Brewster Central School District
Fleet Electrification Plan

NYSERDA Flexible Technical Assistance Program

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Brewster Central
School District

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Acronyms

A	amperage
AC	alternating current
BESS	battery energy storage system
CLCPA	Climate Leadership and Community Protection Act
DC	direct current
DCFC	DC fast charger
EaaS	electrification-as-a-service
ESB	electric school bus
EV	electric vehicle
EVSE	electric vehicle supply equipment
FEP	Fleet Electrification Plan
GHG	greenhouse gas
HVAC	heating, ventilation, and air conditioning
ICE	internal combustion engine
kW	kilowatt
kWh	kilowatt-hour
kVA	kilovolt-amperes
MVA	megavolt-amperes
MW	megawatt
NOAA	National Oceanic and Atmospheric Administration
NYSEG	New York State Electric and Gas
NYSBIP	New York State Bus Incentive Program
NYSDOT	New York State Department of Transportation
NYSERDA	New York State Energy Research and Development Authority
O&M	operations and maintenance
PPA	power purchase agreement
SD	standard deviation
SOC	state of charge
tCO2e	tons of carbon dioxide equivalent
V	voltage

Definitions

Amperage	The rate of flow of electrons through a circuit, a.k.a. current
Demand Charge	Utility charges based on the highest level of power a customer draws at one time during the billing period and the time of day it is needed by the customer
EV Ready	A state of infrastructure preparedness where a site or facility is equipped to support electric vehicle (EV) charging with minimal additional upgrades; this typically includes the installation of sufficient electrical capacity, conduit, wiring, and appropriate electrical panels to accommodate EV chargers
Internal Combustion Engine	Automobiles that use fossil fuels such as gasoline or diesel to power their engines
Feeder	A utility power line that transmits electricity from a substation or generating station to distribution points
Future Proof	In the context of EV infrastructure, future proofing means to design the service and/or electrical equipment to be oversized, capable of handling additional electrical load in the future
Kilowatt	The rate at which power is consumed or delivered
Kilowatt-hour	A unit of measure for electrical energy or the amount of electricity used; 1 kilowatt-hour is the energy delivered by 1 kilowatt of power for 1 hour
Kilovolt-Amperes	A unit of measurement for apparent power, which is the total amount of power in use in an electrical system
Megawatt	A unit of power equal to one million watts, especially as a measure of the output of a power station
State of Charge	The percentage of energy the battery currently has compared to its capacity
Substation	A set of electric equipment that reduces high voltage power to a voltage suitable for distribution to customers
Transformer	A device that changes electricity from one level of voltage to another
Voltage	Pressure created by a difference in electrical charge between two points

1. Objectives and Key Concepts

1.1 Project Objectives

This project provides a conceptual framework for Brewster Central School District (Brewster CSD) to guide the transition of its school bus fleet to electric school buses (ESBs). Located in a region with cold weather and moderately hilly conditions, Brewster CSD faces unique challenges, including higher power demands for its fleet. By incorporating worst-case scenario inputs into the route and charging analysis, this study will estimate the power requirements for each route and determine the maximum range of new ESBs to account for the district's dynamic routing needs.

Additionally, this Fleet Electrification Plan (FEP) outlines the necessary infrastructure upgrades to support ESB charging. Through comprehensive site assessments and utility engagement, the district will gain insight into the feasibility, timelines, power requirements, and costs associated with retrofitting its facilities for an electrified fleet. This strategy equips Brewster CSD with the critical information needed for effective planning and implementation.

1.2 Vehicle Classifications

Type A EV Bus: A small school bus, typically built on a cutaway van chassis with a passenger capacity of 10-30 students. Type A buses are commonly used for shorter routes. Due to their smaller size, they generally require less battery capacity and may be more energy efficient on low-mileage routes.

Type C EV Bus: A standard-sized school bus with a capacity of 50-77 passengers widely used for general student transportation. They are suitable for medium- to long-range routes and typically require larger battery capacities.

Type D EV Bus: A large, transit-style school bus with a passenger capacity of 66-90 students. Type D buses are commonly used on high-capacity routes or longer trips. Due to their size, they require significant battery capacity and are well-suited for districts with large numbers of students or for long-distance routes.

1.3 Charging Types

Level 2: Level 2 chargers operate on 208 to 240 volts AC and can deliver up to 80 amps of power. These chargers typically require between 12 and 30 hours to fully charge a vehicle, depending on the battery size and state of charge. The hardware for Level 2 chargers is relatively affordable, with costs ranging from $1,000 to $10,000, while installation costs typically fall between $8,000 and $20,000 per charging port.

Level 3: Level 3 chargers, also known as DC fast chargers, provide significantly faster charging speeds. They operate on 200 to 500 volts DC and can deliver up to 500 amps of power, enabling a full charge in approximately 1 to 8 hours. This rapid charging capability comes with higher costs, as hardware prices range from $20,000 to $100,000, and installation expenses typically range from $20,000 to $100,000 per charging port.

1.4 Related Legislation

In 2022, as a part of the effort to reduce greenhouse gas emissions and improve the health of students, New York State passed legislation requiring the electrification of school buses. New York's 2022-23 budget set the following mandates:

- **2027:** All school buses purchased after July 1, 2027 must be zero-emission, with the possibility of an additional 24-month extension from the 2027 purchase date (established in the FY2026 budget).
- **2035:** All school buses in operation after July 1, 2035, must be zero-emission.

2. Executive Summary

This Fleet Electrification Plan for Brewster CSD serves as a comprehensive guide to achieving a full transition to an electric school bus fleet, aligning with New York State's zero-emission vehicle mandates. The plan offers a phased approach to electrification, addressing operational challenges, infrastructure requirements, and long-term sustainability.

Electrifying their school bus fleet presents significant benefits for Brewster CSD, including improved air quality for students and the community, reduced greenhouse gas emissions, and lower long-term operating costs. ESBs eliminate tailpipe emissions, creating healthier environments around schools and neighborhoods, particularly benefiting children who are more vulnerable to air pollution. Financially, electric buses offer lower fuel and maintenance costs compared to fossil fuel powered counterparts, with the potential for further savings through strategic charging management and the use of off-peak electricity rates.

Key elements of this plan include a detailed route analysis that accounts for Brewster CSD's unique challenges, such as long routes, hilly terrain, and cold weather conditions. These factors are critical in determining vehicle energy demands and battery performance under real-world conditions. The proposed charging infrastructure strategy ensures sufficient power for daily operations while minimizing costs through efficient site planning and phased implementation of utility upgrades.

The plan also emphasizes workforce readiness as a cornerstone of successful implementation. Driver training programs are designed to maximize vehicle efficiency through techniques such as regenerative braking and pre-conditioning, while maintenance teams are prepared to address the specific needs of ESBs. Additionally, safety protocols, including fire prevention measures and emergency response coordination, are integrated into the transition plan.

Beyond operational improvements, fleet electrification aligns Brewster CSD with broader environmental and social goals, contributing to state and national efforts to combat climate change. It also positions the district as a forward-thinking leader in sustainable transportation, with the potential to inspire other school systems to follow suit.

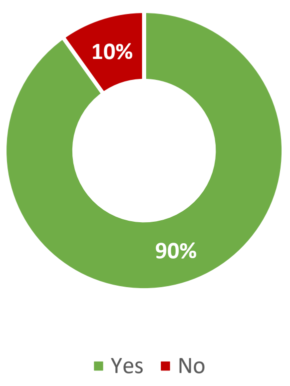
By adopting this plan, Brewster CSD can confidently navigate the transition to an electric fleet while ensuring reliability, sustainability, and long-term cost savings. The phased approach provides flexibility to adapt to advancements in EV technology and district-specific needs, ensuring a successful and scalable transition that benefits the entire community.

2.1 Key Data

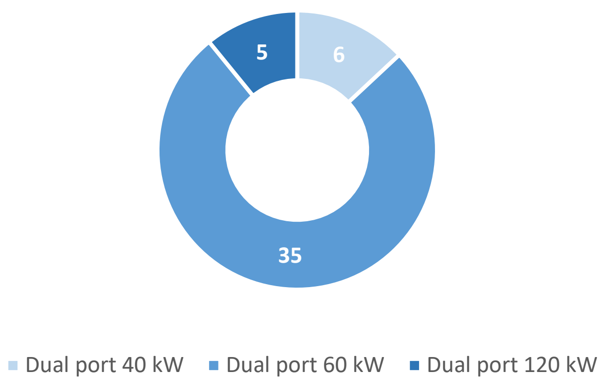
Fleet Information

Brewster CSD operates a fleet of 91 buses from one parking lot located at 40 Farm to Market Road, Brewster, NY 10509. The fleet consists of 39 Type A buses, 6 of which are currently spare, and 52 Type C buses, 3 of which are currently spare. The district has plans to dispose of some of the spares and purchase new vehicles within the next school year. Additional key details regarding the electrification plan are outlined below.

