bus service by the 10 year horizon. The team is also encouraged by the potential interest of local municipalities and adjacent counties to potentially partner with the County to assist with either capital funding for new infrastructure and improvements and/or to assist with offsetting operating or maintenance costs.

Appendix A - UCAT Bus Schedules – Fall 2019

City of Kingston-Weekday

BLUE Route - Weekday

Kingston Plaza	630	730	830	930	1030	**1230**	**130**	**230**	**330**	**430**	**530**	**630**
Academy Green	632	732	832	932	1032	**1232**	**132**	**232**	**332**	**432**	**532**	**632**
Restorative Justice Center	635	735	835	935	1035	**1235**	**135**	**235**	**335**	**435**	**535**	**635**
Broadway/Cedar	638	738	838	938	1038	**1238**	**138**	**238**	**338**	**438**	**538**	**638**
Pine Grove/YMCA	639	739	839	939	1039	**1239**	**139**	**239**	**339**	**439**	**539**	**639**
Mary's Ave: Health Alliance & SUNY Ulster	642	742	842	942	1042	**1242**	**142**	**242**	**342**	**442**	**542**	**642**
Yosman Towers/Broadway	645	745	845	945	1045	**1245**	**145**	**245**	**345**	**445**	**545**	**645**
Wurt & Abeel St.	647	747	847	947	1047	**1247**	**147**	**247**	**347**	**447**	**547**	**647**
PonckHockie: Abruyn/E.Union	650	750	850	950	1050	**1250**	**150**	**250**	**350**	**450**	**550**	**650**
PonckHockie: Lindsley/E.Union	652	752	852	952	1052	**1252**	**152**	**252**	**352**	**452**	**552**	**652**
Garraghan Dr. Across from City Court	655	755	855	955	1055	**1255**	**155**	**255**	**355**	**455**	**555**	**655**
Murray St. at Rondout Gardens	658	758	858	958	1058	**1258**	**158**	**258**	**358**	**458**	**558**	**658**
E. Chester St & Broadway	708	808	908	1008	1108	**108**	**208**	**308**	**408**	**508**	**608**	**708**
Kingston Hospital	710	810	910	1010	1110	**110**	**210**	**310**	**410**	**510**	**610**	**710**
Brodway & Dederick St.	712	812	912	1012	1112	**112**	**212**	**312**	**412**	**512**	**612**	**712**
Broadway & Cornell	715	815	915	1015	1115	**115**	**215**	**315**	**415**	**515**	**615**	**715**
Governor Clinton	720	820	920	1020	1120	**120**	**220**	**320**	**420**	**520**	**620**	**720**
Kingston Plaza	725	825	925	1025	1125	**125**	**225**	**325**	**425**	**525**	**625**	**725**

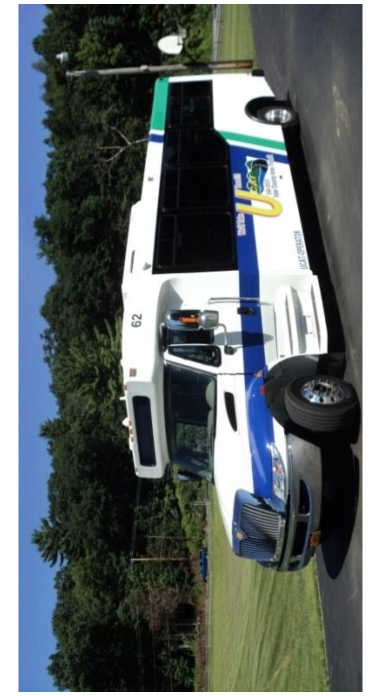
RED ROUTE: WEEKDAYS

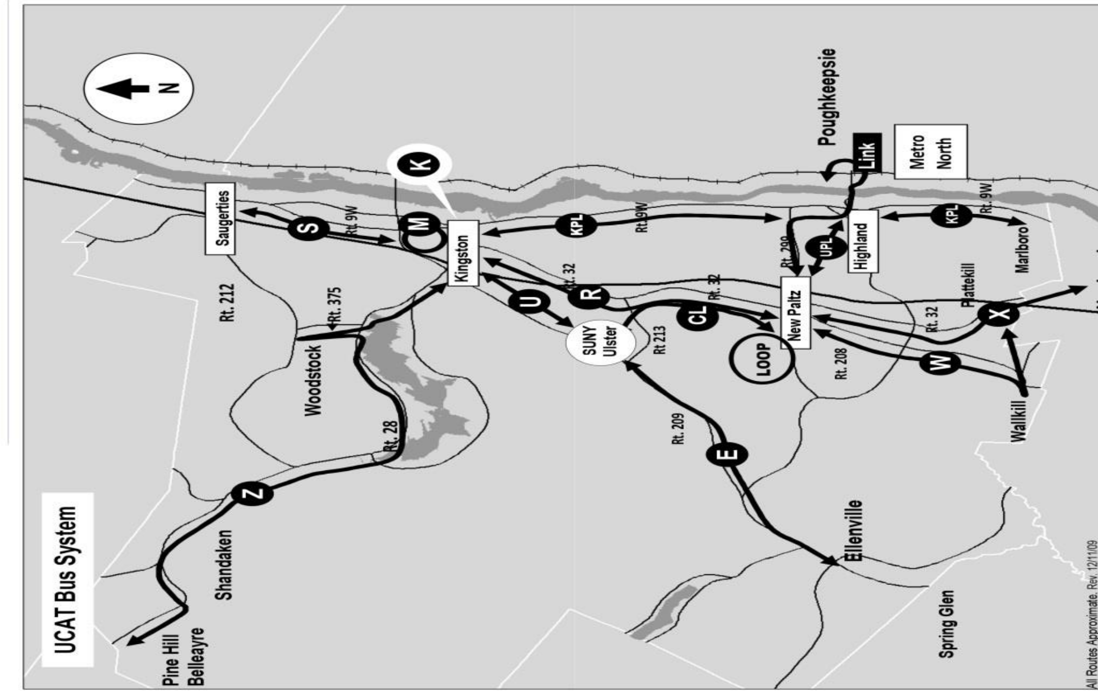
Kingston Plaza	630	730	830	930	1030	**1230**	**130**	**230**	**330**	**430**	**530**	**630**
Main St & Fair St (County Office Building)	635	735	835	935	1035	**1235**	**135**	**235**	**335**	**435**	**535**	**635**
St. James St & Clinton Ave	637	737	837	937	1037	**1237**	**137**	**237**	**337**	**437**	**537**	**637**
Clinton Ave & Greenkill Ave	638	738	838	938	1038	**1238**	**138**	**238**	**338**	**438**	**538**	**638**
Blvd/Stewarts	640	740	840	940	1040	**1240**	**140**	**240**	**340**	**440**	**540**	**640**
Golden Hill Dr.: Mental Health	645	745	845	945	1045	**1245**	**145**	**245**	**345**	**445**	**545**	**645**
Golden Hill Dr: Infirmary	650	750	850	950	1050	**1250**	**150**	**250**	**350**	**450**	**550**	**650**
Gateway/Family Practice	655	755	855	955	1055	**1255**	**155**	**255**	**355**	**455**	**555**	**655**
Law Enforcement Center	*	*	*	*	*	*	*	*	*	*	*	
Washington Ave & Greenkill Ave	700	800	900	1000	1100	**100**	**200**	**300**	**400**	**500**	**600**	
Main St & Washington Ave	705	805	905	1005	1105	**105**	**205**	**305**	**405**	**505**	**605**	
Lucas Ave & Miller's Lane (Forsyth Park)	708	808	908	1008	1108	**108**	**208**	**308**	**408**	**508**	**608**	
Fairview Ave (outside Fairview Apts)	710	810	910	1010	1110	**110**	**210**	**310**	**410**	**510**	**610**	
Quarry St & Hurley Ave	713	813	913	1013	1113	**113**	**213**	**313**	**413**	**513**	**613**	
Schwenk Dr & Frog Alley	715	815	915	1015	1115	**115**	**215**	**315**	**415**	**515**	**615**	
Kingston Plaza	720	820	920	1020	1120	**120**	**220**	**320**	**420**	**520**	**620**	

Law Enforcement Center by request only: Call 845-334-8458 to arrange a pick-up

YELLOW Route- Weekday

Kingston Plaza	630	730	830	930	1030	**1230**	**130**	**230**	**330**	**430**	**530**	**630**
Bruyn Ave & O'Neil St	640	740	840	940	1040	**1240**	**140**	**240**	**340**	**440**	**540**	**640**
Ten Broeck Ave & Foxhall Ave	643	743	843	943	1043	**1243**	**143**	**243**	**343**	**443**	**543**	**643**
Foxhall Ave & Broadway	645	745	845	945	1045	**1245**	**145**	**245**	**345**	**445**	**545**	**645**
Yosman Towers	650	750	850	950	1050	**1250**	**150**	**250**	**350**	**450**	**550**	**650**
Rt 9w & Salem St	700	800	900	1000	1100	**100**	**200**	**300**	**400**	**500**	**600**	**700**
Birches Senior Center	703	803	903	1003	1103	**103**	**203**	**303**	**403**	**503**	**603**	**703**
Rt 9w & Salem St	706	806	906	1006	1106	**106**	**206**	**306**	**406**	**506**	**606**	**706**
Flatbush Ave & Tammany St	710	810	910	1010	1110	**110**	**210**	**310**	**410**	**510**	**610**	**710**
Colonial Gardens	713	813	913	1013	1113	**113**	**213**	**313**	**413**	**513**	**613**	**713**
S. Manor St & Elemendorf St	715	815	915	1015	1115	**115**	**215**	**315**	**415**	**515**	**615**	**715**
Elmendorf St & Broadway	717	817	917	1017	1117	**117**	**217**	**317**	**417**	**517**	**617**	**717**
Kingston Plaza	720	820	920	1020	1120	**120**	**220**	**320**	**420**	**520**	**620**	**720**





We'll Take U There!!! UCAT 340-3333 Ulster County Area Transit

ULSTER COUNTY AREA TRANSIT
System wide route schedule

Ulster County Area Transit Smartphone App
Download For Free By Searching "UCAT" At:
App Store
Google play

FREE Wi-Fi

General Information

Telephone Numbers: (888) 827-8228 Dispatch: (845) 334-8458
TTY: (800) 662-1220 Fax: (845) 340-3336

Addresses: 1 Danny Cir Kingston, NY 12401

Email: ucat@co.ulster.ny.us

Web: www.co.ulster.ny.us/ucat

Hours of Bus Operations:
Mon-Fri: 5am to 10pm
Sat:8am to 7pm Sun:10am to 8pm

Office Hours: Monday-Friday: 9am to 5pm

Director: Sajaa Ahmed

Updated 4/1/2020

General Information

- To board bus: Standing in the direction of travel; riders should hail the bus with hand signal at any safe point along bus route, preferably with a light source (Cell Camera light, flash light)
- Shopping bags and small boxes are permitted, provided they are small enough to fit on your lap or at your feet and do not block the aisles.
- Shopping bags are not permitted to hang from the back of a wheelchair
- Gas-powered bicycles are not permitted

No UCAT bus service on:
New Year's day, Martin Luther King day, Presidents day, Memorial Day, Independence day, Labor day, Columbus day, Thanksgiving day & Christmas day. *Saturday service is provided on day after Thanksgiving & Veterans day.*

No Ulster-Poughkeepsie Link service on:
New Year's day, Presidents day, Memorial Day, Labor day, Thanksgiving day & Christmas day.
Saturday service is provided on: *day after Thanksgiving & Veterans day*
Sunday service is provided on: *Martin Luther King Jr Day, Independence Day & Columbus Day*

All passengers in wheelchairs must allow bus driver to secure wheelchair in accordance to manufacturers recommendations.

Fare information:
- Within Ulster County (fixed route) $1.50 // Half fare $0.75
- Out of County fare: $2.00 // Out of County half fare: $1.00
- City of Kingston Routes: $0.50 // Half fare $0.25

Half fare for qualified seniors aged 60+, persons with disabilities, and Medicare recipients between 9am and 3pm only.

Must present valid identification
- SUNY Ulster Students, Veterans, Active Military Personnel ride for free: **Must present valid identification**
- Para-transit within ¾ mile of fixed route service- $3.00
- Para-transit from ¾ mile - 1 ½ of fixed route service- $4.00
- City of Kingston Para-Transit: $1.00 // $2.00 ¾ to 1.5 miles
- Children 46" and higher pay full fare

UPL ROUTE	NEW PALTZ --- TRAIN STATION --- GRAND CENTRAL																	
Rosendale Park & Ride	520	600	-	-	-	-	-	930	1130	135	300	-	-	435	-	-	-	-
NP Stewarts Rt 32 Southbound	528	610	630	-	745	830	-	938	1138	143	307	345	415	445	550	645	745	900
SUNY New Paltz: Campus Tran Hub	-	-	-	-	-	-	-	-	1143	148	-	353	-	-	-	-	-	-
Rt 299 @ Old New Paltz Rd	538	618	638	-	753	838	-	946	1151	156	315	400	423	452	558	653	753	908
Highland Park & Ride	545	625	645	730	803	845	915	950	1200	205	330	410	430	505	605	700	800	915
CONNECTIONS TO:	-	-	-	KPL	-	KPL	-	KPL	-	-	-	-	-	-	-	-	-	-
Woodside Place	-	-	-	-	806	-	-	-	-	-	331	-	431	-	-	-	-	-
Milton Rd @ Vineyard Ave	-	-	-	733	807	848	-	953	-	208	332	-	432	-	-	-	-	-
Rt. 9W @ Haviland-Tillson Rd	548	628	648	735	808	850	920	955	1203	210	335	413	435	508	608	703	803	918
Poughkeepsie Train Station	600	640	700	745	830	900	930	1015	1215	220	345	425	450	520	620	720	815	930
Train Departure	614	647	710	802	900	950		1050	1250	254	354	452	534		656	754	854	954
Train Arrival	747	832	854	943	1102	1137		1237	237	441	544	645	714		842	942	1042	1207

* Train Arrival and departure times are subject to change, please visit website for most up-to-date schedules

UPL ROUTE	GRAND CENTRAL --- TRAIN STATION --- NEW PALTZ																	
Train Departure	-	-	-	-	645	739		846	1043	1243	143	243	318	414	508	553	615	753
Train Arrival	-	-	-	-	838	935		1036	1233	233	333	433	504	601	645	738	804	939
Poughkeepsie Train Station	600	700	715	745	843	940	940	1045	1245	240	345	445	520	605	650	743	830	940
Main St @ Market St (Bus Depot)	603	703	718	748	848	943	-	1048	1248	243	348	448	523	608	653	745	833	943
Bridgeview Plaza	-	-	-	-	-	-	-	-	-	253	-	-	-	-	-	-	-	-
Rt. 9W @ Haviland-Tillson Rd	613	713	728	754	855	955	-	1058	1258	255	358	457	532	617	702	754	841	948
Milton Rd @ Vineyard Ave	-	-	-	755	857	957	-	1059	-	-	359	458	-	618	-	-	842	-
Highland Park & Ride	-	715	730	800	900	1000	955	1100	100	300	400	500	535	620	705	757	845	950
CONNECTIONS TO:	-	-	KPL	-	-	-	-	-	-	-	-	-	-	-	KPL	-	-	-
Rt 299 @ Old New Paltz Rd	622	-	735	805	905	1005	-	1105	105	305	405	505	540	625	710	802	850	955
SUNY New Paltz: Campus Tran Hub	-	-	-	-	-	-	-	-	112	-	-	510	-	-	-	-	-	-
NP Stewarts Rt 32 Norththbound	630	-	745	815	920	1015	-	1115	120	315	415	515	550	635	720	812	900	1005
Rosendale Park & Ride	-	-	-	-	930	1030	-	1130	135	-	-	530	-	-	-	820	-	1015

* Train Arrival and departure times are subject to change, please visit website for most up-to-date schedules

KPL ROUTE	KINGSTON --- POUGHKEEPSIE --- MARLBORO						
Golden Hill	5:10	-	-	-	2:35	-	-
Kingston Plaza @ Hannaford	5:15	6:15	8:30	11:30	2:45	5:00	8:15
Broadway @ Kingston Hospital	5:16	6:16	8:31	11:31	2:46	-	8:16
Garraghan Dr @ Police Station	5:20	6:20	8:45	11:45	2:50	-	8:20
Hudson Valley Mall	-	-	-	-	-	5:30	-
Port Ewen: 9W @ BOCES	5:25	6:25	8:50	11:50	3:00	5:40	8:25
Highland Park & Ride	5:45	6:45	9:10	12:10	3:20	6:05	8:45
CONNECTIONS TO:	UPL	UPL	NONE	NONE	NONE	UPL	NONE
Marlboro: 9W @ King St.	-	7:00	-	-	-	6:25	-
Poughkeepsie Train Station	6:00	7:00	9:30	12:30	3:45	6:20	9:00
UPL Main & Market Transfer	6:03	7:00	9:43	12:48	3:48	6:08	9:03
CONNECTION LOCATION:	HPR	HPR	TRAIN	TRAIN	TRAIN	HPR	NONE
Train Departure	6:14	7:10	9:50	12:50	3:54	6:56	9:54
Train Arrival	7:47	8:54	11:37	2:37	5:44	8:42	12:07

KPL ROUTE	MARLBORO --- POUGHKEEPSIE --- KINGSTON						
Marlboro: 9W @ King St.	-	7:00	-	-	-	6:25	-
Bridgeview Plaza @ Hannaford	-	7:15	-	-	-	6:45	-
Train Departure	-	-	7:39	10:43	1:43	5:08	7:21
Train Arrival	-	-	9:35	12:33	3:33	6:45	9:07
Poughkeepsie Train Station	-	7:15	9:40	12:40	4:00	6:50	9:15
Highland Park & Ride	5:45	7:30	9:55	12:55	4:15	7:05	9:30
CONNECTIONS TO:	NONE	UPL	NONE	NONE	NONE	UPL	NONE
Port Ewen: 9W @ BOCES	6:00	7:45	10:10	1:10	4:30	7:20	9:40
Hudson Valley Mall	-	7:55	-	-	-	-	-
Garraghan Dr @ Police Station	6:05	-	10:15	1:15	4:35	7:25	9:45
Broadway @ Kingston Hospital	6:06	-	10:16	1:16	4:36	7:26	9:46
Kingston Plaza @ Hannaford	6:15	8:15	10:25	1:25	4:45	7:35	9:55
CONNECTIONS TO:	KS,EU	KS	KS	KS,EU	NONE	NONE	NONE
Golden Hill	-	-	-	1:45	-	-	10:05

NEW PALTZ LOOP	VILLAGE OF NEW PALTZ																				
Boces	8:00	8:30	9:00	9:30	10:00	10:30	11:00	12:00	12:30	1:00	1:30	2:00	3:00	4:00	5:00	6:00	6:30	7:00	8:00	8:30	9:00	9:30
Rt. 32 @ North Front St.	8:02	8:32	9:02	9:32	10:02	10:32	11:02	12:02	12:32	1:02	1:32	2:02	3:02	4:02	5:02	6:02	6:32	7:02	8:02	8:32	9:02	9:32
Main St @ Prospect St (Trailways)	8:05	8:35	9:05	9:35	10:05	10:35	11:05	12:05	12:35	1:05	1:35	2:05	3:05	4:05	5:05	6:05	6:35	7:05	8:05	8:35	9:05	9:35
CONNECTIONS TO:	NONE	NONE	R, CL	NONE	R	NONE	CL	NONE	NONE	CL	NONE	NONE	CL, X	UPL	CL	UPL	UPL	NONE	NONE	NONE	NONE	R
North Putt St @ Henry Dubois Dr.	-	8:41	-	9:41	-	10:41	-	12:11	-	1:11	-	2:11	-	4:11	-	6:11	-	7:11	-	8:41	-	9:41
Shoprite Plaza	8:08	8:45	9:08	9:45	10:08	10:45	11:08	12:15	12:38	1:15	1:38	2:15	3:15	4:15	5:15	6:15	6:38	7:15	8:08	8:45	9:08	9:45
Tops Plaza	8:10	8:48	9:10	9:48	10:10	10:48	11:10	12:18	12:40	1:18	1:40	2:18	3:20	4:20	5:20	6:18	6:40	7:18	8:10	8:48	9:10	9:48
SUNY New Paltz: Campus Tran Hub	8:12	8:50	9:12	9:50	10:12	10:50	11:12	12:20	12:42	1:20	1:42	2:20	3:27	4:27	5:27	6:20	6:42	7:20	8:12	8:50	9:12	9:50
SUNY New Paltz: Huguenot @ Southside	8:14	8:52	9:14	9:52	10:14	10:52	11:14	12:22	12:44	1:22	1:44	2:22	3:28	4:28	5:28	6:22	6:44	7:22	8:14	8:52	9:14	9:52
SUNY New Paltz: Southside @ South Rd.	8:15	8:53	9:15	9:53	10:15	10:53	11:15	12:23	12:45	1:23	1:45	2:23	3:29	4:29	5:29	6:23	6:45	7:23	8:15	8:53	9:15	9:53
SUNY New Paltz: Hawk Dr	8:16	8:54	9:16	9:54	10:16	10:54	11:16	12:24	12:46	1:24	1:46	2:24	3:30	4:30	5:30	6:24	6:46	7:24	8:16	8:54	9:16	9:54
Southside Ave @ Rt. 208	8:17	8:55	9:17	9:55	10:17	10:55	11:17	12:25	12:47	1:25	1:47	2:25	3:33	4:33	5:33	6:25	6:47	7:25	8:17	8:55	9:17	9:55
Rt. 32 @ North Front St.	8:20	8:58	9:20	9:58	10:20	10:58	11:20	12:28	12:50	1:28	1:50	2:28	3:35	4:34	5:34	6:28	6:50	7:28	8:20	8:58	9:20	9:58
Boces	8:22	9:00	9:22	10:00	10:22	11:00	11:22	12:30	12:52	1:30	1:52	2:30	3:40	4:40	5:40	6:30	6:52	7:30	8:22	9:00	9:22	10:00

X ROUTE:	NEW PALTZ --- NEWBURGH			
Main @ Prospect(Trailways)	6:30	1:00	3:15	6:30
Modena: Rt 32 @ Rt 44/55	6:40	1:10	3:26	6:41
Plattekill Post Office	6:48	1:17	3:33	6:48
Newburgh: Shoprite	6:58	1:27	3:43	6:58
Newburgh: Mid-Valley Mall	7:05	1:30	3:46	7:01
Newburgh: Water St @ Colden	7:20	1:37	3:53	7:08
Newburgh: 17k Bus Terminal	7:25	1:49	4:05	7:20
Newburgh Mall	7:35	1:57	4:13	7:28

X ROUTE:	NEWBURGH ---NEW PALTZ			
Newburgh Mall	7:55	2:10	5:30	7:30
Newburgh: 17k Bus Terminal	8:00	2:15	5:37	7:37
Newburgh: Water St @ Colden	8:10	2:19	5:47	7:47
Newburgh: Mid-Valley Mall	8:15	2:24	5:54	7:54
Newburgh: Shoprite	8:20	2:27	5:57	7:57
Plattekill Post Office	8:30	2:38	6:08	8:08
Modena: Rt 32 @ Rt 44/55	8:40	2:48	6:18	8:18
Main @ Prospect(Trailways)	9:00	3:00	6:30	8:30
CONNECTIONS TO:	R,UPL,CL,NPL	CL,UPL,NPL	UPL,NPL	NPL

HOW TO READ:

First Location is where you are: The times going across are the times you would BOARD the bus
Second Location is where you want to Go: The times going across are the times you would ARRIVE