Graph 1: *Percent of Routes That Can Electrify with Current Technology*



Graph 2: *Number of EV Chargers*



Electric Utility Requirements

Table 1: *Electric Utility Requirements Summary*

NYSEG Utility Requirements	
Daily Peak Demand without Charge Management	2940 kW
Daily Peak Demand with Charge Management	2188 kW
% Reduction in Peak Demand with Charge Management	26%
District-side Infrastructure Upgrades	Upgraded service capable of serving 300 kW of initial DC fast charger installations while larger utility upgrades are underway, followed by upgraded service capable of handling 2940 kW total for full fleet electrification
Utility-side Infrastructure Upgrades	Upgrades required at substation (Tilly Foster Bank #1) and circuit (Tilly Foster Feeder #437)
Timeline for Upgrades	2-year estimate for substation and feeder upgrades, to be confirmed by formal load letter submission to NYSEG

Cost Breakdown

Table 2: *Cost Summary**

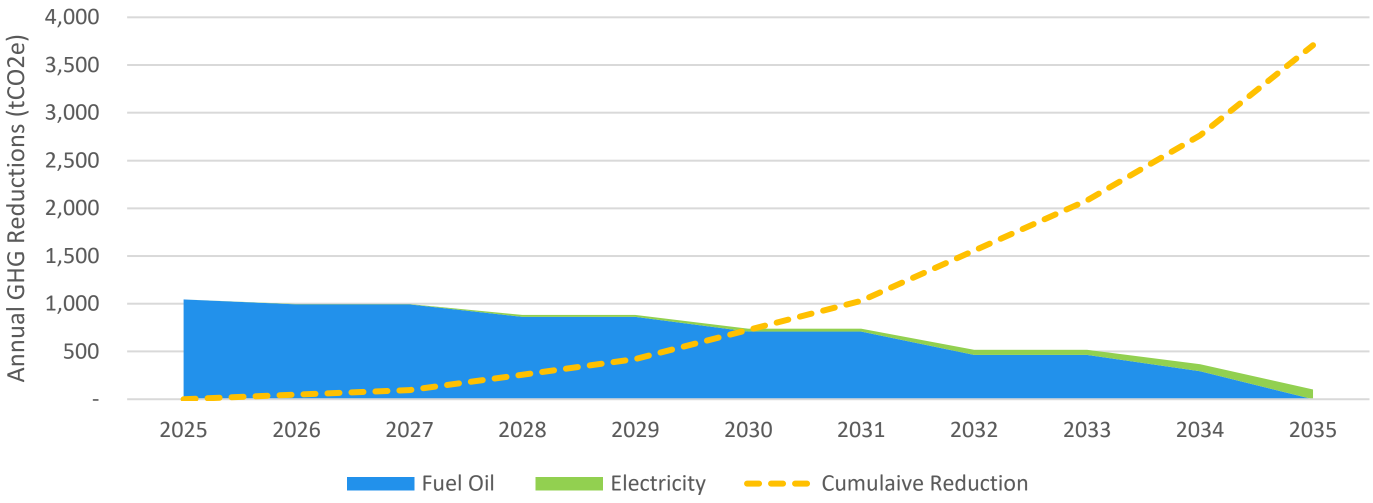
Estimated Total Project CapEx and OpEx	
Total Project CapEx (Without Incentives)	$46,223,793
Total Project CapEx (With Incentives)	$33,575,157
Estimated Annual OpEx of Fully Electrified Fleet	$548,040
Incentive Information	
NYSBIP Bus Voucher	$114,000 / Type A bus $147,000 / Type C bus
NYSBIP Charging Voucher	$55,000 / charger
NYSEG Make Ready Incentive for Utility Upgrades	Up to 50% of utility-side infrastructure costs

Estimated School Bus Costs	
Micro Bird G5 (Type A) Unit Cost	$325,000
International CE (Type C) Unit Cost	$425,000
Total Cost for Buses (Without Incentives)	$38,560,895
Total Cost for Buses (With Incentives)	$31,216,895
Estimated Electric Vehicle Charger Installation Costs	
40 kW Charger Unit Cost	$35,000
60 kW Charger Unit Cost	$45,000
120 kW Charger Unit Cost	$80,000
Total Charger Costs (Without Incentives)	$2,454,103
Total EVSE Infrastructure and Installation Cost (Without Incentives)	$2,508,795
Total Utility Upgrade Costs (Without Incentives)	$2,700,000
Total Cost for Installation (Without Incentives) (Chargers, Utility Upgrade, Installation)	$7,662,898
Total Cost for Installation (With Incentives) (Chargers, Utility Upgrade, Installation)	$2,358,262
Estimated Operational Costs	
Electricity Costs	Supply Charge: $0.03 / kWh Demand Charge: $19.65 / kW
Maintenance Costs	$0.046 / mile
Software Costs	$1,000 / port

* Total costs summarized based on current market price and do not reflect depreciation or escalation assumptions shown in Appendix 11

Environmental Impact

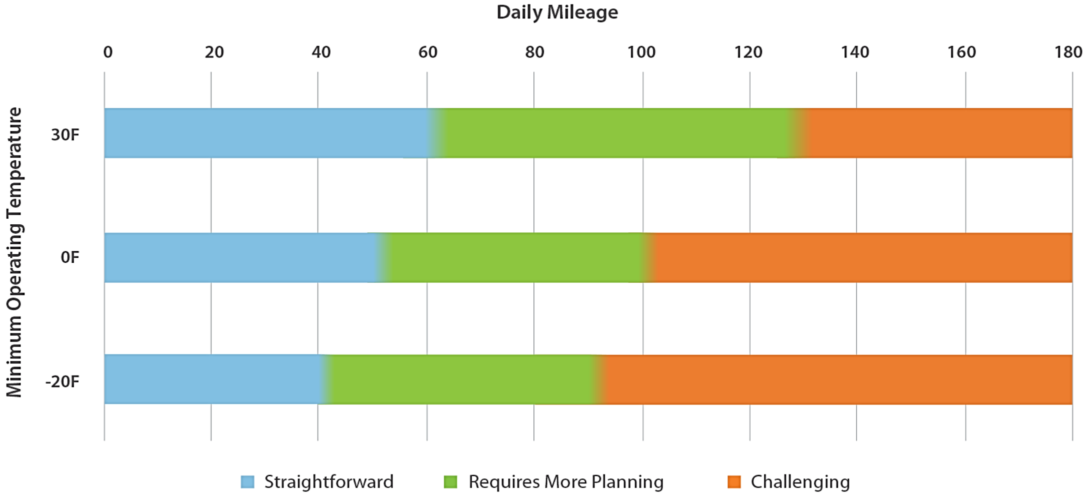
Graph 3: *Projected Annual Greenhouse Gas Emissions of Fleet*



2.2 Phasing Overview

To comply with New York State's 2035 electrification mandates, Brewster CSD must transition all 91 school buses to electric. The initial phase is recommended to serve as a pilot, focusing on electrifying shorter, less demanding routes, while also allowing for necessary utility infrastructure upgrades to occur. This approach allows for the establishment of new driver habits and operational procedures, providing a foundation for the broader transition.

Graph 4: *Electric School Bus Suitability in 2024*[1]



Given that many of Brewster CSD's routes, particularly Type A bus routes, are classified as challenging or requiring additional planning, the implementation strategy has been divided into four distinct phases, some with sub phases. This phased approach ensures a systematic and manageable transition, allowing the district to address specific challenges incrementally while optimizing operational efficiency and enabling technological improvements.

Table 3: *Conceptual Phased Implementation Plan*

Phase	Year(s)	Buses Electrified	New Utility Service	Cumulative Max Power Demand*	ESB Capital Expenditure**	ESB Operational Expenditure
Phase 1	2026-2027	14	+ 300 kW	84 kW	$4,264,585	$35,669
Phase 2.1	2028-2029	20	+ 2640 kW	436 kW	$8,984,767	$125,925
Phase 2.2	2030-2031	20	No new service	984 kW	$7,669,355	$249,075
Phase 3.1	2032-2033	19	No new service	1519 kW	$7,509,434	$372,923
Phase 3.2	2034	8	No new service	1658 kW	$2,068,251	$423,004
Phase 4	2035	10	No new service	2188 kW	$3,078,766	$548,040

* With charge management

** With incentives

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[1] https://afdc.energy.gov/guides/electric-school-bus

3. Route Analysis

This analysis evaluates the compatibility of Brewster CSD's current fleet operations with electric school bus alternatives. These findings can inform decisions made by the district in the transition to an electric bus fleet to comply with New York State's 2035 school bus electrification mandates.

3.1 Route Analysis Inputs

The route analysis incorporates a range of inputs and assumptions to reflect the real-world conditions the district encounters on a year-to-year basis. These inputs and assumptions are outlined in greater detail below.

Electric School Bus Make and Model

Brewster CSD currently uses a variety of school bus models including International (AE, BE, CE Series), Chevrolet (K3500, CG33503, CG33803, CG33903), Trans Tech (4500 Express), and Micro Bird (G5) for Type A buses, and International (CE, FE, RE Series) and Blue Bird (Vision) for Type C buses. The district also has several passenger vans (Dodge Journey and Caravan, and Ford MB-II) used to transport students. As such, this analysis includes modeling for the Micro Bird G5 and Phoenix Motorcars Z-600 for Type A buses, and the International CE Series and Thomas C2 Jouley for Type C buses. The passenger vans were modeled as Type A vehicles. These models were selected following market research to best align with current vehicle utilization and route demand. Key inputs for these buses are outlined in **Table 4**. **Appendix 1** and **Appendix 3** contain the bus specifications for the bus models chosen.

Table 4: *ESB Model Inputs*

	Type A		**Type C**	
Bus Model	**Micro Bird G5**	**Phoenix Motorcars Z-600**	**International CE Series**	**Thomas C2 Jouley**
Nameplate Capacity (kWh)	175	131	315	246
Nameplate Range (miles)	200	165	200	167
Battery Efficiency (kWh/mile)	0.88	0.79	1.58	1.47
Usable Battery	89%*	89%*	90%	89%
Gross Vehicle Weight (lbs.)	14,500	14,500	35,000	33,000

* Assumed

Route Data

Route data for the school year was provided for 82 of the fleet's 91 buses. The remaining 9 buses are currently used as spares. It is understood that routes change from year to year, so this analysis also includes generalized data that can be used for future and extracurricular trip planning in **Table 8** and **Table 9**. On average, Brewster CSD's Type A buses have longer routes than the Type C vehicles, with a 74 mile per day average (Standard Deviation (SD): 51) compared to a 29 mile per day average (SD: 19), respectively.

Temperature

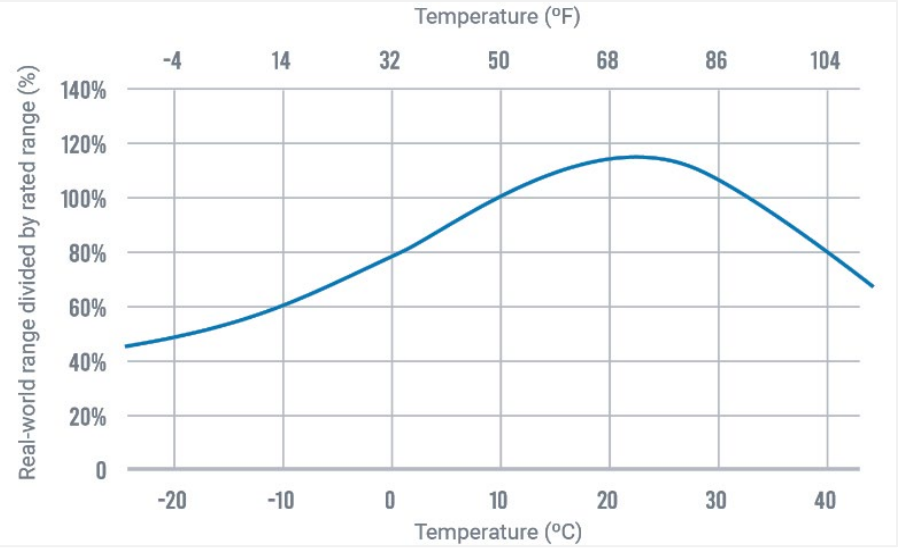
Historical average temperature data for Brewster, NY was taken from the National Oceanic and Atmospheric Administration (NOAA) and can be found in **Table 5** below. Temperature, particularly low temperature, is an important input in the route analysis because the lithium-ion batteries currently used in electric school buses are less efficient in colder weather. As such, the routes simulated in this analysis are based on the lowest average temperature conditions to ensure that routes can be completed in the most demanding, worst-case-scenario conditions.

Table 5: *Average Temperatures in Brewster, NY*

Month	Average High (°F)	Average Low (°F)
January	36°	18°
February	39°	20°
March	46°	28°
April	59°	38°
May	70°	48°
June	76°	57°
July	81°	63°
August	80°	61°
September	73°	54°
October	62°	42°
November	51°	33°
December	40°	24°

Further, as seen in **Graph 5** below, the range of an electric school bus is reduced anywhere from 20% to 50% in temperatures below freezing. This reduced range is attributed to less efficient battery function in colder weather as well as higher demand for heating.[2] This route analysis uses an assumed maximum range reduction of 30% based on the lowest average temperature of 18°F.

Graph 5: *Temperature vs. EV Battery Range*[2]



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[2] Geotab. *To what degree does temperature impact EV range?* https://www.geotab.com/blog/ev-range/

Route Terrain

Turn-by-turn route data was not provided, and an online topography database was used to determine expected elevation changes along the bus routes. **Figure 1** below shows a topographical map of the district. It was noted by Brewster CSD that there are currently routes serving students 15 to 50 miles out of district in hilly areas. As such, the following assumptions were used in the route analysis:

a. Average uphill road angle of 2°

b. 60% of each route through level areas (baseline efficiency)

c. 40% of each route through unlevel areas (20% uphill, 20% downhill)

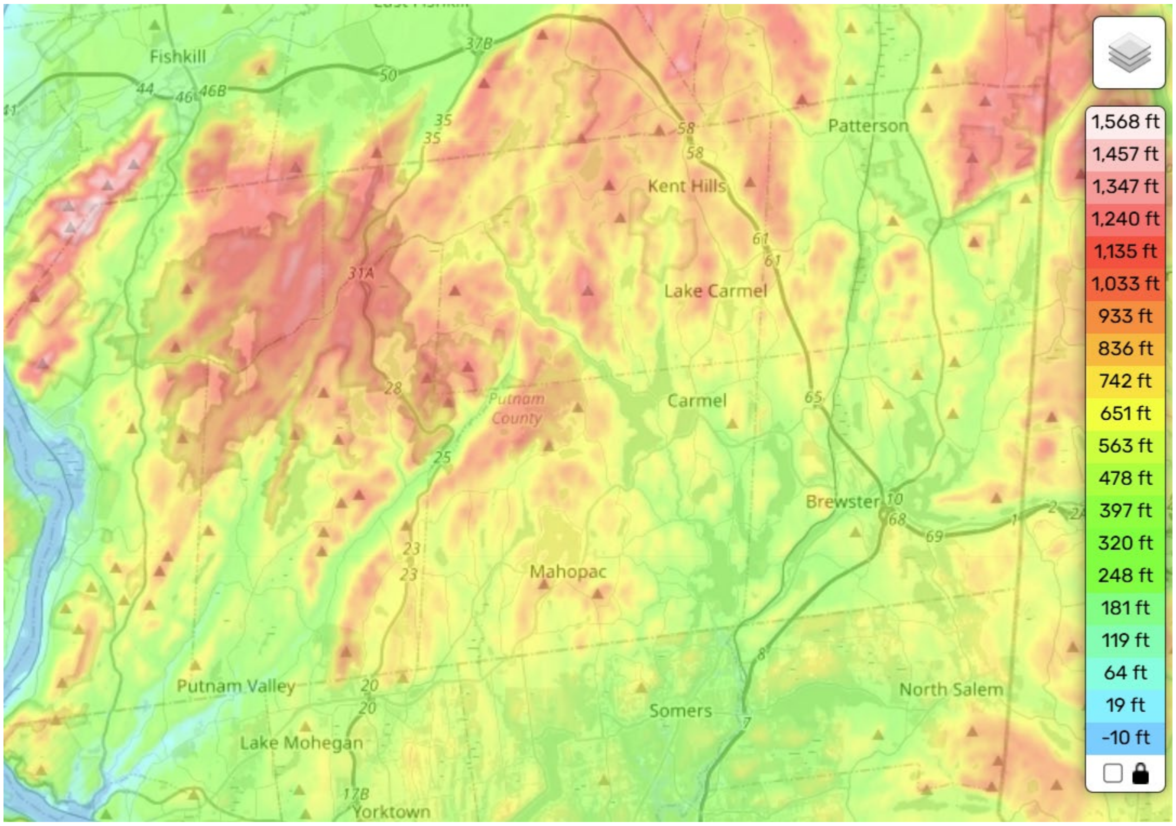
d. 30% recapture of kinetic energy during regenerative braking downhill

To calculate additional power required for uphill drives, the following calculation and inputs were used:

$$E_{vertical} = m \times g \times h$$

$E_{vertical}$: power required to move the ESB up an incline
m: mass of vehicle & ancillary loads
g: gravitational acceleration (9.81 m/s^2)
h: height of the incline

Figure 1: *Topographic Map of Brewster Central School District*



3.2 Route Analysis Results

Summary

By integrating the electric bus specifications, route data, weather conditions, and topography, the usable battery range and battery efficiency were calculated for bus operation in cold weather and hilly terrain. These calculations formed the basis of the route analysis results, offering insights into the performance and feasibility of electric bus operation under challenging conditions experienced in Brewster CSD, as outlined in **Table 6**.