R ROUTE	KINGSTON --- NEW PALTZ													
Golden Hill	5:20	5:50	6:50	7:20	-	9:15	-	-	**12:30**	-	**2:10**	-	**4:15**	**5:20**
Kingston Plaza @ Hannaford	5:30	6:00	7:00	7:30	*7:45*	-	*9:30*	*11:30*	-	***1:30***	**2:20**	***3:30***	-	**5:30**
Rt 32 @ Golden Hill Dr.	5:35	6:05	7:05	7:35	-	9:16	-	-	**12:31**	-	**2:25**		**4:15**	**5:35**
Bloomington: Rt. 32 @ Main St	5:40	6:10	7:10	7:40	-	9:20	-	-	**12:35**	-	**2:30**		**4:20**	**5:40**
SUNY ULSTER- Transfer to CL	-	-	-	-	*8:30*	-	*10:00*	*12:00*	-	***2:00***	-	***4:10***	-	-
Rosendale Park & Ride	5:50	6:20	7:20	7:50	*8:50*	9:30	*10:20*	*12:20*	**12:45**	***2:20***	**2:40**	***4:35***	**4:35**	**5:50**
NP Stewarts Rt 32 Southbound	6:00	6:28	7:28	8:01	*9:00*	9:38	*10:30*	*12:30*	**12:53**	***2:30***	**2:48**	***4:45***	**4:43**	**5:58**
Main St @ Prospect St (Trailways)	-	6:30	7:30	8:05	*9:20*	9:40	*10:40*	*12:40*	**1:00**	***2:40***	**2:50**	***4:55***	**5:00**	-
CONNECTIONS TO:	**UPL, W**	**X**	**UPL, CL**	**NPL**	***UPL***	**UPL**	***NONE***	***NONE***	**CL,NPL,X**	***UPL***	**NONE**	***NONE***	**UPL,NPL, CL**	**NPL, W**

R ROUTE	NEW PALTZ --- KINGSTON												
Main St @ Prospect St (Trailways)	7:00	*7:50*	9:00	9:15	10:12	*11:20*	*1:15*	**3:00**	***3:15***	**5:00**	-	**8:30**	**9:35**
NP Stewarts Rt 32 Northbound	7:03	*7:55*	9:03	9:20	10:15	*11:25*	*11:20*	**3:02**	***3:20***	**5:02**	**6:50**	**8:32**	**9:59**
Rosendale Park & Ride	7:10	*8:05*	9:10	9:30	10:30	*11:35*	*1:30*	**3:10**	***3:35***	**5:10**	**6:58**	**8:40**	**10:08**
Bloomington: Rt. 32 @ Main St	7:15	-	9:15	9:35	10:35	-	-	**3:15**	-	**5:15**	**7:03**	**8:45**	**10:12**
Rt 32 @ Golden Hill Dr.	7:20	-	9:20	9:40	10:40	-	-	**3:20**	-	**5:20**	**7:08**	**8:50**	**10:15**
SUNY ULSTER- Transfer to UE	-	*8:35*	-	-	-	*12:00*	*2:00*	-	***4:10***	-	-	-	-
Kingston Plaza @ Hannaford	7:30	*9:00*	9:30	9:45	10:50	*12:20*	*2:20*	**3:30**	***4:30***	**	**7:18**	**9:00**	*
CONNECTIONS TO:	**KS,UE,Z**	***Z***	**KS,UE**	**KS,UE**	**UE**	***Z***	***Z***	**KS,UE**	***KS***	**KS,UE,Z**	**NONE**	**NONE**	**NONE**
Golden Hill	7:40	-	9:40	9:55	10:55	-	-	**3:40**	***3:45***	**5:25**	**7:28**	**9:10**	**10:16**

**** Location on request**

ITALISIZED TIMES ARE TRANSFERS AT SUNY ULSTER

CL ROUTE	SUNY NEW PALTZ --- SUNY ULSTER					
SUNY New Paltz: Hawk Dr	7:45	9:15	11:15	**1:10**	**3:15**	**4:55**
SUNY New Paltz: Campus Tran Hub	7:48	9:18	11:18	**1:13**	**3:18**	**4:56**
Main St @ Prospect St (Trailways)	7:50	9:20	11:20	**1:15**	**3:20**	**5:00**
NP Stewarts Rt 32 Northbound	7:55	9:25	11:25	**1:20**	**3:25**	**5:02**
Rosendale Park & Ride	8:05	9:35	11:35	**1:30**	**3:35**	**5:10**
High Falls: Rt 213 @ Mohonk Rd	8:15	9:45	11:45	**1:40**	**3:45**	-
Cottekill Rd @ Lucas Ave	8:25	9:55	11:55	**1:50**	**3:55**	-
SUNY Ulster	8:30	10:00	12:00	**1:55**	**4:00**	-
CONNECTIONS TO:	**U,E**	**E**	**U,E**	**U,E**	**U,E**	**NONE**

CL ROUTE	SUNY ULSTER --- SUNY NEW PALTZ				
SUNY Ulster	8:30	10:00	12:00	**2:00**	**4:15**
Cottekill Rd @ Lucas Ave	8:35	10:05	12:05	**2:05**	**4:20**
High Falls: Rt 213 @ Mohonk Rd	8:42	10:12	12:12	**2:12**	**4:28**
Rosendale Park & Ride	8:50	10:20	12:20	**2:20**	**4:35**
NP Stewarts Rt 32 Southbound	9:00	10:30	12:30	**2:30**	**4:45**
SUNY New Paltz: Hawk Dr	9:15	10:40	12:40	**2:40**	**4:55**

EU ROUTE	ELLENVILLE --- SUNY ULSTER --- KINGSTON								
Ellenville: Liberty Sq @ Canal St	6:15	7:30	9:15	11:00	**1:00**	**3:00**	**4:00**	**7:45**	**9:35**
Shoprite & Healthly Way	-	-	9:23	11:08	**1:08**	**3:08**	**4:08**	-	-
Napanoch Walmart	-	7:45	9:30	11:15	**1:15**	**3:15**	**4:15**	-	-
Kerhonkson: Rt 209 @ Stewarts	6:30	7:55	9:40	11:25	**1:25**	**3:25**	**4:25**	**7:55**	**9:45**
Accord: Rt 209 @ Main St	6:35	8:00	9:45	11:30	**1:30**	**3:30**	**4:30**	**8:00**	**9:50**
Stone Ridge: Rt 209 @ Rt. 213	6:43	8:10	9:57	11:42	**1:42**	**3:42**	**4:42**	**8:12**	**9:52**
SUNY ULSTER ARRIVE/**DEPART**	6:45/**6:50**	8:15/**8:35**	10:00/**10:05**	11:45/**12:00**	1:45/**2:00**	3:45/**4:10**	4:45/**4:50**	**8:15**	-
CONNECTIONS TO:	**NONE**	**CL**	**CL**	**CL**	**CL**	**CL**	**NONE**	**NONE**	**NONE**
Rt 209 @ Cottekill Rd	6:53	8:38	10:08	12:03	**2:03**	**4:13**	**4:53**	**8:18**	**9:53**
Hurley: Main St @ Wynkoop Rd	7:00	8:45	10:18	12:13	**2:13**	**4:20**	**5:03**	**8:28**	-
Kingston Plaza @ Hannaford	7:15	9:00	10:30	12:20	**2:20**	**4:30**	**5:15**	**8:35**	**10:15**
Golden Hill	-	-	-	-	-	**4:45**	-	-	**10:30**

UE ROUTE	KINGSTON --- SUNY ULSTER --- ELLENVILLE								
Golden Hill	6:20	-	-	-	-	**2:20**	-	-	-
Kingston Plaza @ Hannaford	6:30	7:45	9:30	11:30	**1:30**	**2:30**	**3:30**	**5:30**	**8:45**
Hurley: Main St @ Wynkoop Rd	-	7:52	9:38	11:38	**1:38**	**2:38**	**3:38**	**5:38**	-
Rt 209 @ Cottekill Rd	-	8:07	9:53	11:53	**1:53**	**2:53**	**3:53**	**5:53**	**9:05**
SUNY ULSTER ARRIVE/**DEPART**	-	8:10/**8:30**	9:55/**10:00**	11:55/**12:00**	1:55/**2:00**	2:55/**3:00**	3:55/**4:10**	5:55/**6:00**	-
CONNECTIONS TO:	**NONE**	**CL**	**CL**	**CL**	**CL**	**NONE**	**CL**	**NONE**	**NONE**
Stone Ridge: Rt 209 @ Rt. 213	6:45	8:32	10:02	**12:02**	**2:02**	**3:02**	**4:12**	**6:02**	**9:06**
Accord: Rt 209 @ Main St	6:53	8:40	10:12	**12:12**	**2:12**	**3:12**	**4:22**	**6:12**	-
Kerhonkson: Rt 209 @ Stewarts	6:58	8:45	10:17	**12:17**	**2:17**	**3:17**	**4:27**	**6:17**	**9:15**
Napanoch Walmart	-	8:55	10:25	**12:25**	**2:25**	**3:25**	**4:35**	**6:25**	-
Healthy Way & Shoprite	-	-	10:30	**12:30**	**2:30**	**3:30**	**4:40**	**6:30**	-
Ellenville: Liberty Sq @ Canal St	7:20	9:15	10:45	**12:45**	**2:45**	**3:45**	**4:45**	**6:35**	**9:30**

W ROUTE: New Paltz --- Wallkill --- Plattekill		
NP Stewarts Rt 32 Southbound	6:00	**5:58**
Rt. 208 @ Jansen Rd	6:05	**6:03**
Gardiner: Rt. 208 @ Rt 44/55	6:10	**6:08**
Gardiner Town Hall	-	**6:10**
Wallkill: Popp Park	6:25	-
Modena: Rt 32 @ Rt 44/55	-	**6:13**
Plattekill: Rt 32 @ New Hurley Rd	6:30	**6:18**
Plattekill Post Office	6:37	**6:20**

W ROUTE: New Paltz --- Wallkill --- Plattekill		
Plattekill Post Office	6:37	**6:20**
Plattekill: Rt 32 @ New Hurley Rd	6:40	**6:22**
Modena: Rt 32 @ Rt 44/55	6:44	-
Wallkill: Popp Park	-	**6:30**
Gardiner Town Hall	6:50	**6:35**
Gardiner: Rt. 208 @ Rt 44/55	6:51	**6:35**
Rt. 208 @ Jansen Rd	6:53	**6:40**
Main St @ Prospect St (Trailways)	6:58	-
NP Stewarts Rt 32 Northbound	7:01	**6:50**
CONNECTIONS TO:	**R,UPL,CL,NPL**	**R,UPL,NPL**

ADA PARATRANSIT INFORMATION:

- Applications for service are available on our website or requested via email to ucat@co.ulster.ny.us
- Reservations for ADA service is available by calling 845-334-8120 Mon-Fri 9am-4pm. After hour reservations can be requested via the automated line .
- Visitor's can use the service for 21 days by presenting documentation from "home" jurisdiction or "proof of disability" via a letter from a doctor or rehab facility to ucat@co.ulster.ny.us
- Requests for reasonable modifications can be made via email to ucat@co.ulster.ny.us or by calling the director at 845-340-3335.
- ADA related complaints should be made to the director by calling 845-340-3335 or mail at 1 Danny Circle, Kingston NY 12401 with attention to director.

HOW TO READ:

First Location is where you are: The times going across are the times you would BOARD the bus
Second Location is where you want to Go: The times going across are the times you would ARRIVE

KS ROUTE	KINGSTON --- MALL --- SAUGERTIES													
Golden Hill	5:20	6:20	-	-	-	-	-	-	**2:20**	**3:20**	-	-	-	-
Kingston Plaza @ Hannaford	5:30	6:30	7:30	8:30	9:30	10:30	**12:30**	**1:30**	**2:30**	**3:30**	**4:30**	**5:30**	**7:00**	**8:30**
DSS/Family Court	-	-	7:40	8:40	9:40	10:40	**12:40**	**1:40**	**2:40**	**3:40**	**4:40**	**5:40**	-	-
Chambers	-	-	-	8:45	9:45	10:45	**12:45**	**1:45**	**2:45**	**3:45**	**4:45**	**5:45**	-	-
Mall Connect @ Tech City	on request	6:55	8:00	9:00	10:00	11:00	**1:00**	**2:00**	**3:00**	**4:00**	**5:00**	**6:00**	-	-
Grant Ave @ North East Center	5:45	7:01	8:01	9:01	10:01	11:01	**1:01**	**2:01**	**3:01**	**4:01**	**5:01**	**6:01**	-	-
9W & Grant Ave	6:00	7:02	8:03	9:03	10:03	11:05	**1:03**	**2:03**	**3:03**	**4:03**	**5:03**	**6:03**	**8:05**	**9:05**
Saugerties: 9w/32	6:10	7:15	8:09	9:15	10:15	11:15	**1:15**	**2:15**	**3:15**	**4:15**	**5:15**	**6:15**	**8:15**	**9:15**
The Mill	-	-	-	9:18	10:18	11:18	-	-	**3:18**	**4:18**	-	-	-	-
West Bridge St @ Main St.	6:15	7:20	8:14	9:20	10:20	11:20	**1:20**	**2:20**	**3:20**	**4:20**	**5:20**	**6:20**	**8:20**	**9:20**
Saugerties Post Office	-	-	-	9:22	-	11:22	-	**2:22**	-	**4:22**	-	**6:30**	-	-
Washington Ave @ Main St	-	-	-	9:23	-	-	-	**2:23**	-	**4:23**	-	-	-	-
Price Chopper	-	7:25	8:17	9:25	10:25	11:25	**1:25**	**2:25**	**3:25**	**4:25**	**5:25**	-	-	-

SK ROUTE	SAUGERTIES --- MALL --- KINGSTON													
Saugerties Post Office	6:30	7:30	8:30	-	10:30	**12:30**	**1:30**	-	**3:30**	-	**5:30**	**7:00**	**8:30**	**9:30**
Washington Ave @ Main St	6:32	7:32	8:32	-	10:32	**12:32**	**1:32**	-	**3:32**	-	**5:32**	**7:02**	**8:32**	**9:32**
West Bridge St @ Main St.	6:33	7:33	8:33	9:33	10:33	**12:33**	**1:33**	**2:33**	**3:33**	**4:33**	**5:33**	**7:03**	**8:33**	**9:33**
The Mill	-	-	-	9:35	10:35	**12:35**	-	**2:35**	-	-	**5:35**	-	-	-
9w/32	6:40	7:40	8:40	9:40	10:40	**12:40**	**1:40**	**2:38**	**3:40**	**4:40**	**5:40**	**7:10**	**8:40**	**9:40**
9W & Grant Ave	6:50	7:50	8:50	9:50	10:50	**12:50**	**1:50**	**2:48**	**3:50**	**4:50**	**5:50**	**7:20**	**8:50**	**9:50**
Grant Ave @ North East Center	6:51	7:51	8:51	9:51	10:51	**12:51**	**1:51**	**2:49**	**3:51**	**4:51**	**5:51**	**7:21**	-	-
Mall Connect @ Tech City	7:00	8:00	9:00	10:00	11:00	**1:00**	**2:00**	**3:00**	**4:00**	**5:00**	**6:00**	**7:30**	-	-
Chambers	-	-	9:05	10:05	11:05	**1:05**	**2:05**	**3:05**	**4:05**	**5:05**	**6:05**	**8:05**	-	-
DSS/Family Court	-	-	9:10	10:10	11:10	**1:10**	**2:10**	**3:10**	**4:10**	**5:10**	**6:10**	-	-	-
Kingston Plaza @ Hannaford	7:20	8:20	9:20	10:20	11:20	**1:20**	**2:20**	**3:20**	**4:20**	**5:20**	**6:20**	**8:20**	**10:00**	**10:30**
CONNECTIONS TO:	**EU,R,Z**	**KPL**	**EU,Z**	**NONE**	**EU,Z**	**EU**	**EU,R,Z**	**EU,Z**	**Z**	**EU,R,Z**	**NONE**	**EU,Z**	**NONE**	**NONE**
Golden Hill	-	-	-	-	-	-	**2:30**	**3:30**	-	-	-	-	**10:15**	**10:45**

Z ROUTE	KINGSTON --- WOODSTOCK --- PINE HILL						
Golden Hill	5:10	5:50	-	-	-	2:20	-
Kingston Plaza @ Hannaford	5:15	6:00	7:45	9:00	**12:30**	2:30	5:30
West Hurley: RT 28 @ Rt. 375	5:30	6:15	8:00	9:15	**12:45**	2:45	5:45
Woodstock: Rt 212 @ Rock City Rd	-	6:30	8:15	9:30	**12:55**	2:55	5:55
Boiceville: Rt. 28 @ Upper B'Ville Rd	5:47	6:45	8:30	9:45	**1:10**	3:10	6:10
Phoenicia: Rt 214 @ Church St	6:00	7:00	8:45	10:00	**1:22**	3:22	6:25
Pine Hill: Main St @ Elm St	6:15	7:15	9:00	10:15	**1:37**	3:37	6:45
Belleayre Mountain	-	-	9:05	-	**1:45**	3:45	-

Z ROUTE	PINE HILL --- WOODSTOCK --- KINGSTON						
Belleayre Mountain	-	-	9:10*	-	**1:45***	**3:45***	-
Pine Hill: Main St @ Elm St	6:15	7:15	9:15	10:15	**1:50**	**3:50**	**6:45**
Phoenicia: Rt 214 @ Church St	6:30	7:30	9:30	10:30	**2:05**	**4:05**	**7:00**
Boiceville: Rt. 28 @ Upper B'Ville Rd	**6:40**	**7:40**	**9:40**	**10:40**	**2:15**	**4:15**	**7:10**
Woodstock: Rt 212 @ Rock City Rd	7:00	8:00	10:00	11:00	**2:35**	**4:35**	**7:30**
West Hurley: RT 28 @ Rt. 375	7:15	8:15	10:15	11:15	**2:45**	**4:45**	**7:40**
Kingston Plaza @ Hannaford	7:30	8:30	10:30	11:30	**3:00**	**5:00**	**7:55**
CONNECTIONS TO	**KS,EU,R**	**KS,EU,R**	**KS**	**KS,EU**	**KS,EU**	**KS,EU,R**	**KS,EU**
Golden Hill	-	-	10:40	-	**3:10**	-	**8:10**

* Bus service on request from April 16th to November 14

MALL LOOP	TOWN OF ULSTER SHOPPING CENTERS													
Tech City	6:55	8:00	9:00	10:00	11:00*	**1:00**	**2:00**	**3:00**	**4:00**	-	-	-	-	-
Mall Area by request	-	-	-	-	-	-	-	-	-	**4:50**	**5:50**	**7:30**	**9:05**	**10:05**
Caremount Medical	7:03	8:03	9:03	10:03	11:03*	**1:03**	**2:03**	**3:03**	**4:03**	**	**	**	**	**
Walmart	7:08	8:08	9:08	10:08	11:08*	**1:08**	**2:08**	**3:08**	**4:08**	**	**	**	**	**
Gander Outdoors	7:10	8:10	9:10	10:10	11:10*	**1:10**	**2:10**	**3:10**	**4:10**	**	**	**	**	**
Hudson Valley Mall	7:15	8:15	9:15	10:15	11:15*	**1:15**	**2:15**	**3:15**	**4:15**	**	**	**	**	**
Shoprite	7:20	8:20	9:20	10:20	11:20*	**1:20**	**2:20**	**3:20**	**4:20**	**	**	**	**	**
Kohl's Plaza	7:22	8:22	9:22	10:22	11:22*	**1:22**	**2:22**	**3:22**	**4:22**	**	**	**	**	**
Ulster Gardens	-	-	9:30	10:30	11:30*	**1:30**	**2:30**	**3:30**	**4:30**	**	**	**	**	**
Kings Mall	7:25	8:25	9:35	10:35	11:35*	**1:35**	**2:35**	**3:35**	**4:35**	**	**	**	**	**
Bed, Bath & Beyond	7:30	8:30	9:38	10:38	11:38*	**1:38**	**2:38**	**3:38**	**4:38**	**	**	**	**	**
Hannaford	7:35	8:35	9:40	10:40	11:40*	**1:40**	**2:40**	**3:40**	**4:40**	**	**	**	**	**
Burlington-Staples Plaza	7:38	8:38	9:43	10:43	11:43*	**1:43**	**2:43**	**3:43**	**4:43**	**	**	**	**	**
Tech City	7:45	8:45	9:50	10:50	-	**1:50**	**2:50**	**3:50**	-	n/s	n/s	n/s	n/s	n/s
CONNECTIONS TO:	S, K	S, K	S, K	S, K	NONE	S, K	S, K	S, K	S, K	S, K	S, K	S, K	S, K	S, K

* DOES NOT GO TO TECH CITY, DROP OFFS ONLY BY REQUEST

** PICK UP & DROP OFF BY REQUEST, BUS DOES NOT AUTOMATICALLY STOP**
Pick-ups at store locatuions must be called into dispatch office at 845-334-8458.
Drop offs at store locations can be told to the bus driver.