Table 6: *Summary of Route Analysis Inputs*

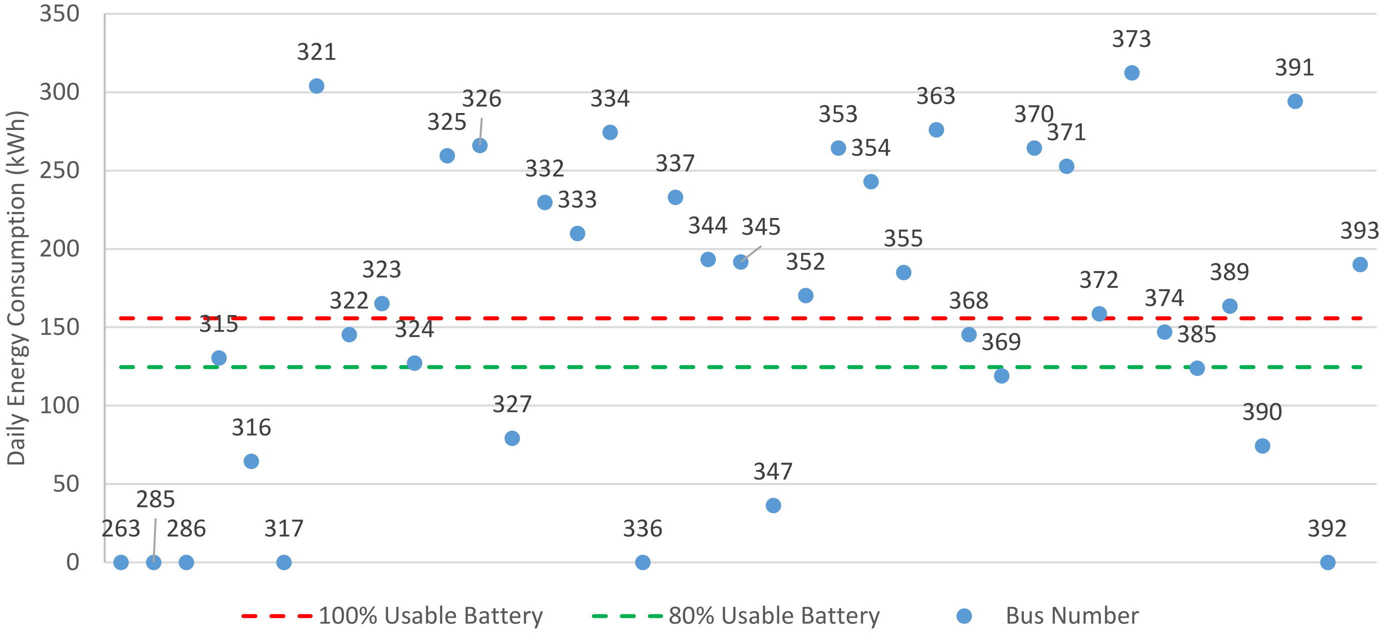
	Type A		**Type C**	
Bus Model	**Micro Bird G5**	**Phoenix Motorcars Z-600**	**International CE Series**	**Thomas C2 Jouley**
Usable Range				
Nameplate Capacity (kWh)	175	131	315	246
Nameplate Range (miles)	200	165	200	167
Battery Efficiency (kWh/mile)	0.88	0.79	1.58	1.47
Usable Battery	89%*	89%*	90%	89%
Usable Capacity (kWh)	156	117	284	219
Usable Range (miles)	178	147	180	149
Usable Range in Cold Weather				
Efficiency Loss in Cold Weather	30%*	30%*	30%*	30%*
Efficiency in Cold Weather (kWh/mile)	1.25	1.13	2.25	2.10
Usable Range in Cold Weather (miles)	124.60	102.80	126	104.04
Usable Range in Hilly Areas and Cold Weather				
Additional Energy Going Uphill (kWh/mile)	1.01	1.01	2.43	2.29
Regenerative Braking Efficiency	30%*	30%*	30%*	30%*
Recouped Energy Going Downhill (kWh/mile)	(0.30)	(0.30)	(0.73)	(0.69)
Percent of Route that is Flat	60%*	60%*	60%*	60%*
Efficiency in Hilly Areas (kWh/mile)	1.58	1.50	3.28	3.08
Efficiency in Hilly Areas and Cold Weather (kWh/mile)	2.26	2.14	4.68	4.40
Range in Hilly Areas and Cold Weather (miles)	94	76	88	73

*Assumed

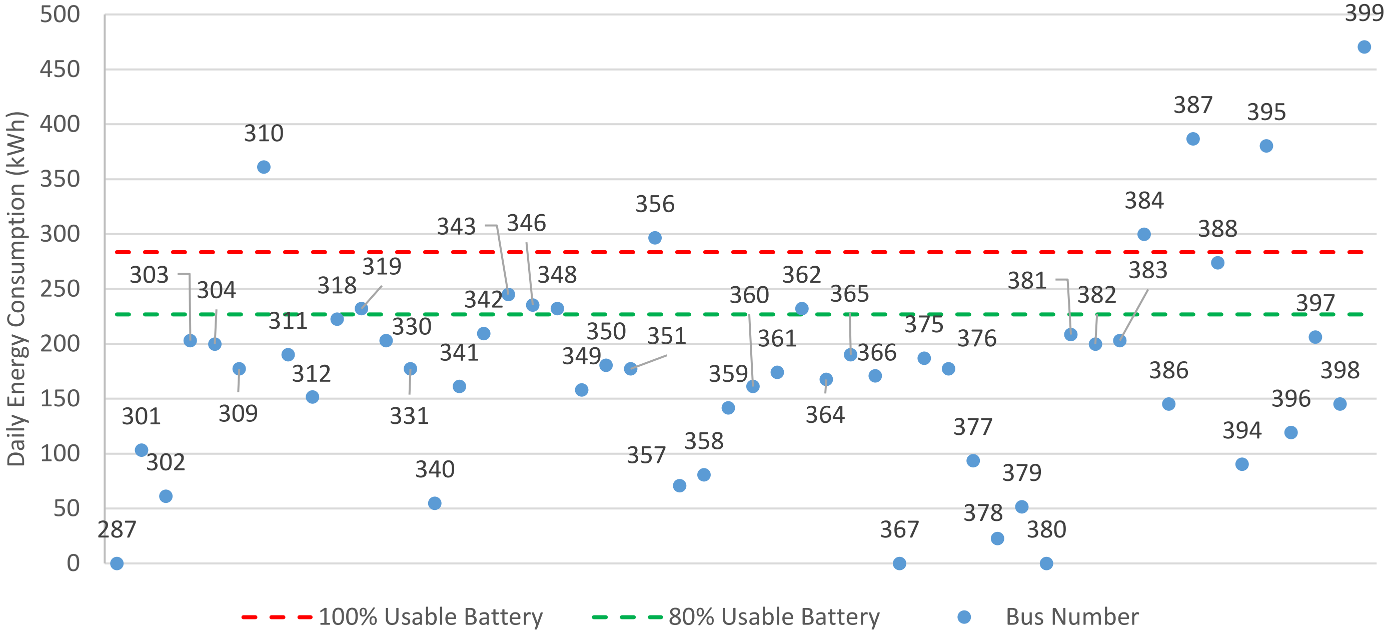
Results

By analyzing route length, elevation changes, and cold weather conditions, this analysis provides insight into the power demand of each unique route under worst-case scenario operational conditions. This helps to identify the routes that may require additional charging infrastructure or adjustments to ensure sufficient range and battery longevity. The results depict the expected daily power demand for each route in cold weather and hilly conditions. This analysis uses the Micro Bird G5 Type A bus and the International CE Type C bus. These buses were found to be the best fit for Brewster CSD's routes, and details and additional modeled results for the other buses included in this study can be found in **Appendix 5**.

Graph 6: *Daily Energy Consumption (kWh) in Cold Weather – Type A Vehicles*



Graph 7: *Daily Energy Consumption (kWh) in Cold Weather – Type C Vehicles*



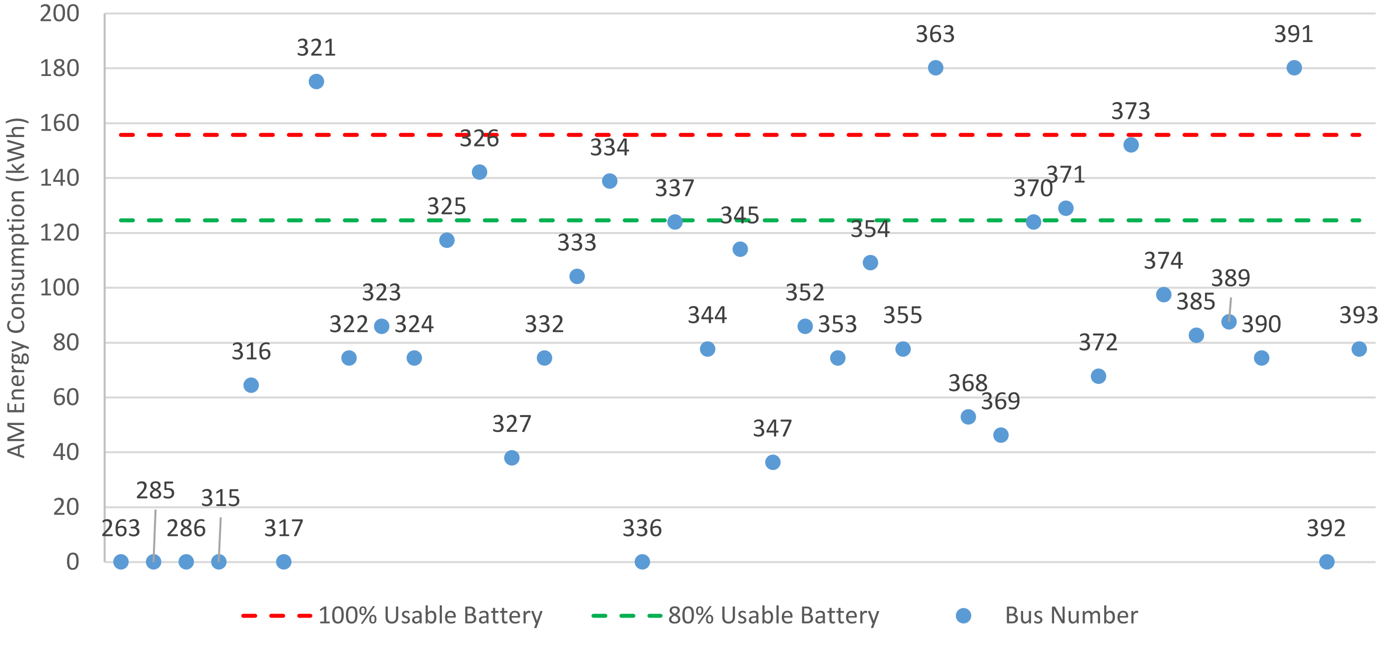
These graphs include a green and red line that represent different thresholds of the usable battery capacity: the red line represents 100% of the usable battery and the green line represents 80% of the usable battery. Buses that are modeled to complete their daily routes with at least 20% of the usable battery remaining fall below the green line. These buses are expected to meet their daily routes without needing a midday charge and are considered the most feasible for electrification and should be prioritized in earlier phases of implementation.