TITLE VI
KNOW YOUR RIGHTS

Notifying the Public of Rights under Title VI

- Ulster County Area Transit operates its programs and services without regard to race, color, or national origin, in accordance with Title VI of the Civil Rights Act of 1964.
- **To obtain additional information about your rights under Title VI, contact Director of Ulster County Area Transit**
- If you believe you have been discriminated against on the basis of race, color, or national origin by Ulster County Area Transit you may file a Title VI complaint by completing, signing, and submitting the agency's Title VI Complaint Form. To obtain a Complaint Form from Ulster County Area Transit contact: Title VI Coordinator or visit our website at www.co.ulster.ny.us/ucat, Ulster County Area Transit, 1 Danny Circle, Kingston, NY 12401 or call (845) 340-3335 In addition to the complaint process at Ulster County Area Transit complaints may be filed directly with the Federal Transit Administration, Office of Civil Rights, VI Program Coordinator, East Building, 5th Floor-TCR, 1200 New Jersey Ave., SE, Washington, DC 20590.
- Complaints must be filed within 180 days following the date of the alleged discriminatory occurrence and should contain as much detailed information about the alleged discrimination as possible. The form must be signed and dated, and include your contact information.
- **If information is needed in another language, contact: (845) 384-6269**

TITULO VI
CONOZCA SUS DERECHOS

Titulo VI Notificación al Público

- UCAT opera sus programas y servicios sin discriminar respecto de raza, color, o origen nacional de conformidad con el Titulo VI de la Ley de Derechos Civiles de 1964.
- **Para obtener información adicional sobre los derechos de el Título VI, contacta la directora de UCAT**
- Cualquier persona que creé que ha sido agraviada por cualquier práctica discriminatoria ilegal bajo el Título VI mientras usaba los servicios de UCAT puede presentar una queja ante la UCAT. Para obtener más información sobre el programa del UCAT y los procedimientos de quejas, puede comunicarse con la cordinador del Título VI de (845) 340-3335; visite nuestro sitio web en www.co.ulster.ny.us/ucat; o visite UCAT en 1 Danny Circle, Kingston, NY 12401. Tambien puede presenter una queja directamente a Federal Transit Administration, Office of Civil Rights, VI Program Coordinator, East Building, 5th Floor-TCR, 1200 New Jersey Ave., SE, Washington, DC 20590.
- La queja debe presentarse dentro de los 180 días de la fecha de la supuesta discriminación y debe incluyar toda la información sobre la discrimanción. Es necesario que incluye la firma, la fecha y información de contacto.
- Si se necesita información en algún otro idioma, llame al (845) 384-6269

Appendix B - Vehicle Block Definitions

Route ID	Rt Name	trip_id	trip_headsign	Start Time	End Time	direction_id	Block	shape_id	Length
DH	DH			6:15:00	6:25:00		1001		1.7
11936	Blue		Blue - MTWRF	6:30:00	7:25:00	1	1001	9127	7.6
11936	Blue		Blue - MTWRF	7:30:00	8:25:00	1	1001	9127	7.6
11936	Blue		Blue - MTWRF	8:30:00	9:25:00	1	1001	9127	7.6
11936	Blue		Blue - MTWRF	9:30:00	10:25:00	1	1001	9127	7.6
11936	Blue		Blue - MTWRF	10:30:00	11:25:00	1	1001	9127	7.6
11936	Blue		Blue - MTWRF	12:30:00	13:25:00	1	1001	9127	7.6
11936	Blue		Blue - MTWRF	13:30:00	14:25:00	1	1001	9127	7.6
DH	DH			14:25:00	14:35:00		1001		1.7
DH	DH			14:15:00	14:25:00		1002		1.7
11936	Blue		Blue - MTWRF	14:30:00	15:25:00	1	1002	9127	7.6
11936	Blue		Blue - MTWRF	15:30:00	16:25:00	1	1002	9127	7.6
11936	Blue		Blue - MTWRF	16:30:00	17:25:00	1	1002	9127	7.6
11936	Blue		Blue - MTWRF	17:30:00	18:25:00	1	1002	9127	7.6
11936	Blue		Blue - MTWRF	18:30:00	19:25:00	1	1002	9127	7.6
DH	DH			19:25:00	19:35:00		1002		1.7
3850	R-SB	126674	New Paltz	6:50:00	7:30:00	0	1003	5399	17.4
3844	CL-NB	9108	SUNY Ulster Campus	7:45:00	8:30:00	0	1003	5400	16.9
4068	CL-SB	83840	SUNY NP	8:30:00	9:15:00	0	1003	5583	16.2
3844	CL-NB	9109	SUNY Ulster Campus	9:15:00	10:00:00	0	1003	5400	16.9
4068	CL-SB	83841	SUNY NP	10:00:00	10:40:00	0	1003	5583	16.2
3844	CL-NB	9110	SUNY Ulster Campus	11:15:00	12:00:00	0	1003	5400	16.9
4068	CL-SB	125178	SUNY NP	12:00:00	12:40:00	0	1003	5583	16.2
3844	CL-NB	9111	SUNY Ulster Campus	13:10:00	13:55:00	0	1003	5400	16.9
4068	CL-SB	125179	SUNY NP	14:00:00	14:40:00	0	1003	5583	16.2
3844	CL-NB	9112	SUNY Ulster Campus	15:15:00	16:00:00	0	1003	5400	16.9
4068	CL-SB	83844	SUNY NP	16:15:00	16:55:00	0	1003	5583	16.2
3844	CL-NB	9113	Rosendale Park and R	16:55:00	17:10:00	0	1003	5400	16.9
4070	R-NB	83875	Kingston	17:10:00	17:25:00	0	1003	8070	13.8
DH	DH			6:14:00	6:15:00		1004		0.5
4065	EU-NB	83879	SUNY Ulster - Kingsto	6:15:00	7:15:00	0	1004	5592	30.6
3845	EU-SB	9151	SUNY Ulster - Ellenvil	7:45:00	9:15:00	0	1004	5412	30.7
4065	EU-NB	83881	SUNY Ulster - Kingsto	9:15:00	10:30:00	0	1004	5592	30.6
3845	EU-SB	9153	SUNY Ulster - Ellenvil	11:30:00	12:45:00	0	1004	5412	30.7
4065	EU-NB	83883	SUNY Ulster - Kingsto	13:00:00	14:20:00	0	1004	5592	30.6
3845	EU-SB	9156	SUNY Ulster - Ellenvil	15:30:00	16:45:00	0	1004	5412	30.7
DH	DH			16:45:00	16:46:00		1004		0.5
3845	EU-SB	9155	SUNY Ulster - Ellenvil	14:20:00	15:45:00	0	1005	5593	32.0
4065	EU-NB	83886	SUNY Ulster - Kingsto	16:00:00	17:15:00	0	1005	5592	30.6
3845	EU-SB	9157	SUNY Ulster - Ellenvil	17:30:00	18:35:00	0	1005	5412	30.7
4065	EU-NB	83887	SUNY Ulster - Kingsto	19:45:00	20:35:00	0	1005	5592	30.6
3845	EU-SB	9158	SUNY Ulster - Ellenvil	20:45:00	21:30:00	0	1005	5412	30.7
4065	EU-NB	83888	SUNY Ulster - Kingsto	21:35:00	22:30:00	0	1005	5579	32.0
3847	KS-NB	9161	Mall - Saugerties	6:20:00	7:25:00	0	1006	5595	16.4
4066	KS-SB	126640	Mall - Kingston	7:30:00	8:20:00	0	1006	5580	14.2
3847	KS-NB	9163	Mall - Saugerties	8:30:00	9:25:00	0	1006	5415	14.8
4066	KS-SB	83852	Mall - Kingston	9:33:00	10:20:00	0	1006	5580	14.2
3847	KS-NB	9165	Mall - Saugerties	10:30:00	11:25:00	0	1006	5415	14.8
4066	KS-SB	126641	Mall - Kingston	12:30:00	13:20:00	0	1006	5580	14.2
3847	KS-NB	9167	Mall - Saugerties	13:30:00	14:25:00	0	1006	5415	14.8
4066	KS-SB	83855	Mall - Kingston	14:33:00	15:30:00	0	1006	5594	16.1
3846	KPL-SB	84334	Highland Park and Ric	5:10:00	5:45:00	0	1007	5911	17.9
4069	KPL-NB	84341	Kingston	5:45:00	6:15:00	0	1007	5917	15.3
3846	KPL-SB	84335	Marlboro	6:15:00	7:00:00	0	1007	5918	31.9
4069	KPL-NB	84342	Kingston	7:00:00	8:15:00	0	1007	5914	39.6
3846	KPL-SB	84336	Poughkeepsie Link	8:30:00	9:30:00	0	1007	5912	21.4
4069	KPL-NB	84343	Kingston	9:40:00	10:30:00	0	1007	5586	21.1
3846	KPL-SB	84337	Poughkeepsie Link	11:30:00	12:30:00	0	1007	5912	21.4
4069	KPL-NB	84344	Kingston	12:40:00	13:45:00	0	1007	5915	22.9
3846	KPL-SB	84338	Poughkeepsie Link	14:35:00	15:45:00	0	1008	5910	23.2

Route ID	Rt Name	trip_id	trip_headsign	Start Time	End Time	direction_id	Block	shape_id	Length
4069	KPL-NB	84345	Kingston	16:00:00	16:45:00	0	1008	5586	21.1
3846	KPL-SB	84339	Marlboro	17:00:00	18:25:00	0	1008	5403	37.3
4069	KPL-NB	84346	Kingston	18:25:00	19:35:00	0	1008	5916	31.1
3846	KPL-SB	84340	Poughkeepsie Link	20:15:00	21:00:00	0	1008	5912	21.4
4069	KPL-NB	84347	Kingston	21:15:00	22:05:00	0	1008	5915	22.9
3847	KS-NB	9168	Mall - Saugerties	15:20:00	16:25:00	0	1009	5595	16.4
4066	KS-SB	83857	Mall - Kingston	16:33:00	17:20:00	0	1009	5580	14.2
3847	KS-NB	9170	Mall - Saugerties	17:30:00	18:30:00	0	1009	5415	14.8
4066	KS-SB	83859	Mall - Kingston	19:00:00	20:20:00	0	1009	5580	14.2
3847	KS-NB	9172	Mall - Saugerties	20:30:00	21:20:00	0	1009	5415	14.8
4066	KS-SB	83861	Mall - Kingston	21:30:00	22:45:00	0	1009	5594	16.1
DH	DH			6:20:00	6:36:00		1010		6.2
3848	M	9195	Ulster Mall Area	6:55:00	7:45:00	0	1010	8067	7.7
3848	M	166827	Ulster Mall Area	8:00:00	8:45:00	0	1010	5418	10.1
3848	M	9199	Ulster Mall Area	9:00:00	9:50:00	0	1010	5418	10.1
3848	M	126642	Ulster Mall Area	10:00:00	10:50:00	0	1010	5418	10.1
3848	M	126643	Ulster Mall Area	11:00:00	11:50:00	0	1010	5418	10.1
3848	M	9201	Ulster Mall Area	13:00:00	13:50:00	0	1010	5418	10.1
3848	M	9208	Ulster Mall Area	14:00:00	14:50:00	0	1010	5418	10.1
3848	M	9209	Ulster Mall Area	15:00:00	15:50:00	0	1010	5418	10.1
3848	M	9210	Ulster Mall Area	16:00:00	16:50:00	0	1010	5418	10.1
DH	DH			16:50:00	17:10:00		1010		6.2
3850	R-SB	9251	New Paltz	17:20:00	17:58:00	0	1011	5399	17.4
3852	W-SB	8812	Plattekill	17:58:00	18:20:00	0	1011	5397	14.2
4071	W-NB	83913	Wallkill - New Paltz	18:20:00	18:50:00	0	1011	5588	22.7
4070	R-NB	83876	Kingston	18:50:00	19:28:00	0	1011	5587	17.3
3850	R-SB	9246	New Paltz	7:20:00	8:05:00	0	1012	5399	17.4
3849	NPL	9230	New Paltz Loop	8:05:00	8:22:00	0	1012	8068	6.3
3849	NPL	9216	New Paltz Loop	8:30:00	9:00:00	0	1012	5417	7.0
3849	NPL	89647	New Paltz Loop	9:00:00	9:22:00	0	1012	8068	6.3
3849	NPL	89660	New Paltz Loop	9:30:00	10:00:00	0	1012	5417	7.0
3849	NPL	89648	New Paltz Loop	10:00:00	10:22:00	0	1012	8068	6.3
3849	NPL	89661	New Paltz Loop	10:30:00	11:00:00	0	1012	5417	7.0
3849	NPL	89649	New Paltz Loop	11:00:00	11:22:00	0	1012	8068	6.3
3849	NPL	126649	New Paltz Loop	12:00:00	12:30:00	0	1012	5417	7.0
3849	NPL	126652	New Paltz Loop	12:30:00	12:52:00	0	1012	8068	6.3
3849	NPL	126650	New Paltz Loop	13:00:00	13:30:00	0	1012	5417	7.0
3849	NPL	126653	New Paltz Loop	13:30:00	13:52:00	0	1012	8068	6.3
3849	NPL	126651	New Paltz Loop	14:00:00	14:30:00	0	1012	5417	7.0
4070	R-NB	83874	Kingston	15:00:00	15:40:00	0	1012	5587	17.3
3850	R-SB	9249	New Paltz	14:10:00	14:50:00	0	1013	5399	17.4
3849	NPL	126647	New Paltz Loop	15:00:00	15:40:00	0	1013	8068	6.3
3849	NPL	126654	New Paltz Loop	16:00:00	16:40:00	0	1013	5417	7.0
3849	NPL	126655	New Paltz Loop	17:00:00	17:40:00	0	1013	5417	7.0
3849	NPL	126656	New Paltz Loop	18:00:00	18:30:00	0	1013	5417	7.0
3849	NPL	126657	New Paltz Loop	19:00:00	19:30:00	0	1013	5417	7.0
3849	NPL	126659	New Paltz Loop	20:00:00	20:22:00	0	1013	8068	6.3
3849	NPL	126661	New Paltz Loop	20:30:00	21:00:00	0	1013	5417	7.0
3849	NPL	126660	New Paltz Loop	21:00:00	21:22:00	0	1013	8068	6.3
3849	NPL	126662	New Paltz Loop	21:30:00	22:00:00	0	1013	5417	7.0
4070	R-NB	83878	Kingston	21:35:00	22:16:00	0	1013	5587	17.3
DH	DH			6:50:00	7:00:00		1014		1.7
11935	Red	182233	Red	7:00:00	7:30:00	1	1014	9126	6.7
11935	Red	182234	Red	7:30:00	8:00:00	1	1014	9126	6.7
11935	Red	182235	Red	8:00:00	8:30:00	1	1014	9126	6.7
11935	Red	182236	Red	8:30:00	9:00:00	1	1014	9126	6.7
11935	Red	182237	Red	9:00:00	9:30:00	1	1014	9126	6.7
11935	Red	182238	Red	10:00:00	10:30:00	1	1014	9126	6.7
11935	Red	182239	Red	10:30:00	11:00:00	1	1014	9126	6.7
11935	Red	182240	Red	11:00:00	11:30:00	1	1014	9126	6.7

Route ID	Rt Name	trip_id	trip_headsign	Start Time	End Time	direction_id	Block	shape_id	Length
11935	Red	182241	Red	12:30:00	13:00:00	1	1014	9126	6.7
11935	Red	182242	Red	13:00:00	13:30:00	1	1014	9126	6.7
11935	Red	182243	Red	14:00:00	14:30:00	1	1014	9126	6.7
11935	Red	182244	Red	14:30:00	15:00:00	1	1014	9126	6.7
DH	DH			15:00:00	15:10:00		1014		1.7
DH	DH			14:50:00	15:00:00		1015		1.7
11935	Red	182245	Red	15:00:00	15:30:00	1	1015	9126	6.7
11935	Red	182246	Red	15:30:00	16:00:00	1	1015	9126	6.7
11935	Red	182247	Red	16:00:00	16:30:00	1	1015	9126	6.7
11935	Red	182248	Red	16:30:00	17:00:00	1	1015	9126	6.7
11935	Red	182249	Red	17:00:00	17:30:00	1	1015	9126	6.7
11935	Red	182250	Red	17:30:00	18:00:00	1	1015	9126	6.7
11935	Red	182251	Red	18:30:00	19:00:00	1	1015	9126	6.7
11935	Red	182252	Red	19:00:00	19:08:00	0	1015	9193	2.7
3847	KS-NB	9160	Mall - Saugerties	5:20:00	6:15:00	0	1016	5595	16.4
4066	KS-SB	83849	Mall - Kingston	6:30:00	7:20:00	0	1016	5580	14.2
3847	KS-NB	9162	Mall - Saugerties	7:30:00	8:17:00	0	1016	5415	14.8
4066	KS-SB	83851	Mall - Kingston	8:30:00	9:20:00	0	1016	5580	14.2
3847	KS-NB	9164	Mall - Saugerties	9:30:00	10:25:00	0	1016	5415	14.8
4066	KS-SB	83848	Mall - Kingston	10:30:00	11:20:00	0	1016	5580	14.2
3847	KS-NB	9166	Mall - Saugerties	12:30:00	13:25:00	0	1016	5415	14.8
4066	KS-SB	83854	Mall - Kingston	13:30:00	14:30:00	0	1016	5594	16.1
3847	KS-NB	9159	Mall - Saugerties	14:20:00	15:25:00	0	1017	5595	16.4
4066	KS-SB	83856	Mall - Kingston	15:30:00	16:20:00	0	1017	5580	14.2
3847	KS-NB	9169	Mall - Saugerties	16:30:00	17:30:00	0	1017	5415	14.8
4066	KS-SB	83858	Mall - Kingston	17:30:00	18:20:00	0	1017	5580	14.2
3847	KS-NB	9171	Mall - Saugerties	19:00:00	20:20:00	0	1017	5415	14.8
4066	KS-SB	83860	Mall - Kingston	20:30:00	22:15:00	0	1017	5594	16.1
3845	EU-SB	9150	SUNY Ulster - Ellenvil	6:20:00	7:20:00	0	1018	5593	32.0
4065	EU-NB	83880	SUNY Ulster - Kingsto	7:30:00	9:00:00	0	1018	5592	30.6
3845	EU-SB	9152	SUNY Ulster - Ellenvil	9:30:00	10:45:00	0	1018	5412	30.7
4065	EU-NB	83882	SUNY Ulster - Kingsto	11:00:00	12:20:00	0	1018	5592	30.6
3845	EU-SB	9154	SUNY Ulster - Ellenvil	13:30:00	14:45:00	0	1018	5412	30.7
4065	EU-NB	83885	SUNY Ulster - Kingsto	15:00:00	16:45:00	0	1018	5579	32.0
DH	DH			6:15:00	6:25:00		1019		1.7
11937	Yellow		Yellow - MTWRF	6:30:00	7:20:00		1019	9129	12.4
11937	Yellow		Yellow - MTWRF	7:30:00	8:20:00		1019	9129	12.4
11937	Yellow		Yellow - MTWRF	8:30:00	9:20:00		1019	9129	12.4
11937	Yellow		Yellow - MTWRF	9:30:00	10:20:00		1019	9129	12.4
11937	Yellow		Yellow - MTWRF	10:30:00	11:20:00		1019	9129	12.4
11937	Yellow		Yellow - MTWRF	12:30:00	13:20:00		1019	9129	12.4
11937	Yellow		Yellow - MTWRF	13:30:00	14:20:00		1019	9129	12.4
DH	DH			14:20:00	14:30:00		1019		1.7
DH	DH			14:15:00	14:25:00		1020		1.7
11937	Yellow		Yellow - MTWRF	14:30:00	15:20:00		1020	9129	12.4
11937	Yellow		Yellow - MTWRF	15:30:00	16:20:00		1020	9155	12.4
11937	Yellow		Yellow - MTWRF	16:30:00	17:20:00		1020	9129	12.4
11937	Yellow		Yellow - MTWRF	17:30:00	18:20:00		1020	9155	12.4
11937	Yellow		Yellow - MTWRF	18:30:00	19:20:00		1020	9129	12.4
DH	DH			19:20:00	19:30:00		1020		1.7
DH/R	DH/R			5:00:00	5:12:00		1021		6.6
3851	UPL-EB	9901	Poughkeepsie LINK	5:20:00	6:00:00	0	1021	8072	19.4
4067	UPL-WB	83892	New Paltz Park and R	6:00:00	6:30:00	0	1021	8075	19.3
3851	UPL-EB	10160	Poughkeepsie LINK	6:30:00	7:00:00	0	1021	8072	19.4
4067	UPL-WB	83893	Highland Park and Ric	7:00:00	7:15:00	0	1021	8075	19.3
3851	UPL-EB	10349	Poughkeepsie LINK	7:30:00	7:45:00	0	1021	8073	19.5
4067	UPL-WB	83895	New Paltz Park and R	7:45:00	8:15:00	0	1021	8076	19.5
4067	UPL-WB	83896	Poughkeepsie LINK	8:43:00	9:30:00	0	1021	8076	19.5
4067	UPL-WB	83898	Highland Park and Ric	9:40:00	9:55:00	0	1021	8075	19.3
DH/R	DH/R			9:55:00	10:28:00		1021		15.8

Route ID	Rt Name	trip_id	trip_headsign	Start Time	End Time	direction_id	Block	shape_id	Length
DH/R	DH/R			5:30:00	5:42:00		1022		6.6
3851	UPL-EB	10129	Poughkeepsie LINK	6:00:00	6:40:00	0	1022	8072	19.4
4067	UPL-WB	83894	New Paltz Park and R	7:15:00	7:45:00	0	1022	8075	19.3
3851	UPL-EB	10413	Poughkeepsie LINK	7:45:00	8:30:00	0	1022	8073	19.5
3851	UPL-EB	10532	Rosendale Park and F	8:30:00	9:00:00	0	1022	8073	19.5
3851	UPL-EB	10563	Poughkeepsie LINK	9:15:00	9:30:00	0	1022	8072	19.4
4067	UPL-WB	83897	Rosendale Park and F	9:40:00	10:12:00	0	1022	8076	19.5
DH/R	DH/R			10:30:00	10:42:00		1022		6.6
DH/R	DH/R			14:45:00	14:57:00		1023		6.6
3851	UPL-EB	35279	Poughkeepsie LINK	15:00:00	15:45:00	0	1023	8073	19.5
4067	UPL-WB	83901	New Paltz Park and R	15:45:00	16:15:00	0	1023	8076	19.5
3851	UPL-EB	35586	Poughkeepsie LINK	16:15:00	16:50:00	0	1023	8073	19.5
4067	UPL-WB	83903	New Paltz Park and R	17:20:00	17:50:00	0	1023	8075	19.3
3851	UPL-EB	71082	Poughkeepsie LINK	17:50:00	18:20:00	0	1023	8072	19.4
4067	UPL-WB	83905	New Paltz Park and R	18:50:00	19:20:00	0	1023	8075	19.3
3851	UPL-EB	71155	Poughkeepsie LINK	19:45:00	20:15:00	0	1023	8072	19.4
4067	UPL-WB	83907	New Paltz Park and R	20:30:00	21:00:00	0	1023	8076	19.5
3851	UPL-EB	71178	Poughkeepsie LINK	21:00:00	21:30:00	0	1023	8072	19.4
4067	UPL-WB	83908	Rosendale Park and F	21:40:00	22:15:00	0	1023	8075	19.3
DH/R	DH/R			22:15:00	22:27:00		1023		6.6
DH/R	DH/R			16:15:00	16:27:00		1024		6.6
3851	UPL-EB	71049	Poughkeepsie LINK	16:35:00	17:20:00	0	1024	8072	19.4
4067	UPL-WB	83904	New Paltz Park and R	18:05:00	18:35:00	0	1024	8075	19.3
3851	UPL-EB	71113	Poughkeepsie LINK	18:45:00	19:20:00	0	1024	8072	19.4
4067	UPL-WB	83906	Rosendale Park and F	19:43:00	20:20:00	0	1024	8075	19.3
DH/R	DH/R			20:20:00	20:32:00		1024		6.6
DH/R	DH/R			9:15:00	9:27:00		1025		6.6
3851	UPL-EB	10671	Poughkeepsie LINK	9:30:00	10:15:00	0	1025	8073	19.5
4067	UPL-WB	83899	Rosendale Park and F	10:45:00	11:30:00	0	1025	8076	19.5
3851	UPL-EB	10809	Poughkeepsie LINK	11:30:00	12:15:00	0	1025	8071	20.4
4067	UPL-WB	83900	Rosendale Park and F	12:45:00	13:35:00	0	1025	8074	20.3
3851	UPL-EB	34273	Poughkeepsie LINK	13:35:00	14:20:00	0	1025	5419	20.5
4067	UPL-WB	83891	New Paltz Park and R	14:40:00	15:15:00	0	1025	5582	14.2
3851	UPL-EB	35421	Poughkeepsie LINK	15:45:00	16:25:00	0	1025	8071	20.4
4067	UPL-WB	83902	Rosendale Park and F	16:45:00	17:30:00	0	1025	5581	20.5
DH/R	DH/R			17:30:00	17:42:00		1025		6.6
3854	Z-WB	9623	Shandaken - Pine Hill	5:50:00	7:15:00	0	1026	4799	43.8
4073	Z-NB	83920	Shandaken - Kingston	7:15:00	8:30:00	0	1026	5597	42.3
3854	Z-WB	9658	Shandaken - Pine Hill	9:00:00	10:15:00	0	1026	5599	42.2
4073	Z-NB	83921	Shandaken - Kingston	10:15:00	11:30:00	0	1026	5597	42.3
3854	Z-WB	9660	Shandaken - Pine Hill	12:30:00	13:45:00	0	1026	5600	44.3
4073	Z-NB	83922	Shandaken - Kingston	13:45:00	15:10:00	0	1026	5591	46.3
3854	Z-WB	9636	Shandaken - Pine Hill	5:10:00	6:15:00	0	1027	8039	36.7
4073	Z-NB	83919	Shandaken - Kingston	6:15:00	7:30:00	0	1027	5597	42.3
3854	Z-WB	9650	Shandaken - Pine Hill	7:45:00	9:05:00	0	1027	5600	44.3
4073	Z-NB	83918	Shandaken - Kingston	9:10:00	10:40:00	0	1027	5591	46.3
DH	DH			10:40:00	10:50:00		1027		1.7
3854	Z-WB	9661	Shandaken - Pine Hill	14:20:00	15:45:00	0	1028	5396	45.9
4073	Z-NB	83923	Shandaken - Kingston	15:45:00	17:00:00	0	1028	5598	44.4
3854	Z-WB	9662	Shandaken - Pine Hill	17:30:00	18:45:00	0	1028	5599	42.2
4073	Z-NB	83924	Shandaken - Kingston	18:45:00	20:10:00	0	1028	5596	44.3
DH	DH			16:44:00	17:00:00		2001		6.2
3848	M	126644	Ulster Mall Area	17:00:00	17:45:00	0	2001	8067	7.7
3848	M	126645	Ulster Mall Area	18:00:00	18:45:00	0	2001	8067	7.7
3848	M	9213	Ulster Mall Area	19:30:00	20:03:00	0	2001	8067	7.7
3848	M	126646	Ulster Mall Area	21:05:00	21:38:00	0	2001	8067	7.7
3848	M	9215	Ulster Mall Area	22:05:00	22:17:00	0	2001	8067	7.7
DH	DH			22:17:00	22:33:00		2001		6.2
3850	R-SB	9244	New Paltz	5:20:00	6:00:00	0	2002	5399	17.4
3852	W-SB	8810	Wallkill - Plattekill	6:00:00	6:37:00	0	2002	5398	20.8