Buses that are modeled to complete their daily routes and have between 0% and 20% of the usable battery remaining fall between the green and red lines. These buses are expected to complete their daily routes without a midday charge, however, the state of charge (SOC) of the battery falls under the 20% suggested threshold, so it is recommended to plan for a midday charge. These buses should also be considered for electrification, as they should only need a small midday charge to ensure all AM and PM routes are met, but they will require additional planning. By utilizing charge management strategies, electricity costs can be minimized while ensuring the PM routes can be met with at least 20% of battery remaining. These strategies are detailed further in Section 4.

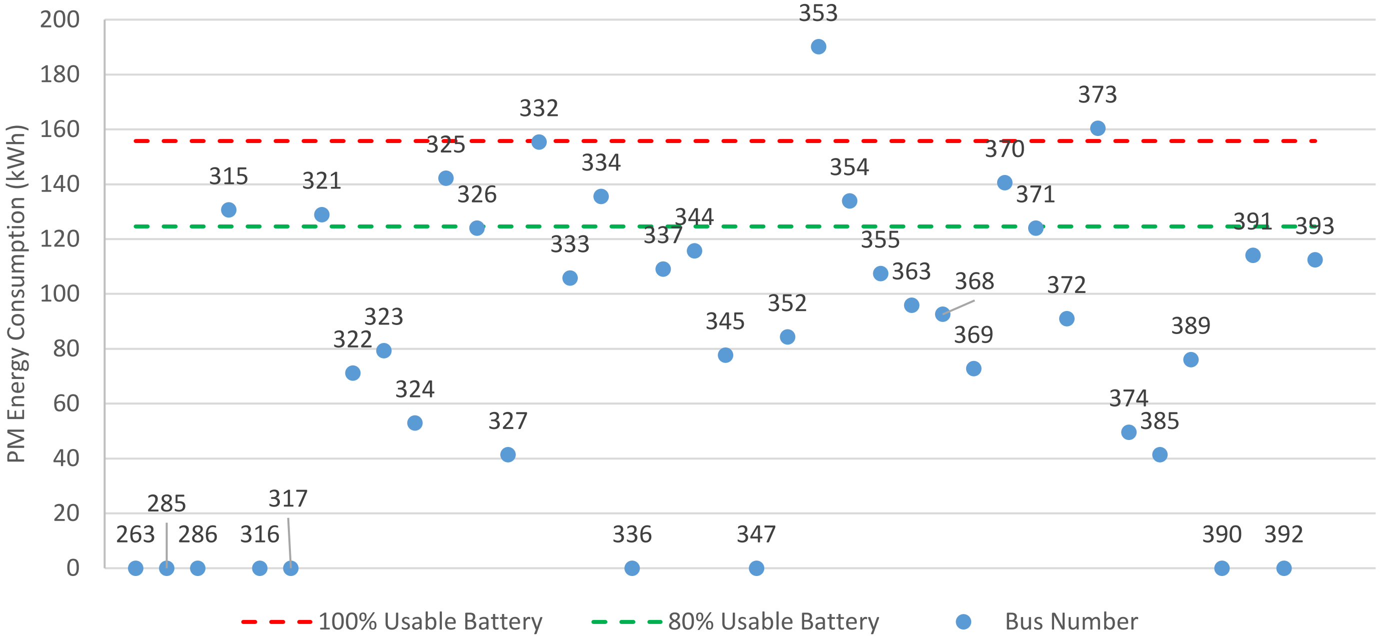
Buses that are modeled to complete their daily routes expending over 100% of the usable battery capacity fall above the red line. These buses either need a midday charge or cannot meet one or more of their routes and are considered more complex to electrify. While some buses only require a small amount of charge in the middle of the day, others require higher power chargers. Buses that require high power chargers should be included in later phases of implementation, allowing more time for driver training and battery technology development. Delaying the installation of higher power chargers will also minimize capital and operating costs.

Since a majority of Brewster CSD's buses, especially Type A buses, cannot meet their daily routes without a midday charge, it is necessary to look into the morning and afternoon power demands separately for each bus. The graphs below show the power demands of each route using the Micro Bird G5 Type A bus and the International CE Type C bus. As stated previously, the full route analysis results can be found in **Appendix 5**.