Route ID	Rt Name	trip_id	trip_headsign	Start Time	End Time	direction_id	Block	shape_id	Length
4071	W-NB	83912	New Paltz	6:37:00	7:00:00	0	2002	5589	14.6
4070	R-NB	83870	Kingston	7:00:00	7:40:00	0	2002	5587	17.3
DH/R	DH/R			12:40:00	13:00:00		2003		13.7
3853	X-SB	9551	Newburgh	13:00:00	13:57:00	0	2003	5401	26.3
4072	X-NB	83915	New Paltz	14:10:00	15:00:00	0	2003	5590	26.7
3853	X-SB	9553	Newburgh	15:15:00	16:13:00	0	2003	5401	26.3
4072	X-NB	83916	New Paltz	17:30:00	18:30:00	0	2003	5590	26.7
3853	X-SB	9554	Newburgh	18:30:00	19:28:00	0	2003	5401	26.3
4072	X-NB	83917	New Paltz	19:30:00	20:30:00	0	2003	5590	26.7
DH/R	DH/R			20:30:00	20:54:00		2003		13.7

Appendix C - New Flyer 35' Xcelsior CHARGE Specifications

TRANSIT BUS SPECIFICATION

TECHNICAL INFORMATION TO BE FURNISHED BY CONTRACTOR WITH RESPONSE FOR EACH VEHICLE Enter "N/A" where not applicable

A. Bus Manufacturer New Flyer of America Inc.
B. Bus Model Number 35' Xcelsior CHARGE™ (XE35)
C. Dimensions

1. Overall Length: a. Over Bumpers 36 ft. 3 in. b. Over Body 35 ft. 5 in.
2. Overall Width: a. Over Body excluding Mirrors 8 ft. 6 in., b. Over Body including Mirrors 11 ft. 0 in., c. Over Tires 8 ft. 5 in.
3. a. Over Height (Maximum) 11 ft. 1 in., b. Over Height (Main Roof Line) 10 ft. 8 in.
4. Angle of Approach 9 Deg., 5. Breakover Angle N/A Deg., 6. Angle of Departure 9 Deg.
7. Doorway Clear Opening (including grab handles) a. Front: Width 33.8 in. Height 77.3in. b. Rear: Width 34.8in. Height 77.3 in.
8. Floor Height from Ground: Front Entrance: a. (Kneeled) 10 in., b. Ride Height 14 in.,
   Rear Exit: a. (Kneeled) 10 in., b. Ride Height 14 in.
9. Overhand, centerline of Axle Over Bumper: a. Front - ft. 15.5 in., b. Rear - ft. 15.5 in.
10. Floor: a. Interior Length 29 ft. 5.5 in.: b. Interior Width 8 ft. 0 in.
11. Seats: a. No. of Seats (No wheelchairs) 32, b. No. of Seats (With wheelchairs) 26, c. No. of Wheelchairs 2
12. a. Minimum Knee to Hip Room 27.57 in., b. Minimum Foot Room 10 in.
13. Interior Head Room (center of aisle) a. Front Axle Location 79 in., b. Rear Axle Location 79 in.
14. Aisle Width Between Seats (Minimum) 20.88 in. 18. Wheel Base ft. 283.75 in.
15. Floor Height Above Ground (at each door): a. Front Door 15.5 in., b. Rear Door 15.5 in.
16. Minimum Ground Clearance (between bus found with bus unkneeled) 10 in.
17. Turning Envelope: a. Outside Body Turning (including bumper radius) 43 ft. 0 in.,
    b. Inside Turning Radius 22 ft. 2 in.

D.

	Weight of Bus	Wet Weight	GVWR
1.	Front Axle	11,700	15,873
2.	Rear Axle	22,180	28,660
3.	Total	33,880	44,533

E. Engine

1. Manufacturer Siemens E-Drive
2. Type and weight rating
3. Model number 1DB2016
4. Net SAE horsepower 561 V / peak power 190 kW
5. Net SAE torque 1770 ft. lbs

F. Hybrid Drive or Transmission

1. Manufacturer N/A, 2. Type
3. Model Number, 4. Speeds,
5. Gear Ratios: Forward Reverse
6. Shift Speeds: a. 1st - 2nd, b. 2nd - 3rd, c. 3rd - 4th, d. 4th - 5th
7. ~~Oil Capacity (including Heat Exchanger)~~ gals.,
8. Retarder: Make, Type and Size , ,

G. Voltage Regulator

1. Manufacturer N/A
2. Model N/A

H. Voltage Equalizer

1. Manufacturer Vanner Power Group
2. Model P/N 80-80-015-2-LVD Software: A817388-E

I. Alternator

1. Manufacturer Vanner EBA, 2.Type Electric Beltless Motor, 3. Model

4. Output at Idle 300 Amps, 5. Output at Maximum Speed 300 Amps
6. Maximum Warranted Speed N/A RPM, 7. Speed at Idle N/A RPM
8. Drive Type N/A, 9. Cooling Type ________

J. Air Compressor
1. Manufacturer Powerex, 2. Type Direct Coupled Scroll Compressor, 3. Capacity, at Idle N/A cfm
4. Capacity, at Maximum Speed N/Acfm, 5. Maximum Warranted Speed 3450 RPM
6. Speed Idle N/A, 7. Drive Type Direct coupled air compressor powered by electric motor

K. Axle, Front
1. Manufacturer MAN, 2.Type Reverse Elliot Cast Beam, Drop Center
3. Model Number VOK-07-F, 4.Gross Axle Weight Rating 15,873 lb.

L. Axle, Rear
1. Manufacturer MAN, 2.Type Single Reduction, Driven
3. Model Number HY-1350-F, 4.Gross Axle Weight Rating 28,660 lb.

M. Drive Axle Ratio
1. Axle Ratio 5.67:1, 2.Final N/A

N. Suspension System
1. Manufacturer New Flyer of America, 2.Type 2 Pneumatic Firestone (Front), 4 Pneumatic Firestone (Rear)
3. Springs: 2 Koni (Front), 2 Koni (Rear)

O. Wheels
1. Make Alcoa 2. Size 22.5" x 8.25" 3. Capacity 7,824
4. Material Aluminum Buffed

P. Tires
1. Manufacturer Michelin 2. Type X InCity Z 3. Size 305/70R22.5
4. Load Range/Air Pressure L/125 PSI

Q. Steering Power
1. Pump
a. Manufacturer & Model No. Parker Hannifin
b. Type DC 3-Phase Brushless with DC Drive Controller
c. Relief Pressure 2,175 psi

2. Booster
a. Manufacturer & Model No. Sheppard
b. Type Recirculating Ball
c. Ratio 23:1

3. Power Steering Fluid Capacity 6 gals.

4. Effort at Steering Wheel 9 lb.
(Unloaded Stationary Bus on dry asphalt pavement)

R. Brakes
1.Make of Fundamental Brake System
MGM
2.Brake Chamber Vendor's Size & Part No.
a. Front 1627717 & 1627718
b. Rear ________

5. Brake Block Manufacturer Ferodo 4567

7. Brake Blocks Per Shoe
a. Front 2
b. Rear 2

3. Slack Adjusters Vendor's Type & Part No.
a. Front
1. Right MAN N2G
2. Left MAN N2G

b. Rear
1. Right MAN N2G
2. Left MAN N2G

c. Length
1. Front Take-up N/A in.
2. Rear Take-up N/A in.

6. Brake Block Identification
a. Front
1. Forward 4567
2. Reverse 4567

b. Rear
1. Forward 4567
2. Reverse 4567

4. Brake Drums-Disc/Rotors
a. Front (Drum /Rotor)
1. Manufacturer MAN
2. Part Number SN 7000 Disc Lateral Run Out: 0.002" (max) Caliper Guides: 0.079" (max play)
3. Diameter (Drum/Rotor) Pad Clearance: 0.027" Pad Thickness: 0.079" Disc Thickness: 1.457"
4. Thickness/Number of Turns ____in./____times

b. Rear (Drum /Rotor)
1. Manufacturer MAN
2. Part Number Pad Length: 7.09" (180 mm) Thickness: 0.827" (21 mm) Total Pad Area per Axle: 121.52 sq in Pad Clearance: 0.027- 0.047 " (0.7 to 1.2 mm)
3. Diameter (Drum/Rotor) Pad Thickness (min) : 0.079" (2 mm) Disc Thickness (min): 1.457" (37mm)
4. Thickness/Number of Turns ____in./____times

8. Brake Block Widths
a. Front 3.378 in.
b. Rear 3.378 in.

9. Brake Block Lengths
a. Front 9.5 in.
b. Rear 9.5 in.

10. Brake Block Thickness
0.827 in.

11. Brake Block Area Per Wheel
a. Front 128 sq. in.
b. Rear 128 sq. in.

S. Cooling System
1. Radiator
a. Manufacturer N/A________________, b. Type N/A____________, c. Model Number______________
d. Number of Tubes__ , e. Tubes Outer Diameter__ in., f. Fins Per Inch____Fins, g. Fin Thickness_________in.
2. Total Cooling and Heating System Capacity____gals.,
3. Radiator Fan Speed Control_________Type
4. Surge Tank Capacity________gals.,
5. Engine Thermostat Temperature Setting _______degrees (F)
6. Overheat Alarm Temperature Sending Unit Setting______degrees (F),

7. Condenser Fan
a. Manufacturer & Model _Thermo King EBM Brushless_
b. Fan Diameter 17.7____in.
c. Speed Maximum 2370RPM______
d. Flow Rate Maximum N/A________CFM

8. Condenser Fan Drive, if Separate Condenser Used - Motor
a. Manufacturer Thermo King_____
b. Model Brushless_____________
c. Type Encased axial____
d. Horse Power 0.75____________
e. Operating Speed 1390 rpm______________

9. Evaporator(s)/Condenser(s)
Evaporators
Condensers
a. Manufacturer & Model _Thermo King___________
b. Quantity/Bus ____________________
c. Number of Rows/Core _5 rows________________
d. Number of Fins 9______in. _______in.
e. Outer Diameter of Tube 0.375___in. .
f. Fin Thickness 0.008__in.

10. Expansion Valve
Manufacturer and Model N/A_________________

11. Filter - Drier
Manufacturer and Model Thermo King Disposable In-line_

a.

12. Heater Blowers
Main Auxiliary
a. Manufacturer & Model _Thermo King___________
b. Horsepower ____________________
c. Speed ____________________________________
d. Capacity____________________________________
17. Driver's Heater
a. Manufacturer & Model MCC________________
b. Capacity 56,880______________BTU

T. Batteries
1. Manufacturer _Odyssey____________________________
2. Model _Group 31____
3. Type _Absorbed Glass Mat (AGM)___

U. Electrical Multiplex System
1. Manufacturer _Vansco__________________________
2. Model _VMM1615___
3. Type ________________

V. Energy Storage
1. Type _Lithium Ion_________________________
2. Cells____________

3. Battery Pack Voltage 388 kWh__________
4. Weight ________

W. Fire Detection System
1. Manufacturer Amerex__________________________
2. Model Number TBD________
3. Fire Detectors 1_______________
4. Type Thermal__
5. Number of Detectors 4

PROPOSER NAME: ______________________________

Buy America

Appendix D - ABB HVC-C UL Depot Charging Equipment Product Sheets and Specifications

PRODUCT LEAFLET

Electric Vehicle Infrastructure
HVC-C UL depot charging for electric fleets

—
HVC Depot Boxes and power cabinets, lined up at a depot site.

ABB HVC-C UL Depot Charging systems offer a highly reliable, intelligent and cost-effective solution to charge large EV fleets such as buses, trucks and other commercial vehicles.

A practical solution for busy depots
ABB Heavy Vehicle Charger (HVC) products enable electric buses and trucks to charge at the depot ensuring flexibility and scale for every fleet operation that is transitioning to zero-emission transportation.

Key Benefits
+ Smart charging
+ Small infrastructure footprint at vehicle interface
+ Flexible design for roof and floor mounting
+ SAE J1772 CCS and OCPP 1.6 compliant
+ Remote diagnostics and management tools

Sequential Charging
Improving total cost of ownership is easy using the sequential charging feature offered by ABB's depot chargers. This feature allows connection of up to three depot charge boxes with a single power cabinet and vehicles are charged sequentially over time. The system can follow an embedded, predefined charging process or remote triggers sent by a fleet management system via OCPP 1.6.

- Vehicles are charged with high power, maximizing vehicle availability
- The required grid connection is smaller, reducing upfront investments and operational costs
- The compact depot box is easy to install at sites with space constraints
- Optimal utilization of installed infrastructure meaning lower investments in charging equipment.

Buy America
ABB can offer the HVC-C Depot Charging Solution with compliance to the Buy America Act Rule 49 CFR Part 661.5.

Future-proof modular design
Power cabinets can be upgraded from 100 or 150 kW in the field, as well as add additional depot charge boxes, allowing operators to scale their operation and to spread investments over time.

Safe and reliable operation
ABB fast chargers are designed to the highest international electrical, safety, and quality standards, and are certified by notified bodies - guaranteeing safe and reliable operation.

Connectivity and remote services
ABB chargers come with an extensive suite of connectivity features including remote services such as monitoring, management, diagnostics and software upgrades. These advanced services provide equipment owners with powerful insights into their charging operations while enabling high uptime.

ABB is your experienced partner
ABB HVC products are based on a decade of high power experience in EV charging solutions. ABB has installed over 13,000 fast charging systems in more than 80 countries – and is the leading EV infrastructure technology supplier globally.

Overnight charging 100 kW - 150 kW

A field upgradeable system with future proof reliability

HVC 100C

HVC 150C

HVC 150C*

—
A power upgrade can be done in the field by adding an extra power module. No groundworks, digging and disturbance to the site are required.

—
* 150 kW overnight charging system with three depot charge boxes; shown mounted on pedestal option.

Technical specifications			
Configurations		**HVC 100C**	**HVC 150C**
Maximum output power		100 kW	150 kW
AC Input voltage		UL: 3-phase, 480Y/277 VAC +/- 10% (60 Hz) CSA: 3-phase, 600Y/347 VAC +/-10% (60 Hz)	
AC Input connection		L1, L2, L3, GND (no neutral)	
Rated input power		117 kVA	170 kVA
Rated input current		UL: 132 A / CSA: 108 A	UL: 198 A / CSA: 168 A
Recommended upstream circuit breaker(s)		UL: 1 x 200 A / CSA: 1 x 150 A	UL: 1 x 250 A / CSA: 1 x 250 A
Output voltage range		150 – 850 VDC	
Maximum DC output current		166 A	200 A
Vehicle connection interface		CCS/Combo Type 1 Connector	
Cable length		3.5 m (11.5 ft) standard; 7 m (23 ft) optional	
DC connection standard		SAE J1772 - IEC 61851-23 / DIN 70121 - ISO 15118	
Environment		Indoor/Outdoor	
Operating temperature		Standard: -10 °C to +50 °C (de-rating characteristic applies) Optional: -35 °C to +50 °C	
Protection		Power Cabinet: IP54 – IK10 (equivalent to NEMA 3R) Depot Charge Box: IP65 - IK10	
Network connection		GSM/3G modem | 10/100 base-T Ethernet	
Compliance and Safety		CSA No. 107.1-16 and UL 2202 certified by TUV BA Rule 49 CFR Part 661.5 (Optional)	
Dimensions			
Power Cabinet	Dimensions (H x W x D)	2030 x 1170 x 770 mm / 79.9 x 46.1 x 30.3 in	
	Weight	1340 kg / 2954 lbs	
Depot Charge Box (without pedestal)	Dimensions (H x W x D)	800 x 600 x 210 mm / 31.5 x 23.6 x 8.3 in	
	Weight	61 kg / 134.5 lbs (with 7 m / 23 ft cable)	
Depot Charge Box (with pedestal)	Dimensions (H x W x D)	1914 x 600 x 400 mm / 75.4 x 23.6 x 16.3 in	
	Weight	181 kg / 398 lbs (with 7 m / 23 ft cable)	

—
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Phoenix, AZ 85040
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Phone: 800-435-7365
E-mail: US-evci@us.abb.com

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—
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PRELIMINARY (FOR INFORMATION ONLY)
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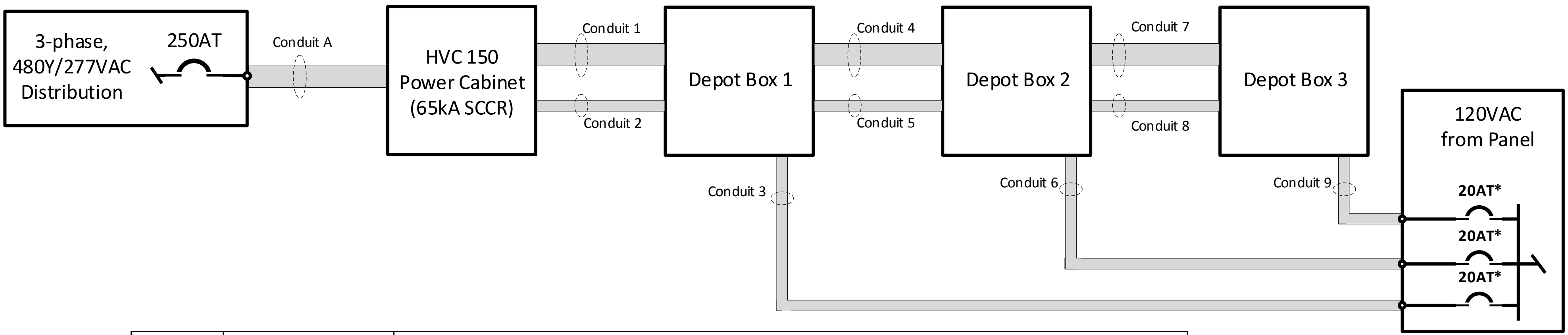

CONDUIT IDs	FUNCTION OF INTERNAL CABLES	CABLE SELECTION
A	AC PRIMARY POWER	(3) 250 MCM TO 500 MCM (CU, 75°C, 600V) + (1) #4 AWG (CU, 75°C, 600V, EGC)
1	DC POWER (200A)	(2) 3/0 AWG TO 350 MCM (CU, 75°C, 1KV) + (3) #2 AWG (CU, 75°C, 600V, EGC)
4	DC POWER (200A)	(2) 3/0 AWG TO 350 MCM (CU, 75°C, 1KV) + (2) #2 AWG (CU, 75°C, 600V, EGC)
7	DC POWER (200A)	(2) 3/0 AWG TO 350 MCM (CU, 75°C, 1KV) + (1) #2 AWG (CU, 75°C, 600V, EGC)
2	INTERLOCK	(1) CABLE THAT HAS (1) TWISTED PAIR OF #18 AWG (SHIELDED, 600V, 120Ω CHAR. IMPEDANCE)
	FIBER CAN	(1) MULTIMODE FIBER (OM3, 8 STRANDS, PCF OR FIBERGLASS, WITH ST CONNECTORS, SEE MANUAL)
	FIBER ETHERNET	
5, 8	FIBER CAN	(1) MULTIMODE FIBER (OM3, 4 STRANDS, PCF OR FIBERGLASS, WITH ST CONNECTORS, SEE MANUAL)
	ETHERNET	(1) ETHERNET (S/FTP, CAT6/CAT5e, 600V, 100Ω CHAR. IMPEDANCE, WITH RJ45 CONNECTORS)
	INTERLOCK	(1) CABLE THAT HAS (2) TWISTED PAIRS OF #18 AWG (SHIELDED, 600V, 120Ω CHAR. IMPEDANCE); EACH PAIR SHOULD HAVE TWO WIRES AND THE CABLE SHOULD HAVE FOUR TOTAL WIRES
	DC GUARD	
3, 6, 9	120VAC CONTROL POWER	(1) CABLE THAT HAS (2) #12 AWG (CU, 75°C, 600V) + (1) #12 AWG (CU, 75°C, 600V, EGC)

*** Control power feeds to depot boxes must have 30mA Ground Fault Circuit Interrupter and support max inrush current of 100A for < 5ms**

N1. Equipment enclosures must be externally labeled according to local codes by the installing contractor to notify service personnel to verify absence of voltage from more than one power source.

N2. Customer must ensure wire sizes for main AC input (in conduit A), DC power (in conduits 1, 4, & 7), and control power (in conduits 3, 6, & 9) maintain an acceptable voltage drop based on their lengths and account for other application specific requirements. There shall be no greater than 2% voltage drop on the complete DC cabling between the HVC power cabinet and the depot box which has the farthest total DC cable distance from the HVC power cabinet. Voltage drop calculations for the DC cable runs shall be performed using 200ADC and the lowest expected electric vehicle battery voltage from the HVC power cabinet output as assumptions. Typically 300VDC is a sufficient worst case assumption for the lowest expected electric vehicle battery voltage, however, it is the customer's responsibility to ensure this is sufficient for each specific application. Voltage drop assumptions and calculations for the AC cables must be defined by the customer.

N3. Each depot box must have an equipment ground conductor directly connected to the HVC 150 power cabinet. As a result conduit IDs 1 & 4 show more than one equipment ground conductor.

N4. It is recommended to consider installing conduits for the future use case if applicable. For example, if on Day One only one or two depot boxes are installed and there is a possibility the site owner would want two or three depot boxes installed in the future, consider installing the conduits for the future possible depot boxes on Day One also. See ABB's conduit and cable concept for the future use case scenario if applicable.

N5. This concept does not show the presence of ground electrodes. It is the responsibility of the customer to determine if a ground electrode per each HVC power cabinet and depot box is required. See the product installation manual for more details.

TITLE

HVC-C 150kW Charging System - Conduits & Cables for (3) Depot Boxes

REV	DATE	BY	DESCRIPTION	DRAWING	REV
A	28/AUG/20		PRELIMINARY FOR DISCUSSION		A
-	-	-	-		
-	-	-	-		

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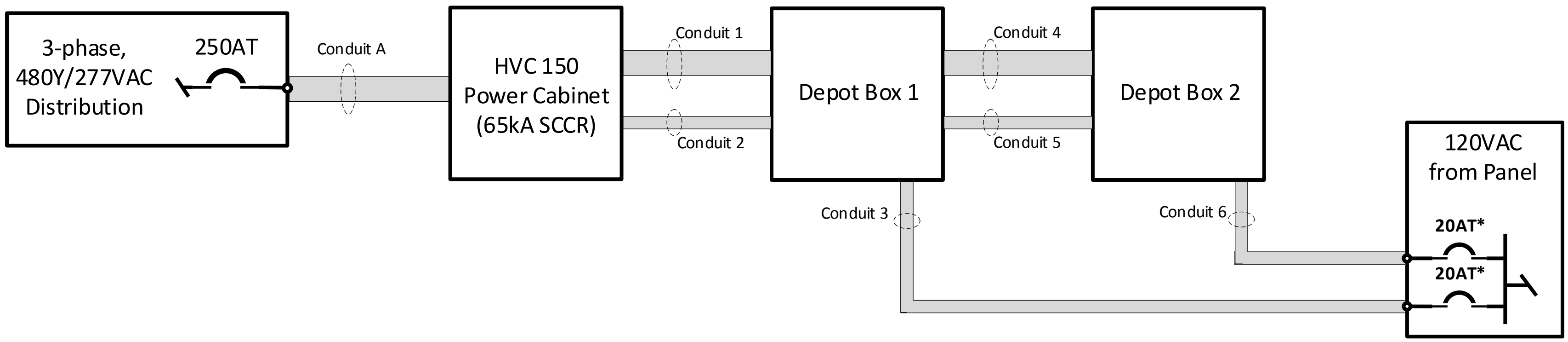


*** Control power feeds to depot boxes must have 30mA Ground Fault Circuit Interrupter and support max inrush current of 100A for < 5ms**

CONDUIT IDs	FUNCTION OF INTERNAL CABLES	CABLE SELECTION
A	AC PRIMARY POWER	(3) 250 MCM TO 500 MCM (CU, 75°C, 600V) + (1) #4 AWG (CU, 75°C, 600V, EGC)
1	DC POWER (200A)	(2) 3/0 AWG TO 350 MCM (CU, 75°C, 1KV) + (2) #2 AWG (CU, 75°C, 600V, EGC)
4	DC POWER (200A)	(2) 3/0 AWG TO 350 MCM (CU, 75°C, 1KV) + (1) #2 AWG (CU, 75°C, 600V, EGC)
2	INTERLOCK	(1) CABLE THAT HAS (1) TWISTED PAIR OF #18 AWG (SHIELDED, 600V, 120Ω CHAR. IMPEDANCE)
	FIBER CAN	(1) MULTIMODE FIBER (OM3, 8 STRANDS, PCF OR FIBERGLASS, WITH ST CONNECTORS, SEE MANUAL)
	FIBER ETHERNET	
5	FIBER CAN	(1) MULTIMODE FIBER (OM3, 4 STRANDS, PCF OR FIBERGLASS, WITH ST CONNECTORS, SEE MANUAL)
	ETHERNET	(1) ETHERNET (S/FTP, CAT6/CAT5e, 600V, 100Ω CHAR. IMPEDANCE, WITH RJ45 CONNECTORS)
	INTERLOCK	(1) CABLE THAT HAS (2) TWISTED PAIRS OF #18 AWG (SHIELDED, 600V, 120Ω CHAR. IMPEDANCE); EACH PAIR SHOULD HAVE TWO WIRES AND THE CABLE SHOULD HAVE FOUR TOTAL WIRES
	DC GUARD	
3, 6	120VAC CONTROL POWER	(1) CABLE THAT HAS (2) #12 AWG (CU, 75°C, 600V) + (1) #12 AWG (CU, 75°C, 600V, EGC)

N1. Equipment enclosures must be externally labeled according to local codes by the installing contractor to notify service personnel to verify absence of voltage from more than one power source.

N2. Customer must ensure wire sizes for main AC input (in conduit A), DC power (in conduits 1, 4, & 7), and control power (in conduits 3, 6, & 9) maintain an acceptable voltage drop based on their lengths and account for other application specific requirements. There shall be no greater than 2% voltage drop on the complete DC cabling between the HVC power cabinet and the depot box which has the farthest total DC cable distance from the HVC power cabinet. Voltage drop calculations for the DC cable runs shall be performed using 200ADC and the lowest expected electric vehicle battery voltage from the HVC power cabinet output as assumptions. Typically 300VDC is a sufficient worst case assumption for the lowest expected electric vehicle battery voltage, however, it is the customer's responsibility to ensure this is sufficient for each specific application. Voltage drop assumptions and calculations for the AC cables must be defined by the customer.

N3. Each depot box must have an equipment ground conductor directly connected to the HVC 150 power cabinet. As a result conduit IDs 1 & 4 show more than one equipment ground conductor.

N4. It is recommended to consider installing conduits for the future use case if applicable. For example, if on Day One only one or two depot boxes are installed and there is a possibility the site owner would want two or three depot boxes installed in the future, consider installing the conduits for the future possible depot boxes on Day One also. See ABB's conduit and cable concept for the future use case scenario if applicable.

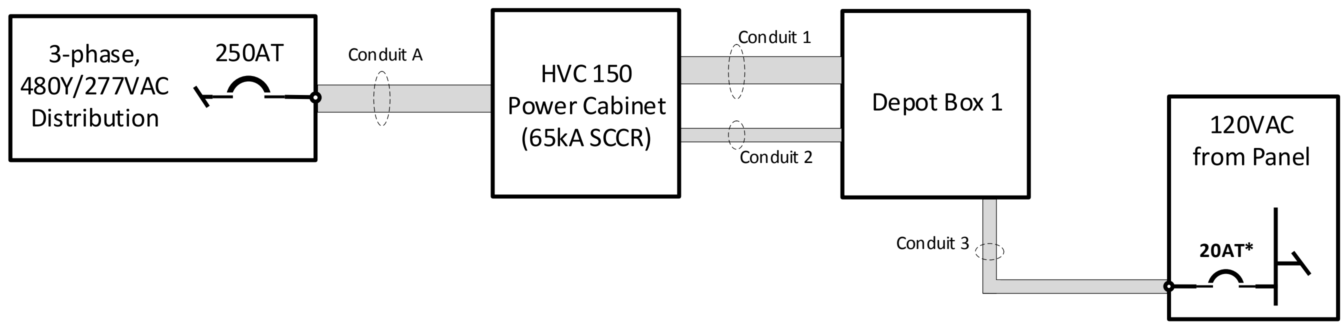
N5. This concept does not show the presence of ground electrodes. It is the responsibility of the customer to determine if a ground electrode per each HVC power cabinet and depot box is required. See the product installation manual for more details.

ABB

TITLE
HVC-C 150kW Charging System - Conduits & Cables for (2) Depot Boxes

REV	DATE	BY	DESCRIPTION	DRAWING	REV
A	28/AUG/20		PRELIMINARY FOR DISCUSSION		A
-	-	-	-		
-	-	-	-		

PRELIMINARY (FOR INFORMATION ONLY)
ABB is not liable for information contained herein which contradicts local codes, permitting requirements, and other requirements. ABB highly recommends a qualified design engineering firm to be responsible for the charging installation to ensure all of these requirements are met. See the ABB product installation manual for more details.



* Control power feeds to depot boxes must have 30mA Ground Fault Circuit Interrupter and support max inrush current of 100A for < 5ms

CONDUIT IDs	FUNCTION OF INTERNAL CABLES	CABLE SELECTION
A	AC PRIMARY POWER	(3) 250 MCM TO 500 MCM (CU, 75°C, 600V) + (1) #4 AWG (CU, 75°C, 600V, EGC)
1	DC POWER (200A)	(2) 3/0 AWG TO 350 MCM (CU, 75°C, 1KV) + (1) #2 AWG (CU, 75°C, 600V, EGC)
2	INTERLOCK	(1) CABLE THAT HAS (1) TWISTED PAIR OF #18 AWG (SHIELDED, 600V, 120Ω CHAR. IMPEDANCE)
	FIBER CAN	(1) MULTIMODE FIBER (OM3, 8 STRANDS, PCF OR FIBERGLASS, WITH ST CONNECTORS, SEE MANUAL)
	FIBER ETHERNET	
3	120VAC CONTROL POWER	(1) CABLE THAT HAS (2) #12 AWG (CU, 75°C, 600V) + (1) #12 AWG (CU, 75°C, 600V, EGC)

N1. Equipment enclosures must be externally labeled according to local codes by the installing contractor to notify service personnel to verify absence of voltage from more than one power source.

N2. Customer must ensure wire sizes for main AC input (in conduit A), DC power (in conduits 1, 4, & 7), and control power (in conduits 3, 6, & 9) maintain an acceptable voltage drop based on their lengths and account for other application specific requirements. There shall be no greater than 2% voltage drop on the complete DC cabling between the HVC power cabinet and the depot box which has the farthest total DC cable distance from the HVC power cabinet. Voltage drop calculations for the DC cable runs shall be performed using 200ADC and the lowest expected electric vehicle battery voltage from the HVC power cabinet output as assumptions. Typically 300VDC is a sufficient worst case assumption for the lowest expected electric vehicle battery voltage, however, it is the customer's responsibility to ensure this is sufficient for each specific application. Voltage drop assumptions and calculations for the AC cables must be defined by the customer.

N3. Each depot box must have an equipment ground conductor directly connected to the HVC 150 power cabinet. As a result conduit IDs 1 & 4 show more than one equipment ground conductor.

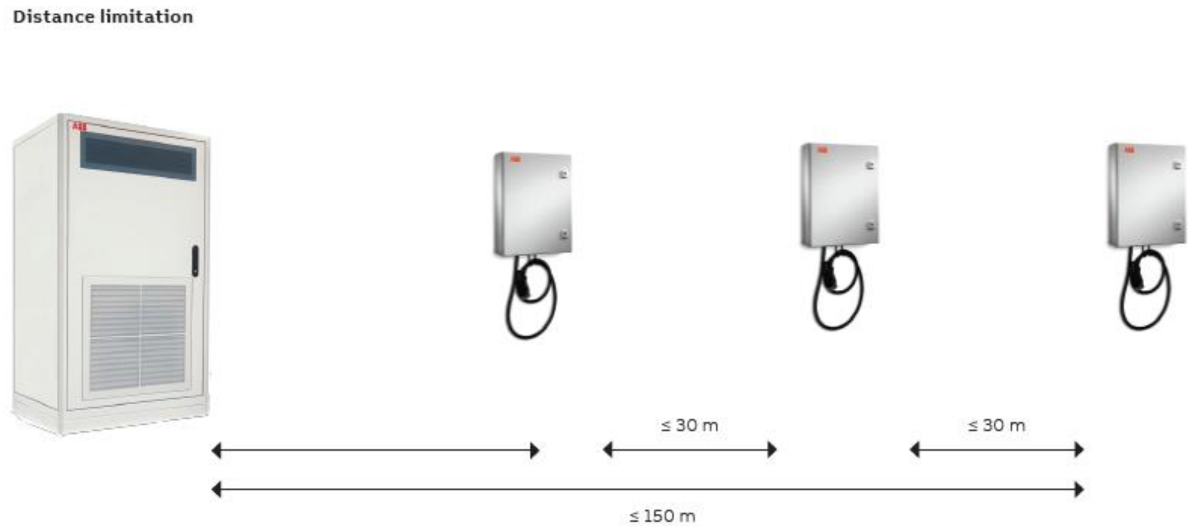
N4. It is recommended to consider installing conduits for the future use case if applicable. For example, if on Day One only one or two depot boxes are installed and there is a possibility the site owner would want two or three depot boxes installed in the future, consider installing the conduits for the future possible depot boxes on Day One also. See ABB's conduit and cable concept for the future use case scenario if applicable.

N5. This concept does not show the presence of ground electrodes. It is the responsibility of the customer to determine if a ground electrode per each HVC power cabinet and depot box is required. See the product installation manual for more details.

TITLE
HVC-C 150kW Charging System - Conduits & Cables for (1) Depot Box

REV	DATE	BY	DESCRIPTION	DRAWING	REV
A	28/AUG/20		PRELIMINARY FOR DISCUSSION		A
-	-	-	-		
-	-	-	-		

PRELIMINARY (FOR INFORMATION ONLY)
ABB is not liable for information contained herein which contradicts local codes, permitting requirements, and other requirements. ABB highly recommends a qualified design engineering firm to be responsible for the charging installation to ensure all of these requirements are met. See the ABB product installation manual for more details.



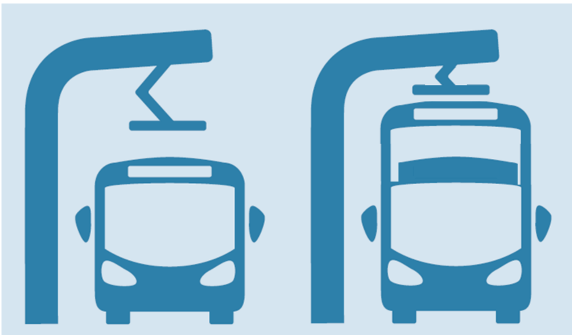
More details on cable entry into the depot box coming soon...

TITLE					
HVC-C 150kW Charging System – Misc. Install Considerations					
REV	DATE	BY	DESCRIPTION	DRAWING	REV
A	28/AUG/20		PRELIMINARY FOR DISCUSSION		A
-	-	-	-		
-	-	-	-		

Appendix E - OPPCharge Specifications, 2nd Edition

OPPCharge
Common Interface for Automated Charging of Hybrid Electric and Electric Commercial Vehicles

2nd Edition



April, 2019

Table of Contents

1. Scope of this document

This document details technical descriptions and considerations for OPPCharge. OPPCharge is defined through the normative standards and the documented deviations from these. This document further contains informative material gathered from existing OPPCharge installations.

2. Objective

The objective is to provide fundamental technical information interface specification required to develop and launch interoperable OPPCharge solutions for commercial operation.

The information provided in this document is intended for:

- Commercial vehicle manufacturers (OEMs)
- Infrastructure equipment manufacturers (EVSE)
- Commercial vehicle and transport operators

Reasonable effort was made to ensure that the information in this document is accurate and complete at the time of its publication. However, the specifications and other information can be subject to change.

3. General

OPPCharge is defined and identified by:

- An Automatic Connecting System (ACS)
- Electric Vehicle Supply Equipment – Type DC conductive charging
- Fixed conductive rails attached to the roof of the vehicle.
- 4 conductive poles
- Wi-Fi communication & control

OPPCharge is a technical solution for charging batteries in electrically powered vehicles. It deploys the principle of opportunity charging, where charging stations are distributed at select locations to replenish vehicle batteries during operation; thus reducing the overall system costs, weight on each vehicle and impact on power grid.

OPPCharge is an automatic interface for charging electrically powered vehicles based on established industry standards, with the intention of supporting a common charging interface for commercial vehicles. Supplier-independent interface can lead to cost reductions, benefiting the city’s ability to offer its citizens more sustainable transportation solutions.

4. Normative References

IEEE 802.11a (1999)
IEEE wireless LAN standard - amendment a
ISO/IEC 15118-1 (2013)
Road vehicles -- Vehicle to grid communication interface
ISO/IEC 15118-2 (2012 DIS)
Part 2: Network and application protocol requirements
ISO/IEC 15118-3 (2015)
Part 3: Physical and data link layer requirements
OpenV2G *OpenV2G edition 0.7 XML schedule*

EN 62262 (2002)
Degrees of protection provided by enclosures for electrical equipment against external mechanical impacts (IK code)
EN 50122-1 (2011)
Railway applications - Fixed installations - Electrical safety, earthing and the return circuit - Part 1: Protective provisions against electric shock

IEC 61851-1 (2017 /edition 3.0)
Electric Vehicle Conductive Charging System – General requirements
IEC 61851-21-2 (2017 /edition 1.0)
Electric vehicle charging system – EMC requirements for OFF board electric vehicle charging systems
IEC 61851-23 (2014 /edition 1.0)
Electric Vehicle Conductive Charging System – DC electric vehicle charging station

IEC 61439-7 (2018/ edition 1.0 CFDIS)
Low voltage switchgear and control assemblies

5. Abbreviations

AC	Alternating Current
ACD	Automated Connection Device
ACD Counterpart	Contact system on vehicle roof also named “Charging Rails”
ACS	Automated Connection System
CE	Control Earth
CP	Control Pilot
DC	Direct Current
EMC	Electro-Magnetic Compatibility
EMI	Electro Magnetic Interference
EV	Electric Vehicle
EVCC	Electric Vehicle Communication Controller
EVSE	Electric Vehicle Supply Equipment – “Charger”
GND	Ground
OEM	Original Equipment Manufacturer
PE	Protective Earth
SECC	Supply Equipment Communication Controller
STD	Standard
TBC	To Be Confirmed
TBD	To Be Defined/Decided
TVS	Traction voltage system
-ve	Negative Pole
+ve	Positive Pole

6. Description

More detailed descriptions of the OPPCharge definitions & identifiers follows in this section.

6.1. Automatic Connecting System

The Automatic Connecting System, ACS, controls and monitors a connection device for conductive charging (e.g. pantograph) fixated to the infrastructure above the vehicle (e.g. on pole, archway, bridge or ceiling etc.).

The Automatic Connecting Device, ACD, is the automated extendable/retractable mechanism to connect/disconnect EVSE conductive components to vehicle interface.

6.2. DC Electric Vehicle Conductive Charging System

The DC Electric vehicle conductive charging system implements the following standards.
IEC 61851-1
IEC 61851-23

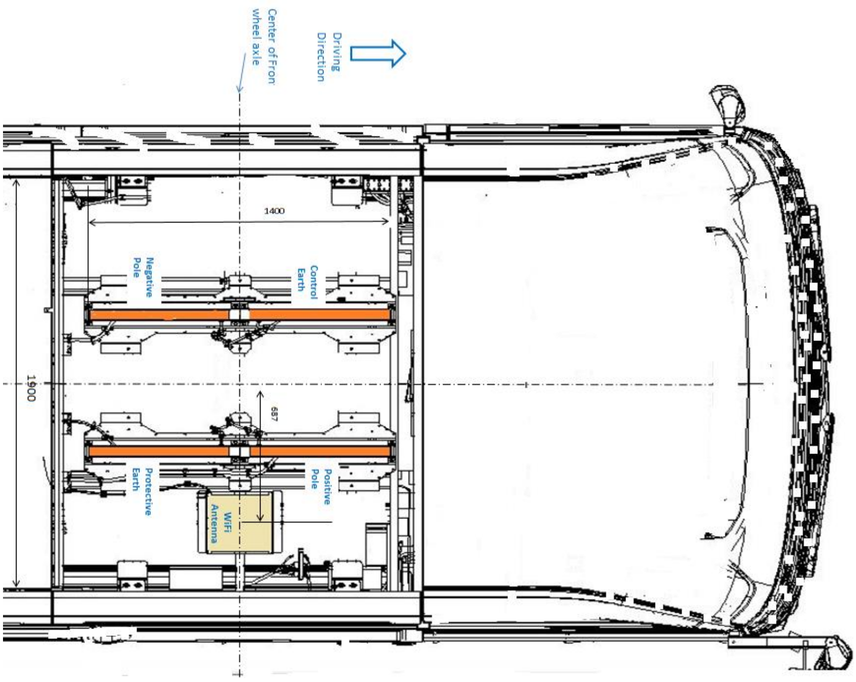
The voltage range is 450V to 750V

The exceptions to the above mentioned standards define the ACS functionality (in work for updated 61851) replacing a manually operated cable & plug system.
This is specified in the following document “Process of Energy Supply (draft)”.
Note: Release documentation is currently in clarification through ASSURED with regard to OPPCharge.

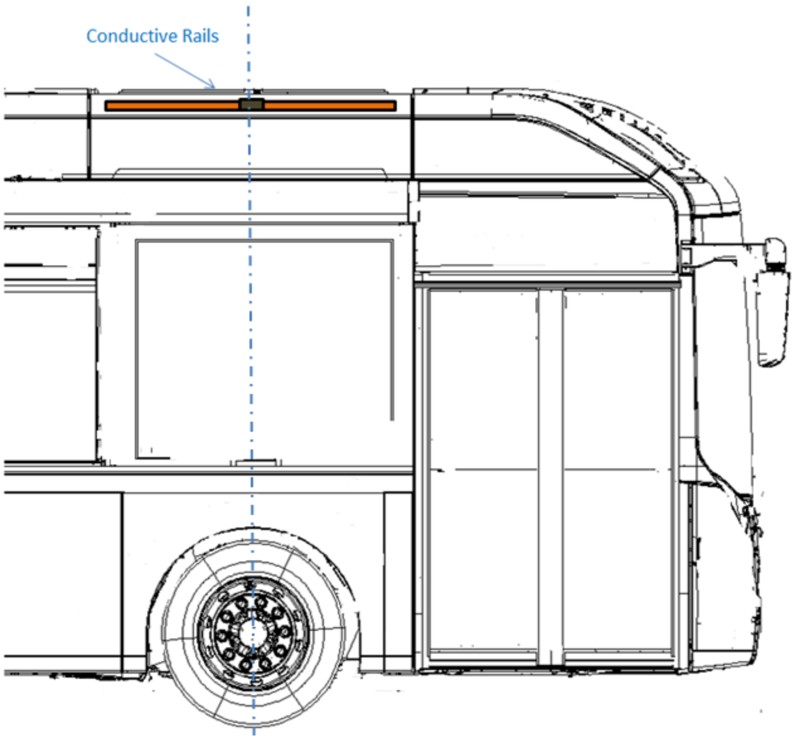
Protection by clearance as specified in EN 50122-1 (2011) is required

6.3. Fixed Rails attached to the roof of the vehicle.

The Conductive Rails are centred over the front axle of the vehicle for alignment.



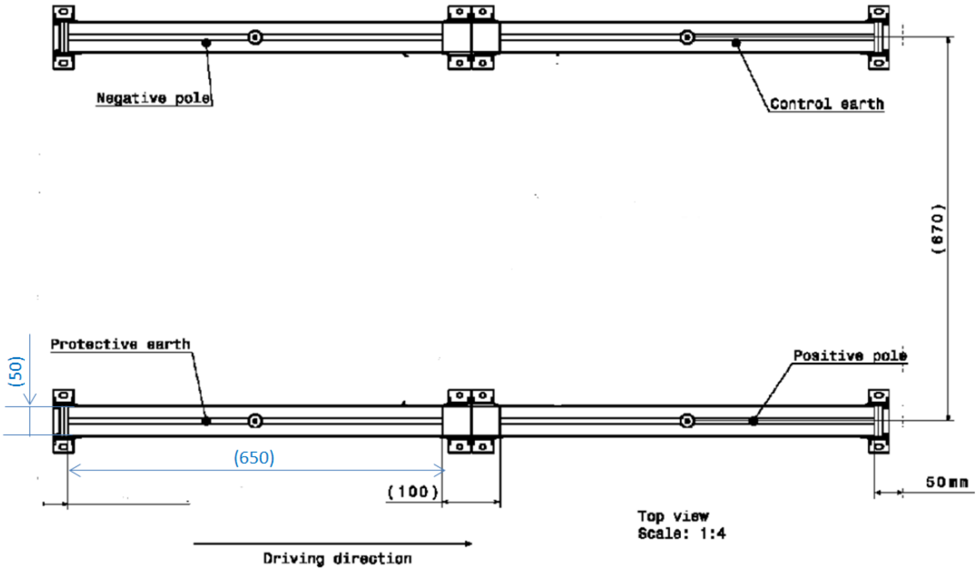
1 Top View of bus roof front section highlighting conductive rails and Wi-Fi antenna



2 Side View of bus roof front section highlighting conductive rails

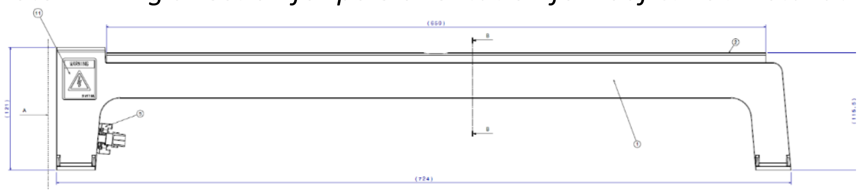
6.4. Conductive Poles

OPPCharge uses 4 conductive poles for the charge interface;
Positive, Negative, Protective Earth (PE) and Control Earth (CE).



3 Top View of conductive rails on roof with dimensions

Note: Driving direction for pole orientation for roof & ASC installation.



4 Side view of a single rail

All functions of the ACD Rails shall have very precise mechanically connected and disconnected positions.
It shall not be possible for the ACD to remain in an undefined position. No unattended activation shall occur physically or electrically.

The minimum application force of the ACD Rails shall be sufficient to fulfil charging requirements.

The total maximum application force for the ACD Rails shall be less than 600 N.

The maximum application force for each pole shall be less than 150 N during connection, charging and disconnection.

Impact sound created by the contact of the ACD contactors shall be lower than 50 dB. Measuring points are inside vehicle and adjacent to bus roof at rail position.

6.5. Wi-Fi Communication

OPPCharge uses Wi-Fi as the communication method between the vehicle and EVSE. Directional antennas are used for communication and association.

IEEE 802.11a specifications are implemented for Wi-Fi communication.

OPPCharge Wi-Fi operates using 5GHz channels.

ISO/IEC 15118 is used as High-level protocol for charging communication with the modification listed within OPPCharge.org.

IEC 61851-1 is used as Low-level protocol for charging communication.
Control Pilot states are implemented.

6.6. Position

The relative position of the ACS and the vehicle's conductive rails is centered over the front axle of the vehicle.

This allows for interoperability between different infrastructure and vehicle manufacturers
The positioning of the vehicle is secured using the front wheel as a reference.