Graph 8: *AM Energy Consumption (kWh) in Cold Weather – Type A Vehicles*

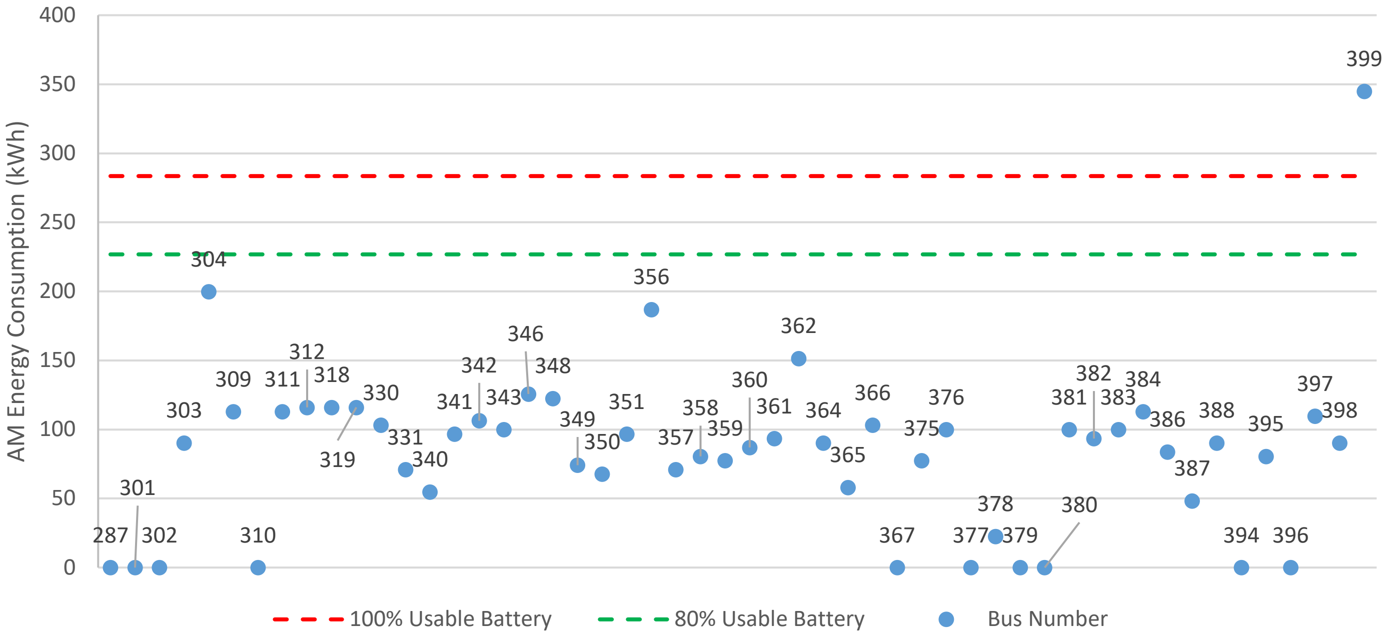


Graph 9: *PM Energy Consumption (kWh) in Cold Weather – Type A Vehicles*

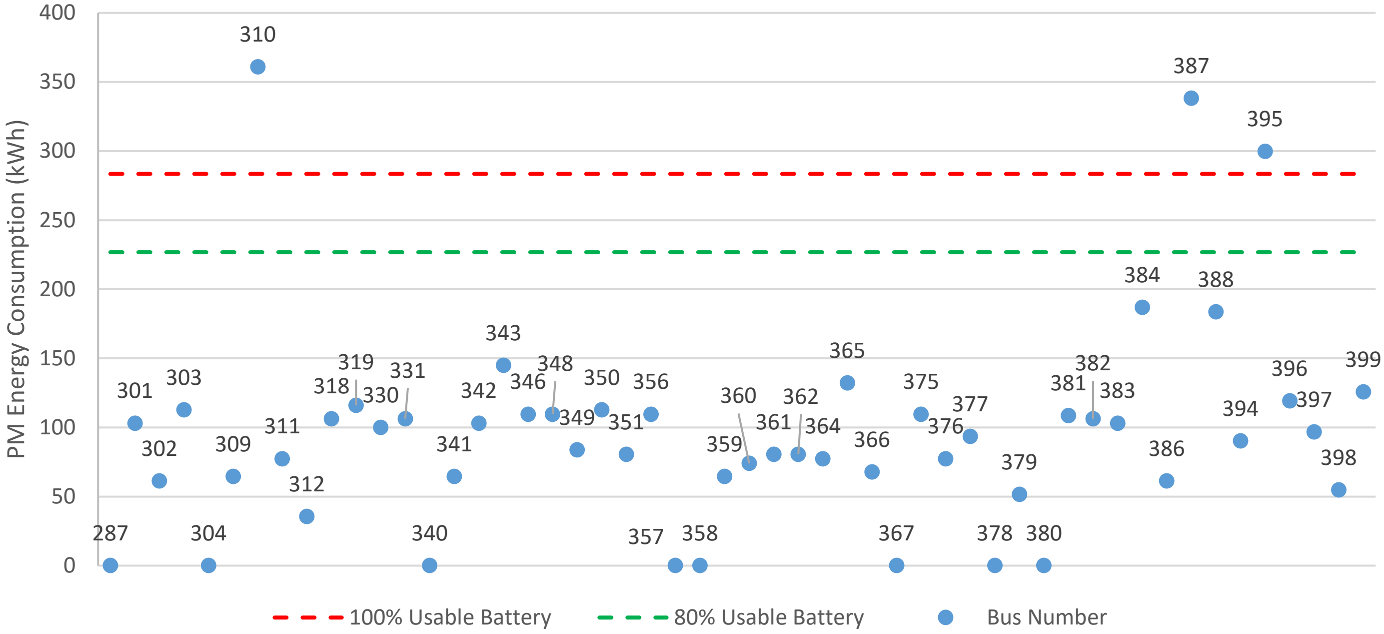


As shown in **Graph 8** and **Graph 9**, 16 Type A buses, including all spares, (263, 285, 286, 316, 317, 322, 324, 327, 336, 347, 368, 369, 374, 385, 390, 392) are considered straightforward to electrify as they are able to complete both AM and PM routes with at least 20% state of charge remaining, and require either a low-power midday charge or no midday charge. Further, 10 Type A buses (323, 333, 337, 344, 345, 352, 355, 372, 389, 393) will require more planning as they complete both routes and require a higher-power midday charge. Finally, 13 Type A buses (315, 321, 325, 326, 332, 334, 353, 354, 363, 370, 371, 373, 391) are considered challenging as they do not complete one or more of their routes or end the route under 20% state of charge.

Graph 10: *AM Energy Consumption (kWh) in Cold Weather – Type C Vehicles*



Graph 11: *PM Energy Consumption (kWh) in Cold Weather – Type C Vehicles*



As shown in the **Graph 10** and **Graph 11**, 12 Type C buses, including all spares, (287, 301, 302, 340, 357, 358, 367, 378, 379, 380, 394, 396) are considered straightforward to electrify as they are able to complete both AM and PM routes with at least 20% state of charge remaining, and require either a low-power midday charge or no midday charge. Further, 34 Type C buses (303, 304, 309, 311, 312, 318, 319, 330, 331, 341, 342, 343, 346, 348, 349, 350, 351, 359, 360, 361, 362, 364, 365, 366, 375, 376, 377, 381, 382, 383, 386, 388, 397, 398) will require more planning as they complete both routes and require a higher-power midday charge. Finally, 6 Type C buses (310, 356, 384, 387, 395, 399) are considered challenging as they do not complete one or more of their routes or end the route under 20% state of charge.

Challenging Routes

Based on the above data, the 9 buses in **Table 7** have an AM or PM route that cannot be completed under the current modeled scenario and are therefore considered challenging and not recommended for immediate electrification. Currently, there are no vehicle models that would meet the requirements of these routes.

Table 7: *Battery Requirements for Challenging Routes*

Bus	ESB Type	Battery Size Needed to be Feasible*
321	Type A	218 kWh
353	Type A	237 kWh
363	Type A	225 kWh
373	Type A	200 kWh
391	Type A	225 kWh
310	Type C	443 kWh
387	Type C	416 kWh

395	Type C	369 kWh
399	Type C	423 kWh

* Inputs: Type A: cold weather & hilly conditions, ending route over 10% SOC, assuming 89% usable battery, 14,500 lbs. and 0.88 kWh/mile efficiency. Type C: cold weather & hilly conditions, ending route over 10% SOC, assuming 90% usable battery, 35,000 lbs. and 1.58 kWh/mile efficiency.

As battery technology improves and driver best practices are implemented, these more challenging routes will become more feasible to electrify. Studies conducted by Bloomberg suggest that, with a conservative assumption on technology development, electric school bus ranges will increase by 5% annually.[3] Additionally, the efficiency in colder weather and hilly areas is expected to be a main focus of improvement within the EV industry. With these assumptions, the New York State Energy Research and Development Authority (NYSERDA) expects that technological advancements will lead to 400 kWh batteries for Type A vehicles and 600 kWh batteries for Type C vehicles becoming available by 2035, making these routes feasible. In the meantime, Brewster CSD can consider pairing longer AM routes with shorter PM routes, using spare buses to split up longer routes, or switching buses in between AM and PM routes.

Future Route Planning

Given that many bus routes are dynamic and change year-to-year, the summary tables below will assist in electrification efforts for future route planning. Using the same inputs and assumptions described previously, the following data was compiled for both average and cold temperatures. The model inputs were calculated for the Micro Bird G5 Type A bus (**Table 8**) and the International CE Series Type C bus (**Table 9**), using an assumed 60 kW dual port charger.

The numbers in red indicate that the expected power demand is higher than the usable battery of the bus. This table clarifies the estimated power demand for unreported or changing routes and how it differs based on distance. Furthermore, this also gives insight into the required time to charge based on your route in both average and cold weather. These charging calculations are further explained in Section 4.

Table 8: *Route Analysis for Range of Distances – Type A Buses*

Type A	**Average Weather**		**Cold Weather**	
Distance (mi)	**Power Consumption** (kWh)	**Time to Charge to Full*** (h)	**Power Consumption** (kWh)	**Time to Charge to Full*** (h)
10	11.57	0.53	16.53	1.19
20	23.14	1.07	33.05	2.38
30	34.71	1.60	49.58	3.57
40	46.28	2.13	66.11	4.76
50	57.85	2.66	82.64	5.94
60	69.42	3.20	99.16	7.13
70	80.98	3.73	115.69	8.32
80	92.55	4.26	132.22	9.51

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[3] https://www.bloomberg.com/news/newsletters/2023-08-01/battery-bloat-could-backfire-on-electric-vehicle-manufacturers

90	104.12	4.79	148.75	10.70
100	115.69	5.33	165.27	11.89
110	127.26	5.86	181.80	13.08
120	138.83	6.39	198.33	14.27
130	150.40	6.92	214.86	15.46

* Time to charge to full is based on a 30 kW charging port

Table 9: *Route Analysis for Range of Distances – Type C Buses*

Type C	**Average Weather**		**Cold Weather**	
Distance (mi)	**Power Consumption** (kWh)	**Time to Charge to Full*** (h)	**Power Consumption** (kWh)	**Time to Charge to Full*** (h)
10	22.55	1.04	32.22	2.32
20	45.11	2.08	64.44	4.64
30	67.66	3.12	96.66	6.95
40	90.22	4.15	128.89	9.27
50	112.77	5.19	161.11	11.59
60	135.33	6.23	193.33	13.91
70	157.88	7.27	225.55	16.23
80	180.44	8.31	257.77	18.54
90	202.99	9.35	289.99	20.86
100	225.55	10.38	322.21	23.18
110	248.10	11.42	354.43	25.50
120	270.66	12.46	386.66	27.82
130	293.21	13.50	418.88	30.13

* Time to charge to full is based on a 30 kW charging port

Since route data was not provided for extracurricular trips, it is important to reference this table when planning extra routes. It is recommended that either the spare buses or buses with the shortest daily routes are utilized for these trips and the total daily mileage of that bus, including the extracurricular trip, does not exceed the maximum distances detailed in **Table 8** or **Table 9**.

4. Charging Strategy

A comprehensive charging strategy is pivotal to fleet electrification success. This section outlines the charging stations required and the subsequent infrastructure plan developed from the route analysis, which assessed daily energy needs, vehicle dwell times, and optimal charging locations. Various chargers were evaluated to align with operational needs, focusing on charging speed, load management, cost-effectiveness, and scalability. The full results of the charging analysis can be found in **Appendix 6**.

Additionally, the infrastructure layout designed to support the chosen chargers is detailed, including electrical capacity, site readiness, and necessary upgrades. This integrated plan ensures immediate operational demands are met while accommodating future growth for a seamless transition to electrified operations.

4.1 Existing Conditions Assessment

Parking Area & Facility Assessment

Brewster CSD parks their buses at 40 Farm to Market Road, Brewster, NY 10509. The electrical infrastructure and spatial arrangement of this parking area was assessed with the intention of installing electric vehicle chargers.