7. Interfaces

7.1. Electrical

Electrical interfaces defined in detail in IEC 68151 standards
Isolation resistance monitoring according to IEC 61851-23

Output Requirements	
Power levels (kW)	150, 300, & 450 kW
DC Voltage (V DC)	450 – 750
Frequency (Hz)	50/60 ± 2 [1]
Output Current (A)	Sufficient for output power 0 to 200 @ 750 V – 150 kW 0 to 400 @ 750 V – 300 kW 0 to 600 @ 750 V – 450 kW

Performance Requirements	
peak to peak ripple 0 to100 (A) DC	10
peak to peak ripple >100 (%)(I_{ripple} / I_{dc})	< 10
Max Voltage peak to peak ripples during charge (V)	±5
Minimum output current (A)	0
Maximum output current (A)	Sufficient for output power
Maximum incremental steps (A) * resolution*	2
Duty Cycle (hrs/day)	18 or TBD[3]
Short Circuit Current Protection *"pole to pole"* (A)	3000
Short Circuit Current Protection timing (ms)	100
Charger Pole to Pole capacitance (mF)	< 10
Differential Mode inductance: Charge Automatic Connecting Device (µH)	≤ 100
Blocking Voltage protection for reversed current (V)	900

Note[1] Frequency is determined by local electrical standards
Note[3] The duty cycle for the station may be more based on bus operation cycles.

7.1.1. Electric safety

The electrical safety levels for the application shall be met according to standards, regulations, norms and legal requirements. All hazardous voltages shall be clearly marked and shielded from unauthorized handling.

To ensure safe vehicle operation the EVSE shall control the following electrical safety considerations amongst others not listed here. Internal Charging station failure should be trapped internally. Built-in protection against short-circuits, voltage and current surges is required, conductors carrying TVS current shall be designed to withstand short-circuiting.

Consider: Emergency Shut off Switch on EVSE

7.1.2. Discharge of Capacitances at Shut- down

To avoid that the cable connector exposes parts with hazardous voltage when disconnected, the DC link capacitance must quickly be discharged at shut-down. There shall be a discharge circuit in the charging station which reduces the capacitor voltage down to a non-hazardous level (<60 V DC) in less than 5 s when the system is disabled due to hardware or a software signal.

7.1.3. Insulation voltage withstand level

The appropriate insulation voltage withstands levels are to be chosen with respect to ISO 6469-3 with Class 1 equipment (basic insulation).
The insulation shall withstand 2.5 kV AC RMS and 1100 VDC for 5 min.

7.1.4. Protection against reverse power flow from ESS

The charging station shall be equipped with a protective device against the uncontrolled reverse power from the ESS during charging.

7.1.5. Electromagnetic compatibility

The electromagnetic compatibility shall comply with:

IEC 61851-21-2 as well as relevant normative EMC standards for EVSE

ECE R10 rev5 as well as relevant normative EMC standards for EV

7.1.6. Common mode filter

The Charging converter shall implement a common-mode filter to prevent EMI in the TVS and also to protect itself from EMI.

7.1.7. Electric isolation

The EVSE shall have galvanic isolation between the traction voltage side and the low voltage side.

The EVSE shall have galvanic isolation from the grid supply.

7.1.8. Grounding connection

The off-board charger shall have a ground connection to connect the *Chassis Frame Potential* on the vehicle to the charging station ground. The ground connection is required to be checked for proper connection with the *Chassis Frame* of the bus by the station in order to avoid false isolation resistance reading.

7.1.9. Parasitic capacitance

The parasitic pole-chassis capacitance of the charging system shall be ≤100nF in total in order to reduce leakage currents between TVS and chassis.

7.2. Communication

7.2.1. Wi-Fi (Channel and Password)

Wi-Fi communication shall be implemented on the following channels:
36, 40, 44, 48, 52, 56, 60, 64, 100, 104, 108, 112, 116, 132, 136, 140

For Wi-Fi communication password contact administration at OPPCharge.org.

7.2.2. SW Communication & Process

Low level communication shall be implemented in accordance with IEC 61851-1 and IEC 61851-23 with the exemptions listed in "OPPCharge deviations from IEC 61851-1 and -23"
High level communication implemented is based on ISO 15118 using Wifi as the physical layer. An example implementation may be found in "Network and application protocol specification for Siemens — Volvo OppCharge implementation"

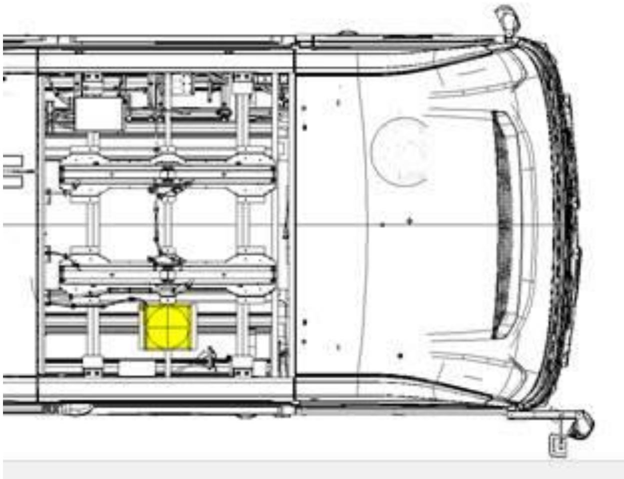
7.3. Wi-Fi antenna information

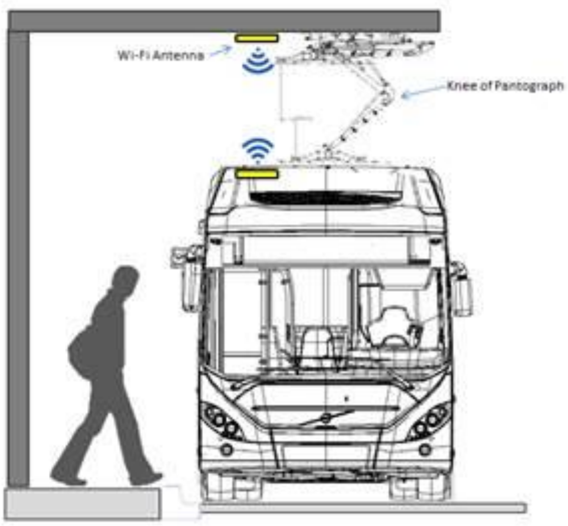
7.3.1. Type:

HUBER+SUHNER
Sencity SPOT-L Antenna: 1356.17.0008
or equivalent directional and polarized antenna.

7.3.2. Position:

Over the RH side of vehicle
Centered over wheel axel
(yellow highlighted marks the position of the Wi-Fi antenna on bus)

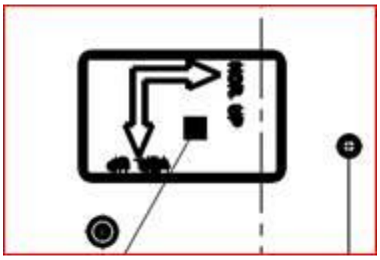




7.3.3. Orientation:

The antenna type defined above is directional and polarized.

Note: the “Horizontal Up” Arrow label on the back side of the antenna shall point in the driving direction of the bus.



7.3.4. Connection:

The electric vehicle communication controller EVCC shall allow charging with a signal strength of -70 dBm or higher.

Recommended signal strength at the EVCC is between -40 dBm to -60 dBm.
The signal shall not be too strong thus communicating with the vehicle well out of range of the charging position.

Installation, routing and connection of Wi-Fi communication equipment shall follow the rules of good practice for installation in order to maximize signal integrity.

7.3.5. Weatherproofing:

This directional antenna type is normally installed vertically to buildings and masts.
Additional measures are required to protect the back-side of the antenna and connector from water intrusion.

7.4. Physical

The OPPCharge equipment shall be designed for:
Commercial electric vehicles LHD & RHD
Heights between 3000 to 4500mm (i.e. single decker, double decker).

It is not intended that the OPPCharge equipment is capable to charge all of the above variants at the same installation.
Keep in mind the variants when designing & preparing equipment (i.e. Poles) for installing ACD, Wi-Fi antennas, cables as well as other equipment.

The ACD shall comply with variable height, angle, pitch and roll due to kneeling function and road conditions.
The ACD shall have satisfactory contact to charge with vehicle rails while the bus is:

- In upright position
- In kneeling position
- During kneeling downward
- During return to upright position
- Passengers boarding and disembarking from vehicle

The OPPCharge equipment shall fulfill Impact Resistance rating IK10 according to EN 62262

Bus Stop designs are most often standardized within regions describing the placement of weather shelters, benches, waste bins, information signs, landscaping and layout of guide stones for the disabled.

Where OPPCharge is implemented at a bus stop the standardized layout may need modification to allow for placing a pole and charge interface. Furthermore the opportunity to align guide-stones and positioning solutions (see chapter 6.6) is possible with design discussions and input together with the city architect.
It is recommended to use of the standardized “Kassel” curbs for bus parking to improve passenger access and allow for less wear on tires.

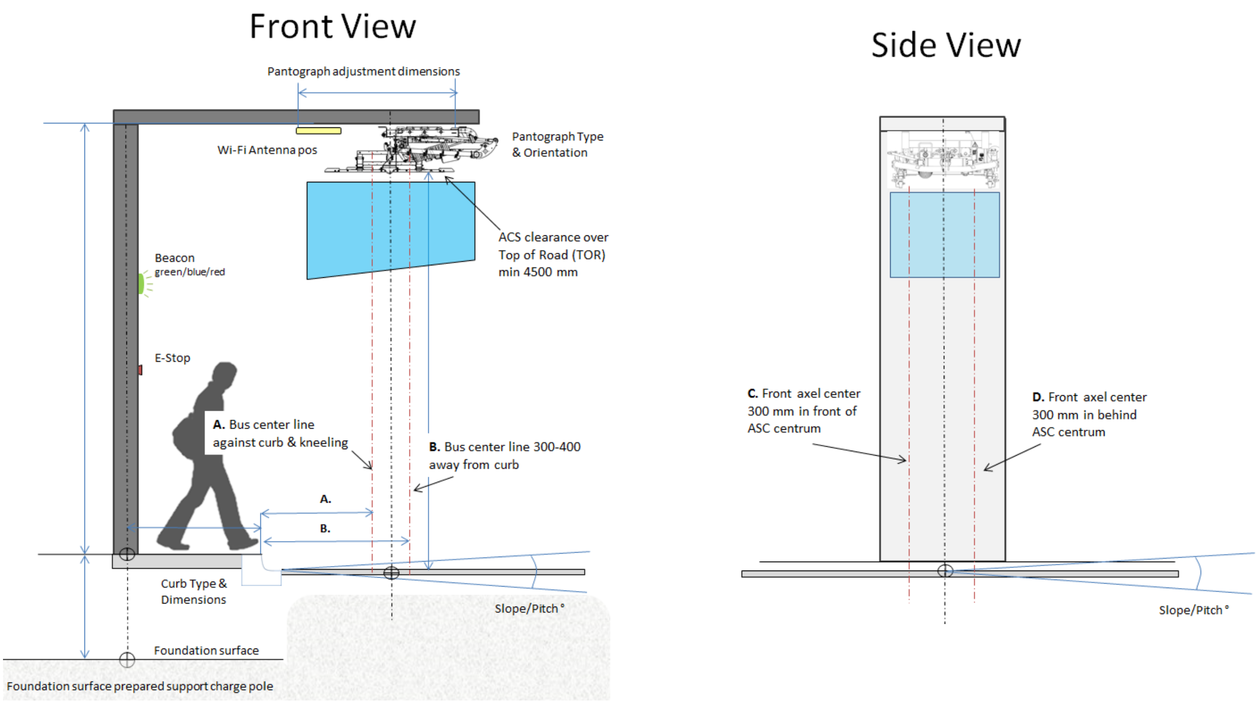
Vehicle Approach path to the charge position shall be considered to allow the driver to easily line up and park underneath the ACS (i.e. away from sharp curves or obstacles to mirrors and chassis).

OPPCharge should not be installed where road conditions have slopes, inclines or pitches greater than ±3,5 °.

All overhead equipment shall have a minimum clearance of 4,5 meters to the top of road surface as well as follow local road safety and civil installation legislation.

Drivers are generally instructed to park close to the curb to allow passengers to “step” aboard the bus. Positioning the ACS on the pole shall allow for optimal parking possibility for the driver in normal circumstances. A site survey of the proposed OPPCharge location and consultation with local operators regarding parking behavior are recommended. The following example expresses optimized parking tolerances:

A. Min Y position: The driver shall be allowed to park with the tires against the curb and kneel the bus.
B. Max Y position: The driver shall be allowed to park the bus 300-400 mm away from the curb and bus upright
C. Max X position: The driver shall be allowed to park the bus 300 mm in front of the pantograph center
D. Min X position: The driver shall be allowed to part the bus 300 mm behind the pantograph center.



8. Considerations

8.1. General

In addition to compliance with the above technical requirements review of the following site specific topics with both vehicle and infrastructure supplier is advised prior to launching a commercial operation:

- Suitable for commercial applications and public installations and operations
- Local Electrical Safety regulations
- Crash Safety
- Charging Scenario
- Equipment placement & site set up (approach, positioning etc.)
- Ownership
- Service plan
- Contractor and Drawings
- Maintenance & Repair
- Data collection / Communication

8.2. Cabling

Cabling shall follow electrical engineering guidelines for optimal function

- Use separate cable ducts for Power Cables and Signal cables.
- The ducts shall be separated 300 – 500 mm apart to reduce EMI.
- Shielded cables are to be used where needed.
- Implement Wi-Fi installation guidelines to reduce signal attenuation
- Define cable lengths to fulfil function
- Fulfil lightning protection where required
- Underground cables and ducts shall fulfil necessary environmental requirements

8.3. HW Pilot Signal

The HW pilot signal determines the various states in the charge process in accordance with IEC 61851.

- ACD rails not connected
- ACD rails connected to vehicle – initialization - not charging
- ACD rails connected to vehicle – charging
- ACD rails connected to vehicle – shut down - charging to not charging
- Error

It is important in the design of the HW pilot control to safeguard the signal tolerances from EMI caused by for example power cables which are in close proximity.

8.4. HMI

Human Machine Interfaces (HMI) may be designed to assist the operator with intuitive and user friendly OPPCharge functionality.

- Positioning and Identification used to easily locate charge interface and park.
- Information in the driver display to inform driver over charging process (position, charge status, messages and notifications).
- Beacons or lamps indicating charging status on the charge infrastructure.
- E-Stop buttons to end the charge session quickly
- Visual & audio verification methods as well as haptic responses to inform user of charge status.

8.5. Positioning

Stopping the vehicle in the correct position underneath the ACS can be improved by for example:

- Parking lines in front of and alongside bus
- Guiding landmark (i.e. Bus info sign aligned with bus front)
- Curbs (type “Kassel” for alignment without wear on tires) on one or two sides of bus
- Wheel bumps (to give the driver a haptic response they are in correct position)
- Semi-automatic or automatic parking systems.

9. Options

Depending on local conditions the following options should be considered.

9.1. De-Icing conductors

OPPCharge Conductors may have integrated heaters for de-icing purposes.
Vehicle side conductor heating system shall not exceed 300W power consumption.
The heating system shall be temperature controlled to only be activated when needed.

9.2. Emergency Stop

OPPCharge equipment may have Emergency stop switches to actively stop the charge process at any time “in case of emergency”.

On OPPCharge equipment installed in public areas an emergency stop switch can be protected with a switch cover to avoid unwanted activation.

In the event of an Emergency stop activation. The ACD shall retract to the upper position and the SECC shall inform the EVCC of the ACD position.

9.3. Beacon (Lamp) Function

OPPCharge equipment may have beacons to actively indicate the charge equipment status. The beacons should be visible to the driver to show if the charge equipment is operational or not.

The beacon(s) should be visible in daylight and at nighttime.

9.4. Convex mirror

A Convex mirror placed in an appropriate spot may give drivers visual feedback if the ACD is Up, Down or Moving.

9.5. Position Assistance

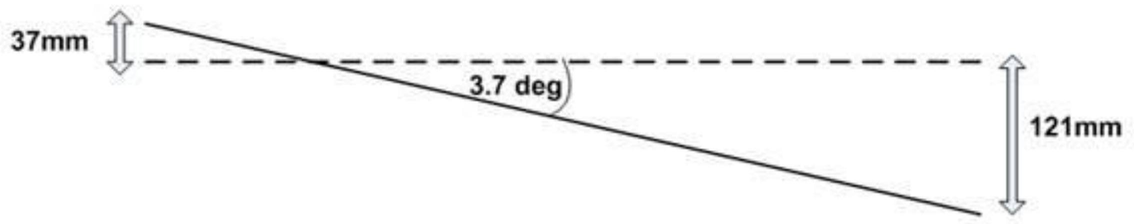
Position assistance systems are available to help drivers center the vehicle underneath the ACD. Such systems need to consider interoperability as well as constraints defined by the environment such as dirt, rain and snow.

10. Appendix

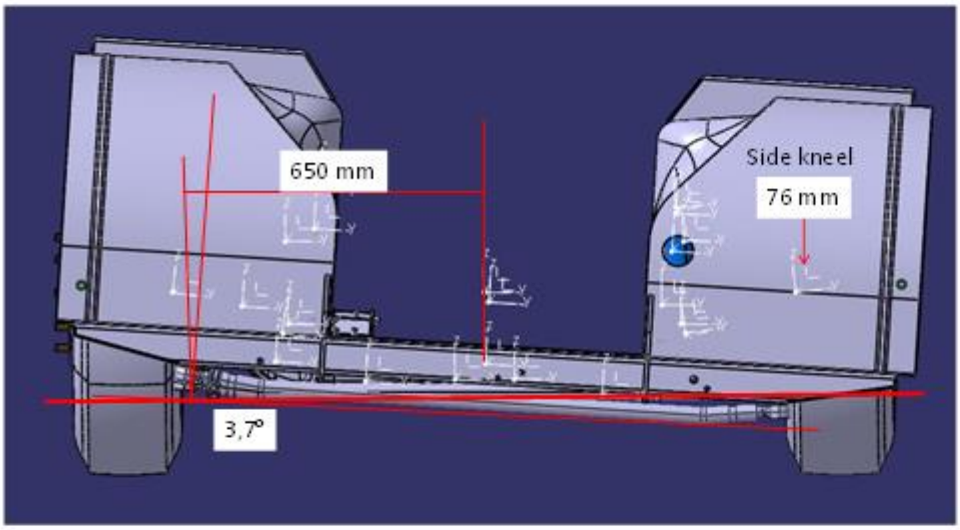
10.1. An example for bus kneeling

The following is a calculation of vehicle kneeling illustrating the changes in angle and height. Please note that vehicle kneeling characteristics can vary between OEMs.

All calculations are done on the wheel axis as shown on the figure below.
Maximum tilt for the left wheel = 37mm
Maximum tilt for the right wheel =121mm
Vehicle width = 2544



Worst case
Side kneel 76 mm (3,7°)



Low rotation in z-dir – estimated on the ground and 650 mm to the side in y-dir.

Appendix F - Conceptual UCAT Bus Charge Plans

Potential 'Year Zero' Sequential Charge Plan

Three Depot-Charge Only Buses in Revenue Service

Buses on garage recharge			**0**	**0**	**0**	**0**	**0**	**0**	**0**	**1**	**1**	**1**	**1**	**1**	**1**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Bus charging demand KW										**150 kW**	**150 kW**	**150 kW**	**150 kW**	**150 kW**	**150 kW**								
			4:00 AM	5:00 AM	6:00 AM	7:00 AM	8:00 AM	9:00 AM	10:00 AM	11:00 AM	12:00 PM	1:00 PM	2:00 PM	3:00 PM	4:00 PM	5:00 PM	6:00 PM	7:00 PM	8:00 PM	9:00 PM	10:00 PM	11:00 PM	12:00 AM
Blue Route	1002	2:30 PM – 7:25 PM								*Depot Charging*				**Bus 1 - In Revenue Service + Deadhead**									
M Route	2001	5:00 PM – 10:33 PM	*Depot Charging Opportunities*											*Depot Charging*		**Bus 2 - In Revenue Service + Deadhead**						*Depot Charging Opportunities*	
Red Route	1015	3:00 PM – 7:08 PM										*Depot Charging*		**Bus 3 - In Revenue Service + Deadhead**									

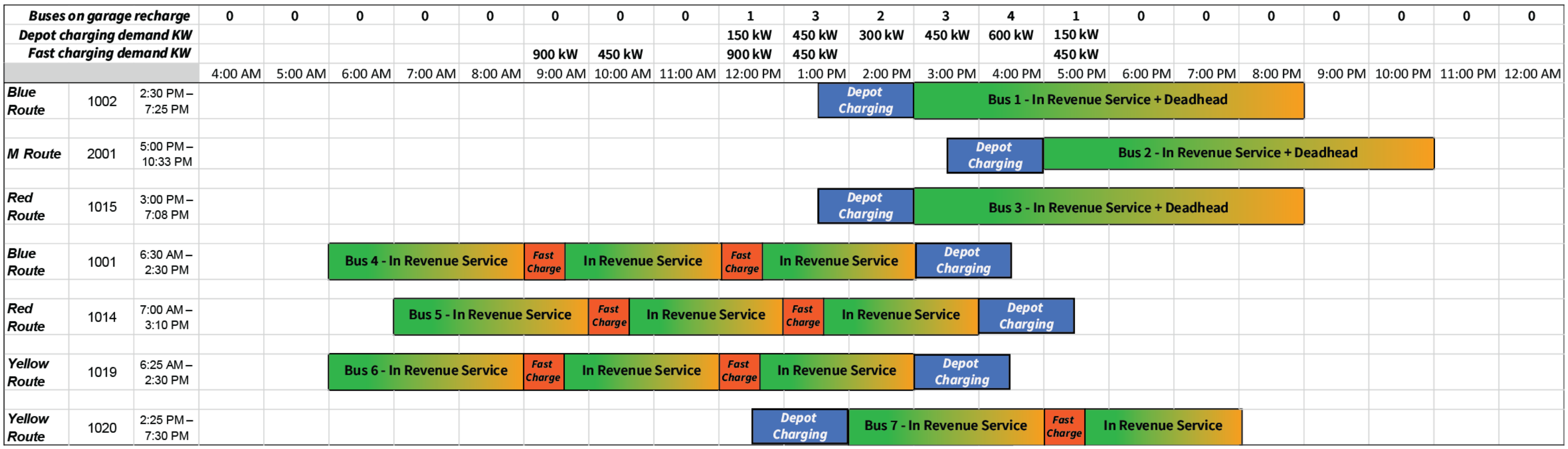
Potential ‘Year Five’ Sequential Charge Plan

Three Depot-Charge Only Buses and Four Fast-Charging Compatible Buses in Revenue Service

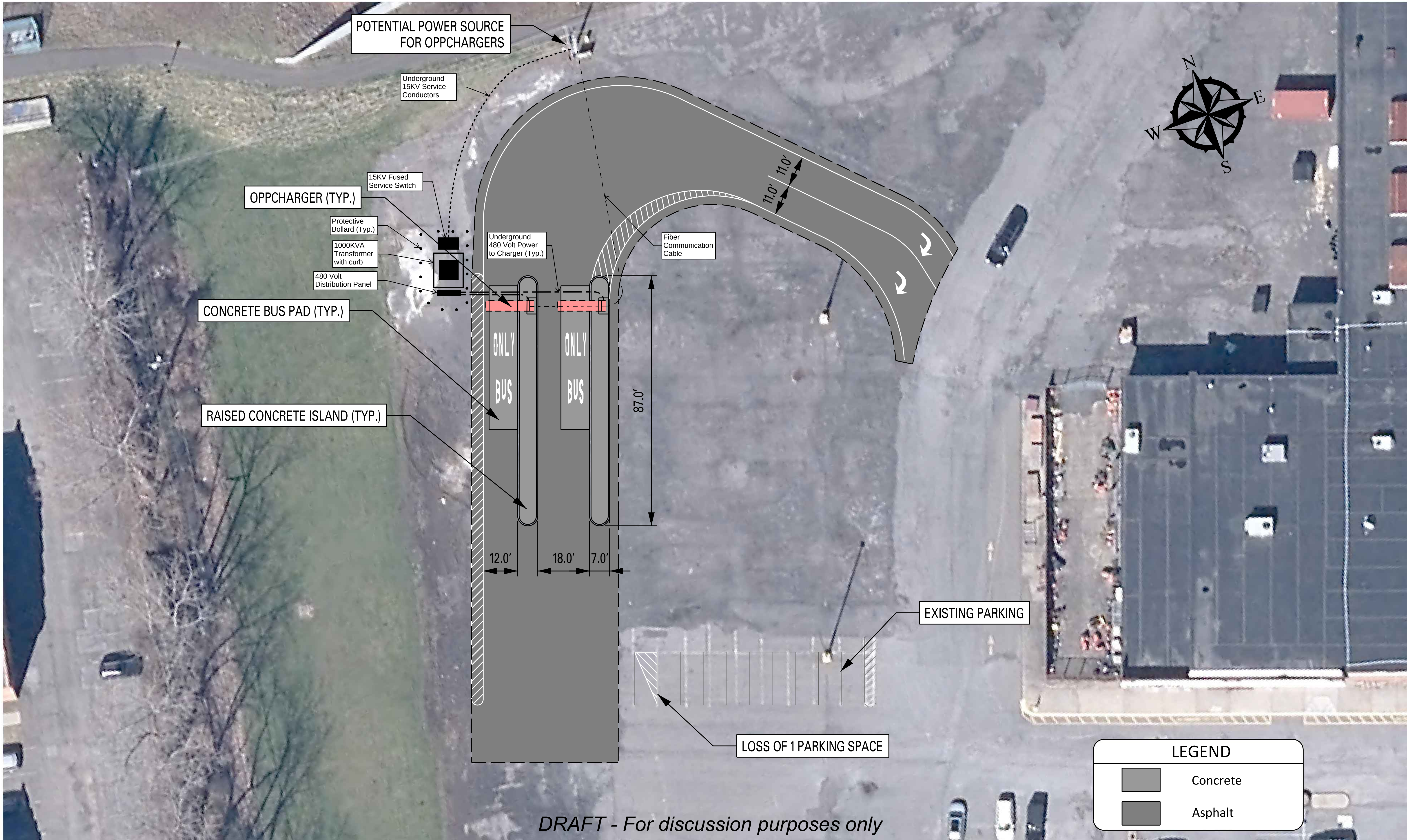
			4:00 AM	5:00 AM	6:00 AM	7:00 AM	8:00 AM	9:00 AM	10:00 AM	11:00 AM	12:00 PM	1:00 PM	2:00 PM	3:00 PM	4:00 PM	5:00 PM	6:00 PM	7:00 PM	8:00 PM	9:00 PM	10:00 PM	11:00 PM	12:00 AM
Buses on garage recharge			1	1	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	0	0	0
Depot charging demand KW			150 kW	150 kW						150 kW	150 kW	150 kW	150 kW	150 kW	150 kW	150 kW	150 kW	150 kW	150 kW	150 kW			
Fast charging demand KW								900 kW	450 kW		900 kW	450 kW				450 kW							
Blue Route	1002	2:30 PM – 7:25 PM								*Depot Charging*				Bus 1 - In Revenue Service + Deadhead									
M Route	2001	5:00 PM – 10:33 PM												*Depot Charging*		Bus 2 - In Revenue Service + Deadhead							
Red Route	1015	3:00 PM – 7:08 PM										*Depot Charging*		Bus 3 - In Revenue Service + Deadhead									
Blue Route	1001	6:30 AM – 2:30 PM			Bus 4 - In Revenue Service			*Fast Charge*	In Revenue Service		*Fast Charge*	In Revenue Service				*Depot Charging*							
Red Route	1014	7:00 AM – 3:10 PM				Bus 5 - In Revenue Service			*Fast Charge*	In Revenue Service		*Fast Charge*	In Revenue Service				*Depot Charging*						
Yellow Route	1019	6:25 AM – 2:30 PM	*Depot Charging*		Bus 6 - In Revenue Service			*Fast Charge*	In Revenue Service		*Fast Charge*	In Revenue Service											
Yellow Route	1020	2:25 PM – 7:30 PM											Bus 7 - In Revenue Service			*Fast Charge*	In Revenue Service		*Depot Charging*				

Potential 'Year Five' Simultaneous Charge Plan

Three Depot-Charge Only Buses and Four Fast-Charging Compatible Buses in Revenue Service



Appendix G - Fast Charging Station Concept Designs and Conceptual Cost Estimates



Ulster County - Bus Fleet
Electrification Project
PROJECT: 119-275 DATE: 1/2021

Creighton Manning

15 0 15 30 45 60'
1" = 30'

KINGSTON PLAZA CHARGING STATION Concept

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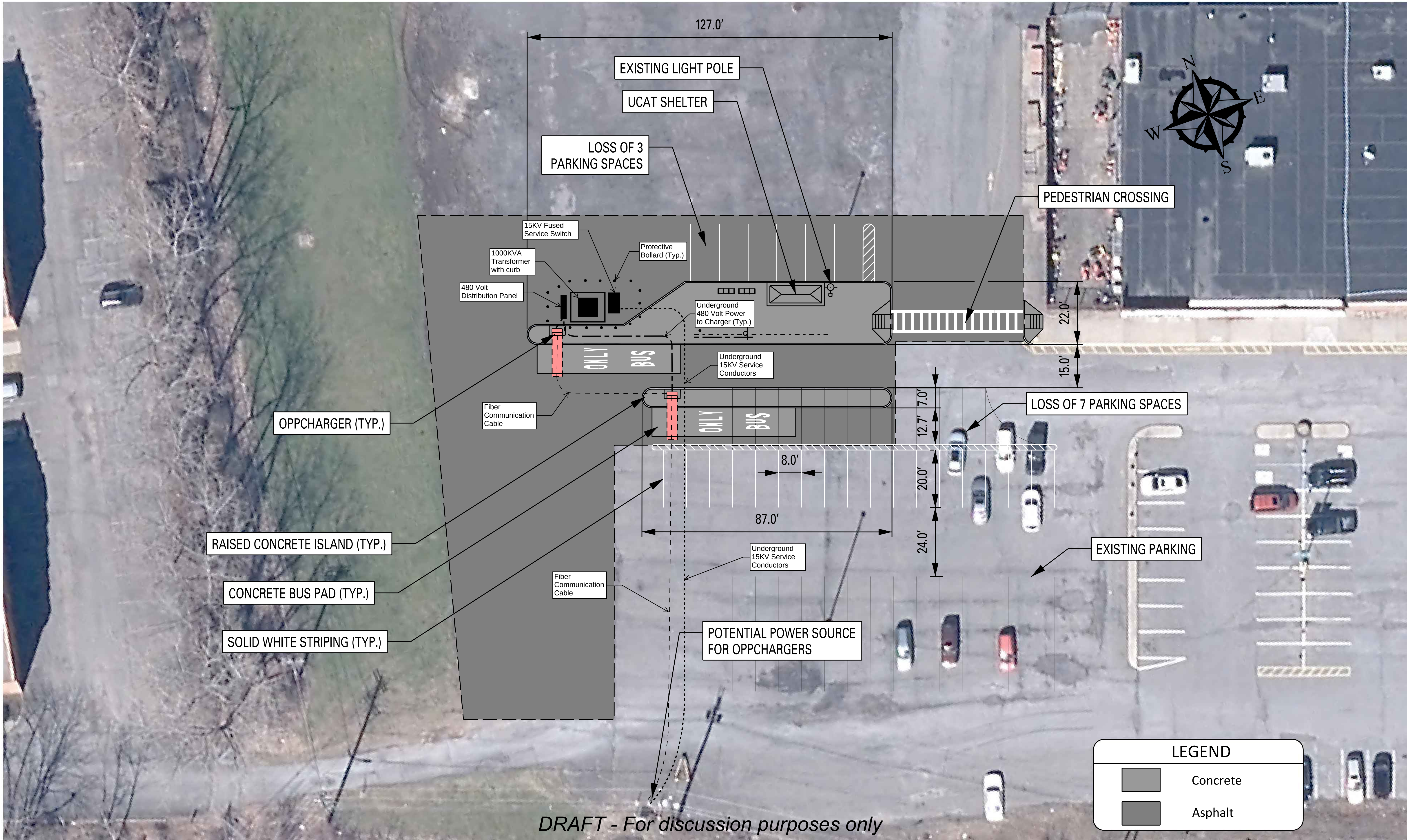

Ulster County - Bus Fleet
Electrification Project
PROJECT: 119-275 DATE: 1/2021

Creighton Manning

15 0 15 30 45 60'
1" = 30'

KINGSTON PLAZA CHARGING STATION Concept

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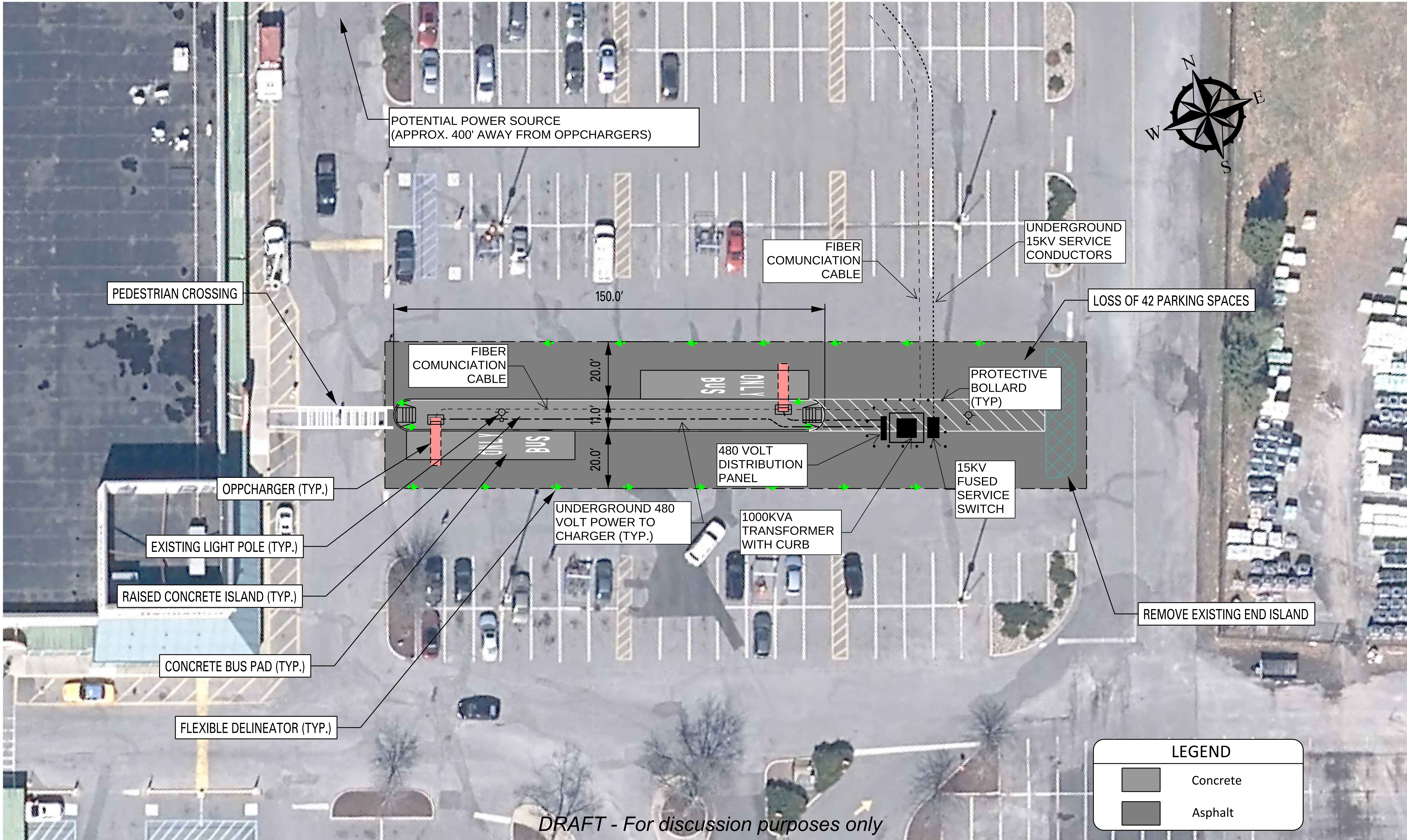
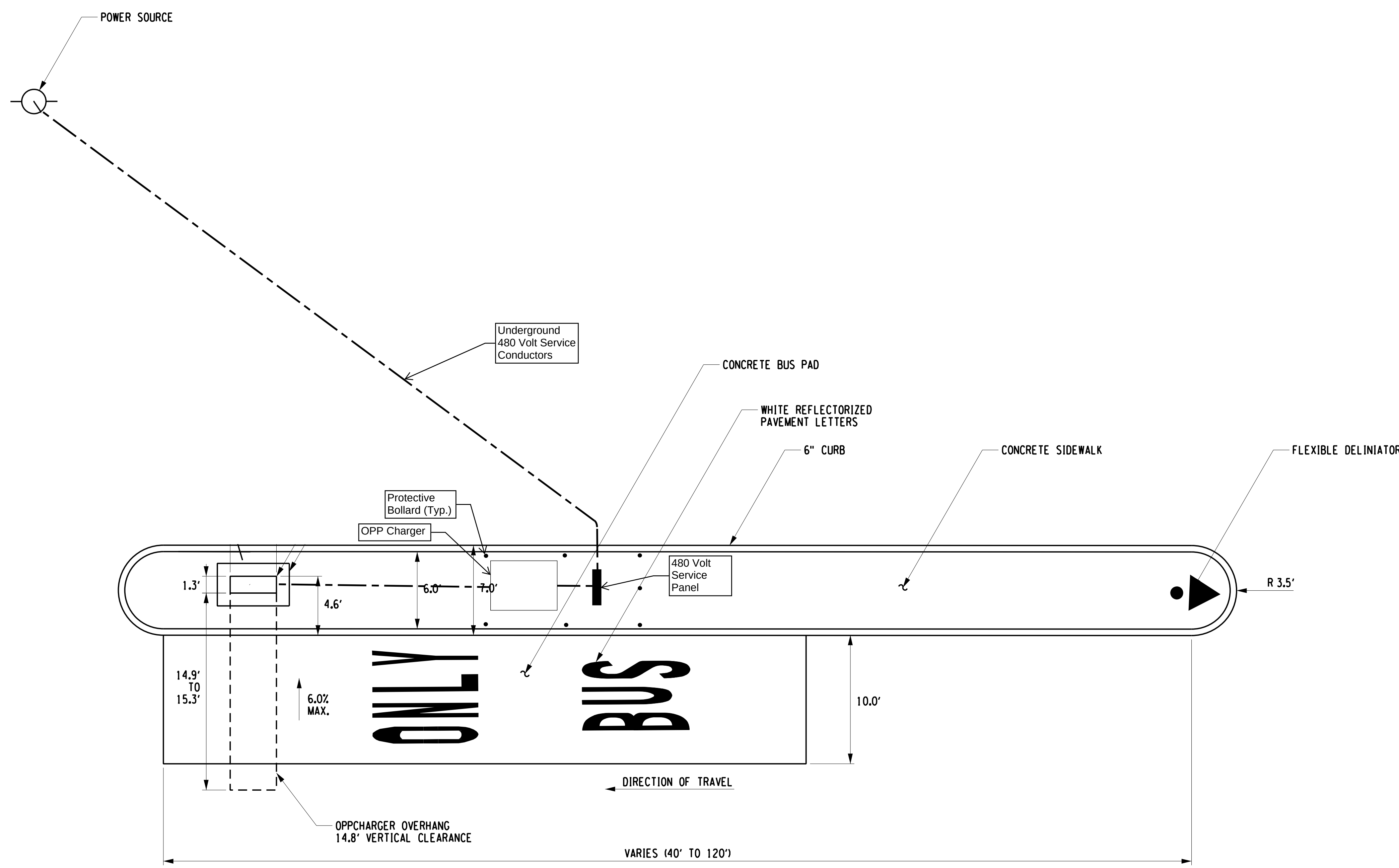


Ulster County - Bus Fleet
Electrification Project
PROJECT: 119-275 DATE: 1/2021

Creighton Manning

15 0 15 30 45 60'
1" = 30'

KINGSTON PLAZA CHARGING STATION *Concept*



DRAFT - For discussion purposes only

Ulster County - Bus Fleet
Electrification Project
PROJECT: 119-275 DATE: 1/2021

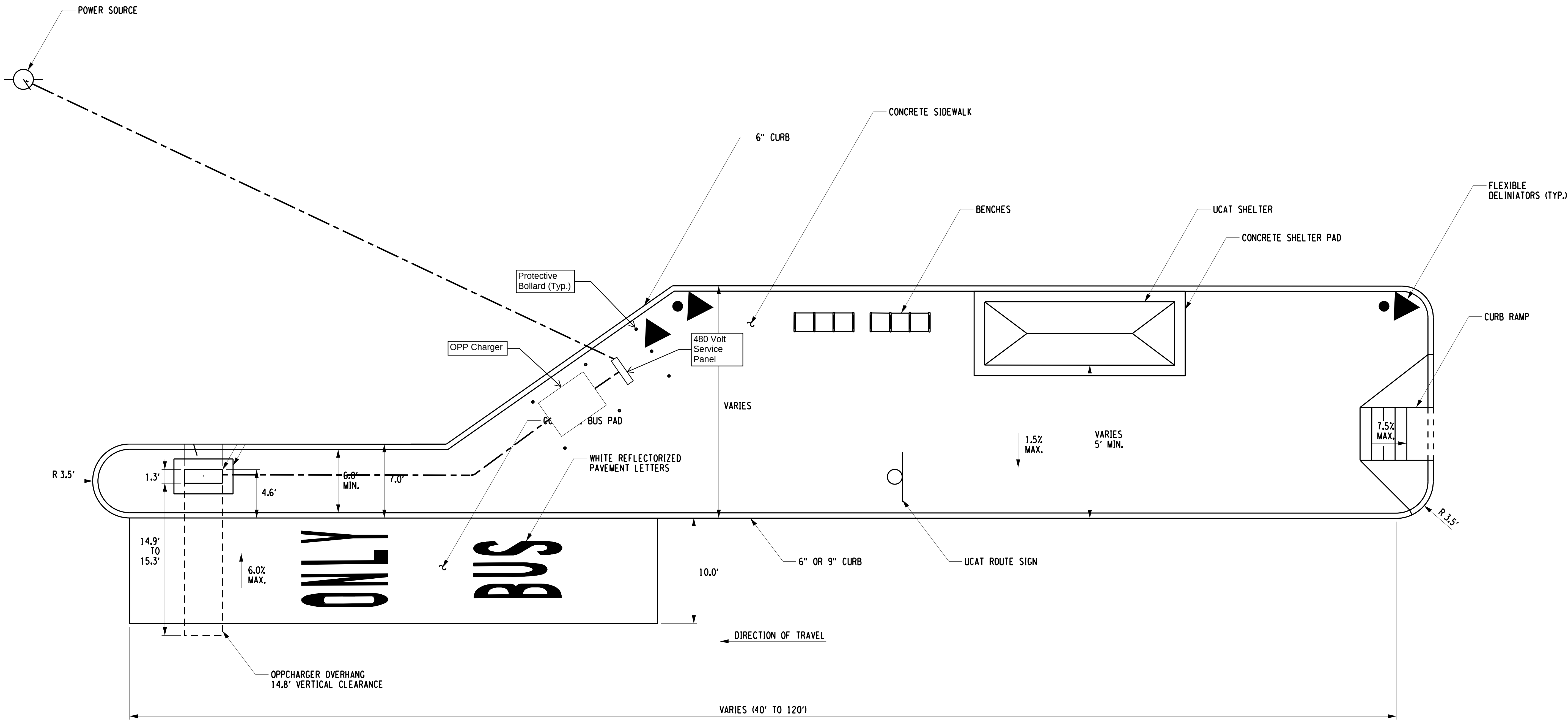
Creighton Manning

5	0	5	10	15	20'

1" = 10'

BUS CHARGING STATION ISLAND DETAIL

FILE : N:\Projects\2019\119-275 Ulster County - Bus Fleet Electrification\Working\CADD\dgn\figures\119-275_dtl_con_pln_02A.dgn



DRAFT - For discussion purposes only

Ulster County - Bus Fleet
Electrification Project
PROJECT: 119-275 DATE: 1/2021

Creighton Manning

5 0 5 10 15 20'
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BUS CHARGING STATION ISLAND DETAIL

FILE : N:\Projects\2019\119-275 Ulster County - Bus Fleet Electrification\Working\CADD\dgn\figures\119-275.dtl.con.pln.01A.dgn

Calculated By:__________
Calculated Date:__________
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Checked Date: __________

UCAT Bus Fleet Electrification

January 18, 2021

Description of Major Improvements:

UCAT Bus Charging Stations at Kingston Plaza Concept without Shelter

Approximate ROW required:		SF	0.0000	Acres
ITEM DESCRIPTION	**UNITS**	**PRICE**	**QUANTITY**	**TOTAL**
UNCLASSIFIED EXCAVATION AND DISPOSAL	CY	$15.00	1030	$15,450
EMBANKMENT IN PLACE	CY	$20.00	40	$800
FULL DEPTH PAVEMENT AND SUBBASE	SF	$8.00	13840	$110,720
SIDEWALKS	SF	$8.75	1020	$8,925
CONCRETE BUS PAD (10'x50')	SF	$30.00	1000	$30,000
CONCRETE CURB	LF	$30.00	190	$5,700
SIGNING AND STRIPING	LS	$5,000.00	1	$5,000
DRAINAGE BASINS	EA	$6,000.00	4	$24,000
DRAINAGE PIPE	LF	$60.00	460	$27,600
POTETIAL UNDERGROUND UTILITY RELOCATIONS	LS	$25,000.00	1	$25,000
STORMWATER MANAGEMENT ($50,000 /acre)	AC	$50,000.00	0.4	$20,000
EROSION CONTROL	LS	$2,000.00	1	$2,000
ELECTRICAL WORK	LS	$214,000.00	1	$214,000
OPPCHARGER	EA	NOT INCL.	2	
WORK ZONE TRAFFIC CONTROL	LS	8%	1	$39,200
SURVEY AND STAKEOUT	LS	5%	1	$24,500
MOBILIZATION	LS	4%	1	$19,600
CONTINGENCY	LS	20%	1	$97,900

CONSTRUCTION SUBTOTAL:	**$**	**671,000**
DESIGN ENGINEERING (10%)	$	67,100
CONSTRUCTION INSPECTION (20%)	$	134,200
ANTICIPATED ROW COST	$	-
PROJECT TOTAL:	**$**	**873,000**

Calculated By:__________
Calculated Date:__________
Checked By:__________
Checked Date: __________

UCAT Bus Fleet Electrification

January 18, 2021

Description of Major Improvements:

UCAT Bus Charging Stations at Kingston Plaza Concept with Shelter

Approximate ROW required: **SF** **0.0000** **Acres**

ITEM DESCRIPTION	UNITS	PRICE	QUANTITY	TOTAL
UNCLASSIFIED EXCAVATION AND DISPOSAL	CY	$15.00	1310	$19,650
EMBANKMENT IN PLACE	CY	$20.00	90	$1,800
FULL DEPTH PAVEMENT AND SUBBASE	SF	$8.00	16660	$133,280
SIDEWALKS	SF	$8.75	2560	$22,400
CONCRETE BUS PAD (10'x50')	SF	$30.00	1000	$30,000
CONCRETE CURB	LF	$30.00	490	$14,700
SIGNING AND STRIPING	LS	$4,000.00	1	$4,000
DRAINAGE BASINS	EA	$6,000.00	2	$12,000
DRAINAGE PIPE	LF	$60.00	480	$28,800
POTETIAL UNDERGROUND UTILITY RELOCATIONS	LS	$25,000.00	1	$25,000
STORMWATER MANAGEMENT ($50,000 /acre)	AC	$50,000.00	0.5	$25,000
EROSION CONTROL	LS	$2,000.00	1	$2,000
ELECTRICAL WORK	LS	$214,000.00	1	$214,000
OPPCHARGER	EA	NOT INCL.	2	
SHELTER AND AMENITIES	LS	$25,000.00	1	$25,000
WORK ZONE TRAFFIC CONTROL	LS	8%	1	$44,700
SURVEY AND STAKEOUT	LS	5%	1	$27,900
MOBILIZATION	LS	4%	1	$22,400
CONTINGENCY	LS	20%	1	$111,600