Figure 2: *Overhead Map of Parking Lot at 40 Farm to Market Road*

This lot is a fenced-in parking area used for both Type A and Type C buses, with ample space for charger installations. The current electrical equipment is being fed overhead from a utility pole to the west of the property approximately 220 feet away. Due to the location of the utility transformer and proposed phasing plan outlined in Section 5, it is suggested that a service upgrade is requested and new service equipment is installed at a location in the northwest corner of the lot to reduce costs and centrally serve future phases of charger installations.

As seen in the overhead site map above, the buses all have their own parking spaces and the lot is partially surrounded by open land, which is ideal for charger installations. Using dual port chargers would be the appropriate solution for this location, minimizing installation and material costs. This would require careful planning of the parking arrangements, since the buses would need to be paired based on combined power demand and would need to be parked so that the chargers can reach the charging port on both buses. Depending on the length of charger cable and bus model chosen, one bus may have to pull in headfirst, while the other would back in.

Electrical Capacity Assessment

An existing conditions assessment was conducted to assess the electrical capacity at the parking lot. The parking lot service is located at a shed at the northern entrance of the lot and is fed via an overhead line to a pole-mounted transformer adjacent to the parking lot. There are three 150A/208V panels with 225A frames at this shed which are fed by a 400A/208V main distribution panel. While these 150A panels have a few switches labelled as spare, a 40 kW dual port charger exceeds the entire capacity of these panels. Furthermore, the 400A/208V main distribution panel also does not have spare capacity for a 40 kW dual port charger.

Fed from a different pole-mounted transformer adjacent to the parking lot, there is a separate 1600A/208V service at the transportation building on-site feeding a main distribution board with approximately 200A of spare power observed. While this could potentially feed one 40 kW dual port charger, it would require a step-up transformer and long wire and conduit run.

Given the limited availability of capacity, it is not recommended to install chargers off existing power. Instead, the service in the parking lot should be upgraded and requested at 480V to accommodate the DC fast chargers needed for an electrified bus fleet.

Figure 3: *Service in Parking Lot*

Figure 4: *Parking Lot Meter*

Figure 5: *Parking Lot Main Distribution Panel*

Figure 6: *150A Service Panels Feeding Parking Lot Equipment*

Figure 7: *Panel 1 Interior*

Figure 8: *Panel 2 Interior*

Figure 9: *Panel 3 Interior*

Figure 10: *1600A Service Equipment in Building*

Figure 11: *Service Switchboard with Spare Switches*

4.2 Charger Selection

Charge Analysis Inputs

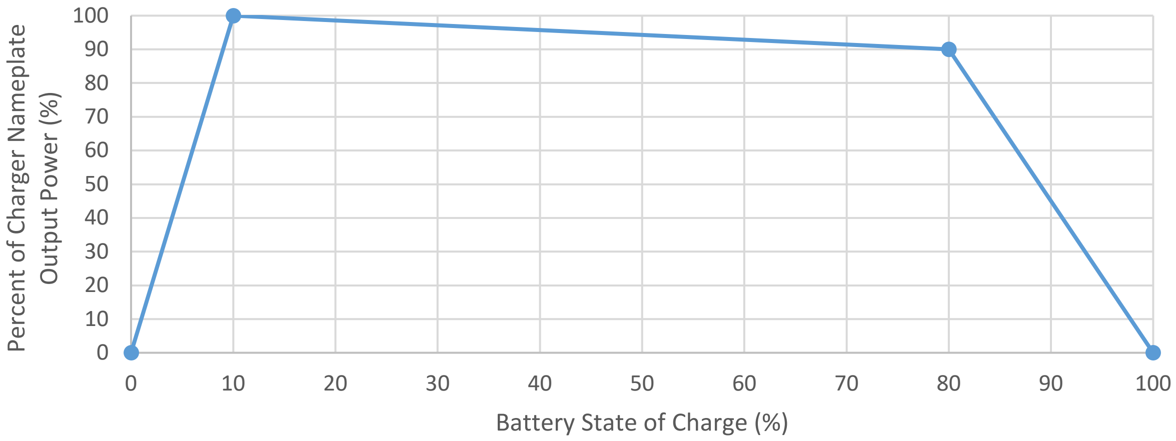
Using the results of the route analysis, the charge power needed for the AM and PM routes were determined. To calculate the resulting charger size required for each bus, various real-world inputs were considered. The inputs considered are listed below.

1. **Efficiency loss due to weather conditions:** Cold weather conditions impact the flow of electrons, making chargers less efficient in colder weather, similar to EV batteries. Studies show that EV batteries take in 36% less energy in cold weather[4], which was applied to the charging analysis.

2. **Charging curves:** EV charging curves generally consist of three phases: ramp-up, peak, and ramp-down. During the ramp-up phase, charging power gradually increases as the vehicle's battery management system assesses the battery's condition and thermal state. Once optimal conditions are met, the charger delivers maximum power during the peak phase, often reaching the advertised charging rate of the vehicle and station. As the battery approaches a higher SOC—typically 80%—the ramp-down phase begins, during which charging power tapers off significantly to prevent overheating and reduce stress on the battery. This tapering effect, critical for long-term battery health, can considerably extend the time needed to fully charge.

   A typical charging curve is provided below which models the various charging speeds the ESB battery will accept, dependent on the battery's SOC. Using this typical charging curve, a 27.6% reduction in charging speed is calculated. This was accounted for when determining the required output power of charging stations for the ESB fleet.

   Graph 12: *Typical Charging Curve*

3. **Minimization of infrastructure requirements:** The model was created with the intention of minimizing infrastructure and power demand while still ensuring the fleet vehicles will meet their routes. The following assumptions were made within the charging analysis to minimize the power demand during peak hours and charger size required:

   a. **Midday charge:** Since the dwell time for the fleet is much shorter than overnight charging, midday charges were limited to charge the ESBs only to the amount of power they need to end the PM route with 20% SOC. This reduces the max demand of midday charging as well as the size of charger required.

   b. **Overnight charge:** The overnight charge was modelled to charge the ESB battery to full for the start of the next day. With dwell times ranging from 12-16 hours, the ESB has more time to charge up to 100% at a lower output (with charging management systems). Charging to full overnight reduces the amount needed during the midday charge the next day, therefore reducing demand charges, size of charger required, and demand on the grid.

Results

Using these inputs, the charging load needed to meet each route was calculated. The results for the buses with route data are summarized in **Table 10** along with the subsequent recommended charger sizes. Overall, it was found that 12 Type A

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[4] https://media.electrifyamerica.com/fivetips-charging-electric-vehicles-cold-weather

buses and 40 Type C buses (57% of the fleet) do not need a midday charge to meet their daily route, while the remaining 27 Type A buses and 12 Type C buses (43% of the fleet) will need a midday charge to meet their daily route or are currently infeasible.

Further, even though these routes are not currently feasible, charging for buses 321, 353, 363, 373, 391, 310, 387, 395, and 399 was calculated as charging from empty to full using the assumption that there will be sufficient battery technology at the time of electrification.

Table 10: *Charging Analysis Results and Recommended Dual Port Charger Sizes*

Bus	ESB Type	**Midday Charge Needed** (kW)	**Overnight Charge Needed** (kW)	Recommended Dual Port Charger Size
263	Type A	0.00	0.00	60 kW
285	Type A	0.00	0.00	120 kW
286	Type A	0.00	0.00	60 kW
287	Type C	0.00	0.00	40 kW
301	Type C	0.00	10.25	60 kW
302	Type C	0.00	6.0	40 kW
303	Type C	0.00	31.0	60 kW*
304	Type C	0.00	20.29	60 kW
309	Type C	0.00	26.75	60 kW
310	Type C	0.00	29.51	60 kW**
311	Type C	0.00	28.76	60 kW
312	Type C	0.00	21.41	60 kW
315	Type A	0.00	13.86	60 kW
316	Type A	0.00	6.37	40 kW
317	Type A	0.00	0.00	60 kW
318	Type C	0.00	33.95	60 kW*
319	Type C	1.98	33.87	60 kW*
321	Type A	80.67	21.46	120 kW**
322	Type A	7.98	20.07	60 kW
323	Type A	18.68	19.07	60 kW
324	Type A	0.95	18.85	60 kW
325	Type A	74.12	22.75	120 kW*
326	Type A	65.43	19.46	120 kW*
327	Type A	0.00	11.39	40 kW