CONSTRUCTION SUBTOTAL:	**$**	**765,000**
DESIGN ENGINEERING (10%)	$	76,500
CONSTRUCTION INSPECTION (20%)	$	153,000
ANTICIPATED ROW COST	$	-
PROJECT TOTAL:	**$**	**995,000**

Creighton Manning

Calculated By:__________
Calculated Date:__________
Checked By:__________
Checked Date: __________

UCAT Bus Fleet Electrification

February 1, 2021

Description of Major Improvements:

UCAT Bus Charging Stations at Kingston Plaza Concept near Existing Stop

Approximate ROW required: **SF** **0.0000** **Acres**

ITEM DESCRIPTION	UNITS	PRICE	QUANTITY	TOTAL
UNCLASSIFIED EXCAVATION AND DISPOSAL	CY	$15.00	180	$2,700
EMBANKMENT IN PLACE	CY	$20.00	60	$1,200
FULL DEPTH PAVEMENT AND SUBBASE (REMOVAL OF END ISLAND)	SY	$8.00	425	$3,400
MILL AND FILL PAVEMENT	SF	$3.00	9230	$27,690
SIDEWALKS	SF	$8.75	1490	$13,038
CONCRETE BUS PAD (10'x50')	SF	$30.00	1180	$35,400
CONCRETE CURB	LF	$30.00	320	$9,600
SIGNING AND STRIPING	LS	$4,000.00	1	$4,000
DELINEATORS	EA	$175.00	20	$3,500
DRAINAGE BASINS	EA	$6,000.00	1	$6,000
DRAINAGE PIPE	LF	$60.00	130	$7,800
POTETIAL UNDERGROUND UTILITY RELOCATIONS	LS	$25,000.00	1	$25,000
STORMWATER MANAGEMENT ($50,000 /acre)	AC	$50,000.00	0.1	$5,000
ELECTRICAL WORK	LS	$214,000.00	1	$214,000
OPPCHARGER	EA	NOT INCL.	2	
WORK ZONE TRAFFIC CONTROL	LS	8%	1	$28,700
SURVEY AND STAKEOUT	LS	5%	1	$18,000
MOBILIZATION	LS	4%	1	$14,400
CONTINGENCY	LS	20%	1	$71,700

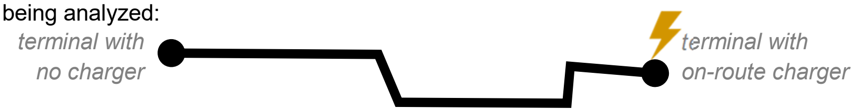
CONSTRUCTION SUBTOTAL:	**$**	**492,000**
DESIGN ENGINEERING (10%)	$	49,200
CONSTRUCTION INSPECTION (20%)	$	98,400
ANTICIPATED ROW COST	$	-
PROJECT TOTAL:	**$**	**640,000**

Appendix H - Estimation Tool for Determining Block Suitability for Electrification

Estimating Requirements for On-Route Charging

Developed by Sam Schwartz Consulting for UCAT (2020-21)
This spreadsheet tests the charging requirements of an example bus route with an on-route charger at one end.
This represents a simplified analysis that does not account for factors such as deadhead/pull trips, interlines, etc.

Diagram of route being analyzed:



Yellow cells are inputs
Green cells are results

Predefined Scenarios

Conservative Technology Assumptions

Vehicle Characteristics

3.18	kWh/mi burn rate
320	battery nominal kWh
205	battery adjusted kWh
184	starting state of charge (kWh)
41	minimum reserve state of charge (kWh)

On-Route Charger Characteristics

450	kW Fast charger

Route Characteristics

16	mi one way
32	mi round trip
12	mph
80	min one way
160	min round trip time
20%	recovery time
192	min full cycle time

Requirements to Operate Indefinitely

102	kWh burned per cycle
✓ 1.0	can SOC remain above minimum?
13.6	min charging needed per cycle
18.3	min layover at charger needed per cycle
57%	share of layover needed at charger

Requirements to Complete 8 hr Shift

8	hr shift length to evaluate
2.5	cycles per shift
102	kWh burned per cycle
42	extra kWh overall
17	extra kWh per cycle
11.3	min charging needed per cycle
15.7	min layover at charger needed per cycle
49%	share of layover needed at charger

Appendix I - Phased Purchase Plan towards Zero Emission Fleet

Ulster County Area Transit

Fleet Electrification – Final Assumptions and Proposed Action Plan

This document intends to outline a proposed purchase and implementation plan for Ulster County Area Transit (UCAT) bus fleet electrification while considering future and projected capital costs. The goal of this plan is to achieve maximum fleet electrification as quickly as possible while keeping capital spending to a minimum. This document is divided into three sections. Section 1 summarizes market trends and current market trends and projections for BEBs and related infrastructure, Section 2 details a year-by-year fleet replacement schedule, and Section 3 includes projections for annual operating costs.

Section 1: BEB Market Trends and Price Projections

1.1 Current BEB Prices and Market Trends

Current market trends and industry literature suggests that the cost differential between BEBs and conventional diesel-powered buses will decrease over the next decade as battery production becomes cheaper and more efficient. BEBs will still likely have higher up-front costs than diesel buses, including costs of vehicles, costs associated with charging infrastructure, and facility upgrades. However, it likely that state and federal grants will be available to offset some of these costs.

Table 1 (below) summarizes the differences in projected costs of BEBs and conventional buses, the costs of other BEB components and infrastructure, and the projected price trends for these components.

Table 1. Summary of BEB and conventional bus cost assumptions

Cost Component	2021 Price (approx.)	2030 Price (assuming +2.5% inflation/yr)	Price Trend Assumption (relative to inflation)
35' BEB	$875,000	$875,000	Price will trend down
40' BEB	$1,000,000	$1,000,000	Price will trend down
35' Diesel bus	$500,000	$625,000	Price will remain constant
35' CNG bus	$520,000	$674,000	Price will remain constant
Depot charging installation (per cabinet)	$254,000	$317,000	Price will remain constant
Depot charging equipment (per three dispensers)	$137,000	$171,000	Price will remain constant
On-route charging equipment (per charger)	$500,000	$625,000	Price will remain constant
On-route charging installation (per charger)	$200,000	$250,000	Price will remain constant

Sources: California Air Resources Board, Transit Cooperative Research Program, UCAT provided project costs

Table 2 summarizes recent BEB procurements made by other peer American transit agencies, including price paid, purchase year, bus manufacturer, and bus size. Utilizing these data points provides a baseline from which we can calculate average market prices and begin to observe market trends. *Table 3* provides a summary of the total average procurement cost of both 35- and 40-foot electric buses after adjusting for inflation.

Table 2. Peer Transit Agency Battery Electric Bus Procurements, 2018 - 2021

City/Region	Agency	Purchase Year	Bus Price	Bus Mfg.	Bus Size
Los Angeles, CA	LADOT	2018	$720,000	BYD	35'
Madison, WI	Metro Transit	2018	$667,000	Proterra	35'
Rhode Island	RIPTA	2018	$855,000	Proterra	40'
Dallas, TX	DART	2019	$970,000	Proterra	35'
St. Louis, MO	Metro St. Louis	2019	$950,000	Gillig	40'
Chicago, IL	CTA	2020	$900,000	Proterra	40'
New York, NY	MTA	2020	$1,960,000*	Multiple	Multiple
Seattle, WA	King County Metro	2020	$925,000	New Flyer	40'
Philadelphia, PA	SEPTA	2020	$800,000	Proterra	40'
Marin Co., CA	Marin Transit	2020	$1,000,000	Gillig	40'
Orange Co., CA	OCTA	2020	$1,000,000	New Flyer	40'
Ulster Co.	UCAT	2021	$865,000	New Flyer	35'
Niagara Falls, NY	NFTA	2021	$1,000,000	New Flyer	Unknown, likely 40'
North LA area, CA	Antelope Valley Transit	2021	$545,000	BYD	30'

Sources: see "Sources" section

* Purchase price likely includes charging infrastructure and additional costs

Table 3. Average Battery Electric Buses Prices Adjusted for Inflation

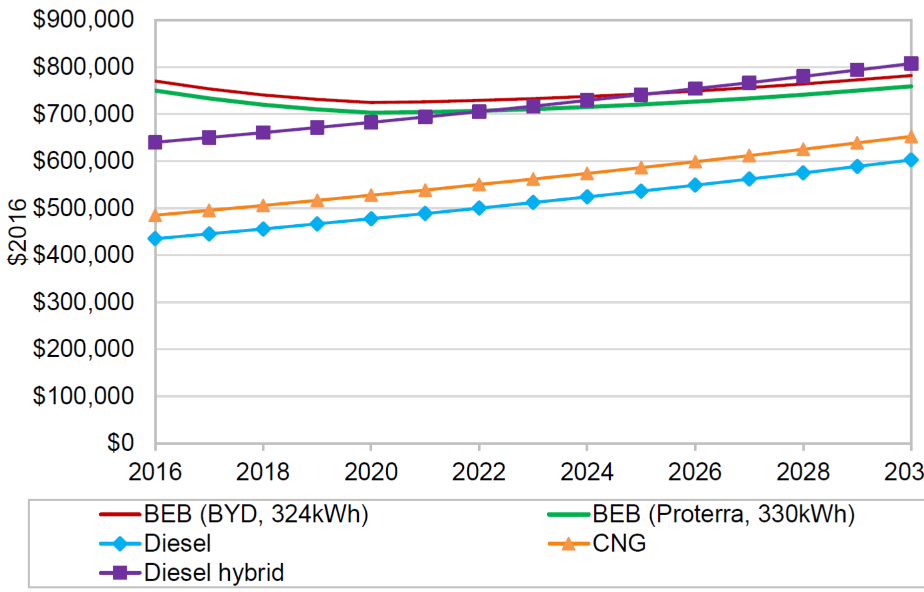
Purchase Year	Bus Size	35' Bus Cost		40' Bus Cost	
		Purchase Year Dollars	2021 Dollars	Purchase Year Dollars	2021 Dollars
2018	35'	$693,000	$737,000	$855,000	$909,000
2019	35'	$970,000	$1,001,000	$950,000	$992,000
2020	35'	--	--	$925,000	$954,000
2021	35'	$865,000	$865,000	--	--
		Average 2021 Cost, 35'	$867,000	Average 2021 Cost, 40'	$951,000

1.2 BEB Price Projections

The California Air Resources Board (CARB) projects that the price differential between BEBs and conventionally fueled buses will *decrease* over the next decade (*Figure 1*). The price of fossil-fuel powered buses is expected to rise along with inflation year to year while the relative price of BEBs is anticipated to decrease as battery technology advances and current research and development investment levels continue. Adjusting for inflation, the real price of BEBs will decrease each year as the nominal price remains somewhat constant, and the average sticker price of a BEB in 2021 will be the same in 2030.

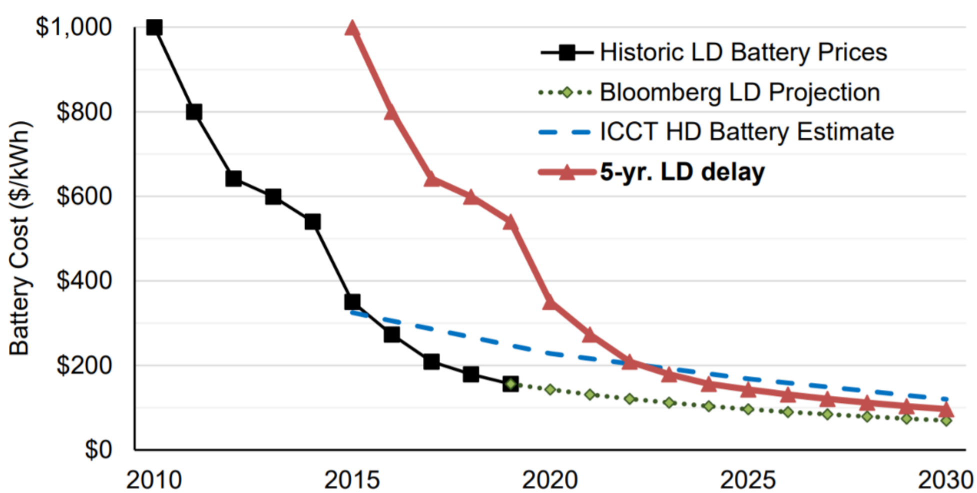
It should be noted that the decreasing production costs and purchase prices of BEBs is largely due to the development of cheaper and more efficient battery technologies. CARB also predicts a continual downward trend in battery prices, thus resulting in lower BEB prices (*Figure 2*).

Figure 1. *Bus price projections for conventional buses and BEBs*



Source: California Air Resources Board

Figure 2. *Lithium battery price projections*



Source: California Air Resources Board

1.3 UCAT Operating Costs of Fossil-Fuel Powered Buses vs. BEBs

The feasibility study found the average annual operating cost of the current UCAT fleet in 2020 to be approximately $59,500 per vehicle. This includes amortized purchase price, annual maintenance, and fuel costs, social costs from GHG and noise emissions. The calculated average considered variations in purchase price, fuel consumptions and maintenance costs of the various vehicles comprising UCAT's fleet and weighted by the quantity of each vehicle type in operation.

Using 2020 prices, annual operating costs for BEBs will be significantly greater than fossil fuel-powered buses due to higher vehicle costs and current electric utility price schedules. Year one annual operating costs for BEBs is projected at approximately $90,500 per vehicle, more than a 50% increase. However, it is likely that this net differential will decrease over time as the purchase cost of BEBs decrease and more favorable electric utility price schedules are introduced. Further detail is provided in Section 3 of this study.

Section 2: Proposed Procurement and Action Plan

2.1 Action Plan Summary

The proposed bus replacement schedule *(Table 4)* considers several factors previously identified by both UCAT and Creighton Manning. These factors are as follows:

- **35' BEB and cutaway vehicle replacements** – While there is no currently FTA-approved zero-emission cutaway vehicle available for purchase, we project that some type of sub-35' electric vehicle will become readily available by 2024. If there is no suitable cutaway replacement available by mid-decade, this plan assumes that all non-paratransit diesel/CNG buses would be replaced by fast-charge capable 35' BEBs, regardless of existing vehicle size and in accordance with their planned replacement date. The capital cost estimate for 35 foot electric buses is used throughout the proposed bus replacement schedule as no reliable pricing for these future vehicles is available. It is reasonable to assume that smaller vehicles would be available at a lower purchase price. As such, using the cost of 35-foot BEBs throughout this exercise provides a conservative capital estimate projection.
- **Staggered installation of on-route charging equipment** – On-route charging equipment presents the challenge of high up-front capital costs. Conceptual cost estimates developed for en-route charging equipment and site work developed previously in study totaled approximately $1.1 million per fast charger. This cost is consistent with cost estimates listed in available literature.

  The cost of this equipment will be staggered through implementation by assuming each layover location will be constructed separately. Following construction of each, BEBs purchased should be assigned to a route that utilizes that layover location until all routes which utilize that charger location are electrified. This continues until all four layover locations are completed and all buses are electrified.
- **Preemptive purchase of depot charging infrastructure** – All BEBs will dock overnight at the existing UCAT depot or the new future facility. Three charge cabinets and three depot-box charging plugs will be installed at the existing facility with the first BEB purchase in FFY 2021.

These cabinets will have the capacity to support up to 9 vehicles with overnight plug-in capability after additional depot box units are procured and installed. This installation of an additional 6 depot boxes at the facility is planned for FFY 2022. A fourth cabinet will be installed in FFY 2024 increasing depot charging capacity to 12 vehicles. It will be assumed that all future depot charging infrastructure investment will be included in the new UCAT depot facility, tentatively slated for completion in 2026. It is assumed that this facility will be designed to be ready to support electric charging equipment.

- **Charging Equipment at New UCAT Facility** – Capital costs associated with the construction of the new facility are not included in this phased implementation plan and it is assumed that the facility will be constructed to be ready to accommodate charging demands. However, this plan does assume that installation of charging equipment at the new facility will be phased over time on an as-needed basis. As such, the capital costs for incremental implementation of BEB charge equipment is included in this plan.
- **Full Electrification** – As discussed in the report, 100% electrification of the UCAT fleet is not feasible with current battery technology and operational structures. Routes with long one-way trips, such as those serving Pine Hill, NY and Bellaire Mountain, would require opportunity chargers at each end of the route and significantly extended layover times between each trip to be electrified with current battery technology. Agencies across the world have begun to assess hydrogen fuel cell powered buses to achieve zero emission fleets with routes that cannot be electrified. Challenges with hydrogen fuel cells include the cost of fuel and the reliability of supply. While outside the scope of this study, UCAT may wish to begin exploring this emerging propulsion technology as a way to reach full electrification in the future.

2.2 *Fleet Replacement and Charger Procurement Schedule*

Table 4 (below) describes a proposed UCAT fleet replacement plan. As stated above, there are several key years that involve both the procurement of buses and the installation of charging equipment. Although financial burden will be higher in these years, the resulting infrastructure will be vital for the subsequent electrification of UCAT's fleet.

Table 4. *BEB and Charger Procurement Plan*

FFY	# of BEBs to be Replaced	Total Vehicle Cost** (millions, USD)	Fast Charger Layover Area	Fast Charger Costs† (millions, USD)	Depot Charger Costs††	# of Depot Plugs Available	Annual CO_2e Reduction (tonnes)	Total BEBs in UCAT Fleet	Total Capital Costs* (millions, USD)	Five Year Running Total (millions, USD)
2021	3	$2.595	--	--	$762,000	3	110	3	$3.357	
2022	3	$2.595	Kingston	$2.200	$281,000	9	215	6	$5.076	
2023	4	$3.460	--	--	--	9	357	10	$3.460	$18.577
2024	3	$2.595	--	--	$280,000	12	461	14	$2.875	
2025	3	$2.595	New Paltz	$1.185	--	12	583	18	$3.809	
2026	3	$2.595	--	--	$575,000	18	679	22	$3.170	
2027	3	$2.595	--	--	--	18	776	24	$2.595	
2028	3	$2.595	Tech City	$1.276	--	18	890	26	$3.903	$15.934
2029	3	$2.595	-	-	$619,000	24	1,004	28	$3.214	
2030	2	$1.712	Poughke epsie	$1.340	--	24	1,080	30	$3.052	
2031	1	$0.865	--	--	--	24	1,127	31	$0.865	$3.460
2032	3	$2.595	--	--	--	24	1,237***	34	$2.595	
									GRAND TOTAL	$37.971

* Amounts shown **exclude** monies from state and federal grants and reflect full purchase price
** Total vehicle cost remains constant independent of inflation (see Section 1.2, *Figure 4*)
*** Assuming UCAT is able to transition the Z Route to use zero-emissions buses.
† Fast charger costs are adjusted for 2.5% annual inflation
†† Depot charger costs are adjusted for 2.5% annual inflation and include a 20% design and mobilization cost

Table 5 provides a more granular snapshot of year-by-year bus replacement. The only exception to this is Bus #83 which is currently 40'. Depending on ridership demands and route considerations, this bus can be replaced by either a 35' or a 40' BEB. While electric cutaway options are assumed to be available starting in 2024, the cost is unknown. To determine the capital cost estimate in Table 4 above, the 35' BEB replacement cost was used.

Table 5. *Year-by-Year Bus Replacement*

Proposed Replacement Year	Bus #	Life Cycle Year End	Existing Bus Length	Proposed BEB Replacement Length	Bus Route
2021	55	2022	35'	35'	UCAT
	56	2022	35'	35'	UCAT
	58	2022	35'	35'	UCAT
2022	9037	2019	35'	35'	CitiBus
	9161	2021	23'	35'	CitiBus
	9162	2021	23'	35'	CitiBus
2023	59	2022	35'	35'	UCAT
	60	2022	30'	35'	UCAT
	61	2022	30'	35'	UCAT
	80	2022	26'	35'	UCAT
2024	81	2022	26'	Elec. Cutaway	UCAT
	82	2022	26'	Elec. Cutaway	UCAT
	9111	2023	35'	Elec. Cutaway	CitiBus
2025	9112	2023	35'	35'	CitiBus
	62	2024	30'	35'	UCAT
	63	2024	30'	35'	LINK
2026	67	2025	30'	35'	KPL
	84	2025	26'	Elec. Cutaway	UCAT
	85	2025	26'	Elec. Cutaway	UCAT
2027	86	2025	23'	Elec. Cutaway	UCAT
	87	2025	23'	Elec. Cutaway	UCAT
	69	2026	30'	35'	LINK
2028	70	2026	30'	35'	LINK
	71	2026	30'	35'	LINK
	73	2027	30'	35'	UCAT
2029	74	2027	30'	35'	UCAT
	75	2027	30'	35'	UCAT
	76	2027	30'	35'	UCAT
2030	78	2028	30'	35'	UCAT
	79	2028	30'	35'	UCAT
2031	83	2031	40'	35' or 40'	UCAT
2032	88	2032	35'	35'	UCAT
	89	2032	35'	35'	UCAT
	90	2032	35'	35'	UCAT

Section 3: Annual Operating Cost Comparison Details

The following provides some additional detail and context as to how the annual operating costs for both fossil-fueled and BEBs were calculated. The previously submitted final report for the feasibility study included a calculation of the annual operating costs of the current UCAT fleet. These were based on real purchase, maintenance, and fuel costs reported by UCAT, with vehicle purchase costs amortized over the anticipated lifecycle of the vehicles. The annual operating costs (in 2020 dollars) of UCAT's existing fleet is summarized in Table 6.

Table 6. UCAT Operating Annual Operating Costs by Vehicle Type

Vehicle Type	Cost per Mile (2020)			Cost per Year (2020)		
	Purchase cost	Fuel cost	Maintenance cost	Purchase cost	Fuel cost	Maintenance cost
25ft Gas	$0.74	$0.25	$0.20	$23,784	$7,933	$6,312
30ft Diesel	$0.89	$0.25	$0.33	$28,638	$8,094	$10,496
35ft Diesel	$1.05	$0.30	$0.32	$33,809	$9,768	$10,166
40ft Diesel	$1.13	$0.31	$0.31	$36,458	$10,024	$9,836
35ft Hybrid	$1.70	$0.31	$0.43	$54,858	$10,104	$13,981
40ft Hybrid	$1.47	$0.26	$0.51	$47,241	$8,465	$16,307

The social costs for the existing fleet, calculated by assigning a monetary value to the greenhouse gas and noise emissions of the fleet, was also calculated in the final report. The total average operating cost of the existing fleet, including calculated social costs and weighted by the number of each vehicle type currently serving the UCAT service area is summarized in Table 7*:*

Table 7. *Weighted Average Annual Operating Cost of Existing UCAT Fleet*

	Cost per Year (2020)
Purchase Cost	$33,400
Maintenance Cost	$10,400
Fuel Cost	$8,700
Social Cost	$7,100
Total	$59,600

Table 8. *Calculated Annual Operating Cost of Electric Buses*

	Cost per Year (2020)
Purchase Cost	$67,379
Maintenance Cost	$12,753
Fuel Cost	$9,226
Social Cost	$966
Total	$90,324

The projected annual operating costs for BEBs was calculated by amortizing the purchase price over the lifecycle of the bus, projecting maintenance cost savings over current costs based on a review of research and peer agency experience, and estimating electricity costs. The social costs of electric buses is estimated to be less than 14% that of the existing fleet, with only noise contributing to annual costs. The annual operating costs of electric buses, calculated in 2020 dollars and based on 2020 market trends and utility pricing, is summarized in Table 8 (above).