330	Type C	0.00	30.82	60 kW*
331	Type C	0.00	27.85	60 kW
332	Type A	38.22	25.02	60 kW*
333	Type A	34.52	18.83	60 kW*
334	Type A	85.6	20.01	120 kW*
336	Type A	0.00	0.00	60 kW
337	Type A	49.27	17.77	60 kW*
340	Type C	0.00	5.35	40 kW
341	Type C	0.00	23.84	60 kW
342	Type C	0.00	31.87	60 kW*
343	Type C	6.65	35.0	60 kW*
344	Type A	34.25	19.03	60 kW*
345	Type A	27.16	19.32	60 kW
346	Type C	3.05	35.6	60 kW*
347	Type A	0.00	3.44	40 kW
348	Type C	1.95	35.0	60 kW*
349	Type C	0.00	23.29	60 kW
350	Type C	0.00	27.26	60 kW
351	Type C	0.00	26.97	60 kW
352	Type A	26.26	17.37	60 kW
353	Type A	32.1	25.59	60 kW**
354	Type A	47.56	21.78	60 kW*
355	Type A	23.6	18.67	60 kW
356	Type C	26.6	35.77	60 kW*
357	Type C	0.00	6.93	40 kW
358	Type C	0.00	7.97	40 kW
359	Type C	0.00	21.25	60 kW
360	Type C	0.00	24.4	60 kW
361	Type C	0.00	26.63	60 kW
362	Type C	1.95	34.92	60 kW*
363	Type A	85.24	19.14	120 kW**

364	Type C	0.00	25.43	60 kW
365	Type C	0.00	30.77	60 kW*
366	Type C	0.00	26.58	60 kW
367	Type C	0.00	0.00	60 kW
368	Type A	8.94	19.03	60 kW
369	Type A	0.00	17.92	60 kW
370	Type A	60.57	21.01	120 kW*
371	Type A	58.28	18.13	60 kW*
372	Type A	16.96	19.18	60 kW
373	Type A	77.21	23.05	120 kW**
374	Type A	10.79	18.23	60 kW
375	Type C	0.00	28.5	60 kW
376	Type C	0.00	26.78	60 kW
377	Type C	0.00	26.19	60 kW
378	Type C	0.00	2.06	40 kW
379	Type C	0.00	4.78	40 kW
380	Type C	0.00	0.00	60 kW
381	Type C	0.00	33.58	60 kW*
382	Type C	0.00	30.22	60 kW*
383	Type C	0.00	31.86	60 kW*
384	Type C	39.81	34.71	60 kW*
385	Type A	0.00	17.04	60 kW
386	Type C	0.00	21.83	60 kW
387	Type C	15.26	46.47	60 kW**
388	Type C	24.39	33.76	60 kW*
389	Type A	21.97	18.55	60 kW
390	Type A	0.00	7.31	40 kW
391	Type A	84.03	20.53	120 kW**
392	Type A	0.00	0.00	60 kW
393	Type A	34.6	19.25	60 kW*
394	Type C	0.00	8.76	40 kW

395	Type C	29.63	46.47	60 kW**
396	Type C	0.00	11.63	60 kW
397	Type C	0.00	32.17	60 kW*
398	Type C	0.00	22.25	60 kW
399	Type C	133.11	34.39	120 kW**

* Max charge amount needed is more than half of the charger power. Pair with a bus that has small charge requirement and utilize a charger with sequential charging capability.

** One of the bus routes cannot be met with current battery technology.

The total number of chargers needed for this fleet is 6 dual port 40 kW DC fast chargers, 35 dual port 60 kW DC fast chargers, and 5 dual port 120 kW DC fast chargers. When selecting a charger, it is important for Brewster CSD to engage with their contractor and bus provider to ensure the chargers and software are compatible with the bus models purchased.

In addition to installing chargers that meet the minimum requirements, it is recommended to include backup high-power chargers at the parking facilities. Backup fast chargers provide redundancy, ensuring continued charging availability if one or more chargers are out of service or if there is an unexpected need to charge buses assigned to lower-power chargers. Assuming that some of the spare buses remain idle in the future, their designated chargers can serve as backups, reducing or eliminating the need for additional chargers.

By 2035, in cold weather conditions and no charge management, this parking facility will experience a maximum demand of 2940 kW, driven by the charger sizes noted in **Table 10** above. With charge management in place, this maximum demand can be reduced to 2188 kW. The full charging analysis found in **Appendix 6** provides further specifications on the levels of charge management needed for midday and overnight charging.

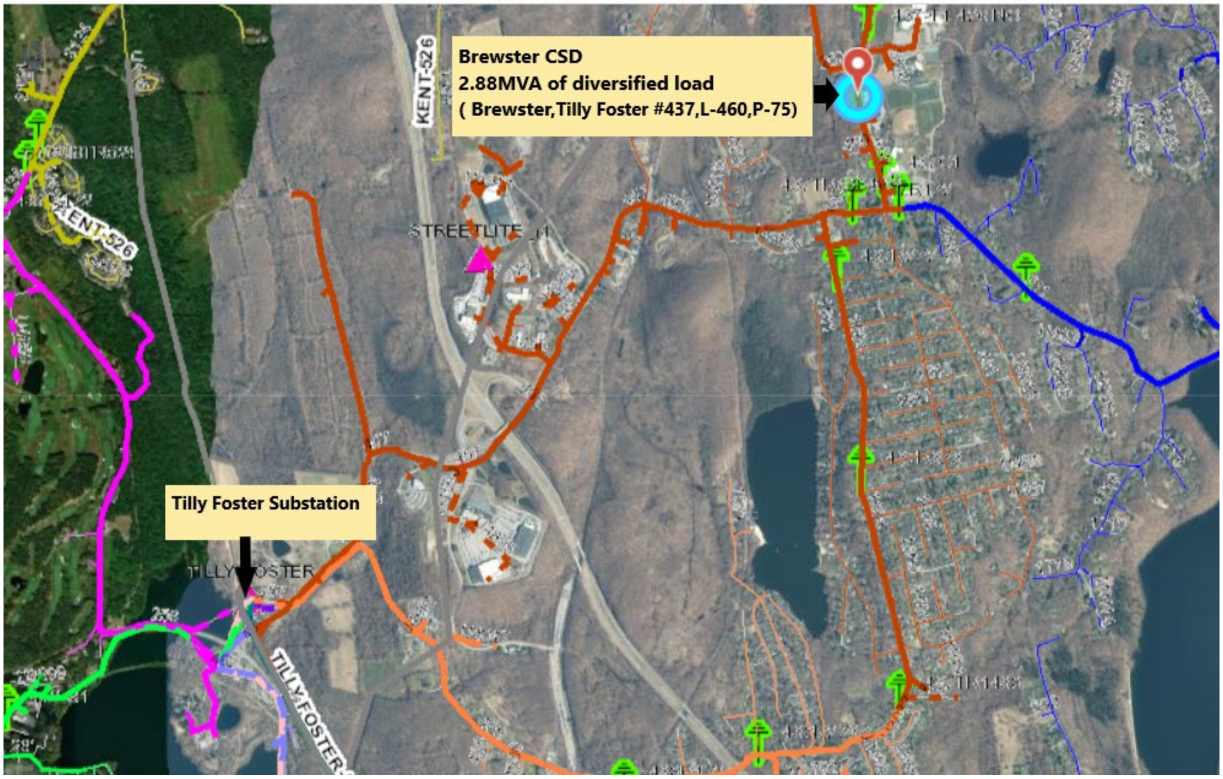
4.3 Electric Utility Analysis

The feasibility of delivering power to Brewster CSD's parking facility was evaluated in coordination with the local utility, NYSEG. A preliminary phasing plan was submitted to NYSEG based on the charging requirements determined from the route and charging analysis. NYSEG's full evaluation can be found in **Appendix 7**, with key details highlighted hereafter. It should be noted that the original load submitted to NYSEG (2880 kW) was slightly less than what was calculated to be necessary in the charging analysis (2940 kW). The results are still applicable to this proposed solution.

The utility assessment based on Brewster CSD's preliminary phasing plan states that there is around 500 kW of spare distribution capacity at the feeder circuit, Tilly Foster #437, and the substation transformer, Tilly Foster Bank #1. There is not enough distribution capacity at the feeder and substation to accommodate more than 500 kW due to large queued loads on the feeder and substation totaling 7.796 megavolt-amperes (MVA). The 2880 kW originally submitted would increase the feeder load to 16.86 MVA or 127% of its rated capacity, and increase the substation load to 42.88 MVA or 114% of its rated capacity. Given the proposed load, NYSEG found that it is not possible to connect to the feeder without increasing the thermal load above 100%, and that there does not seem to be enough capacity for the load under normal conditions at the substation.

These capacity constraints would necessitate upgrades to both the feeder and substation, which would contribute significantly to the cost of fleet electrification, as some of the upgrade costs would need to be incurred by the district, as well as delay the timeline for electrification for the majority of their fleet given that utility upgrades could take years to complete. Due to these constraints, Brewster CSD may elect to request one or both of the two-year extensions granted by NYSERDA under this program while the utility upgrades are underway to ensure compliance with state electrification requirements.

Figure 12: *NYSEG Tilly Foster Substation #1 and Tilly Foster Feeder #437*



NYSEG also provided monthly demand charge bill estimates for each proposed phase of electrification, which is further detailed in Section 5. With charge management, Brewster CSD is expected to have a monthly peak demand of 92 kW in the proposed Phase 1, subject to an estimated demand charge of $19.65/kW. By the end of electrification in the proposed Phase 4, the full fleet is expected to have a monthly peak demand of 2534 kW with charge management, subject to an estimated demand charge of $15.35/kW. These demand charges are based on example rates which are further subject to change once the Phase-in Rate (PIR), a new rate structure for commercial EV charging customers in the NYSEG service territory, is active in Q4 2025. These utility rates are included in the total cost of ownership calculations described in Section 6.

4.4 Proposed Charging Solution

Using the findings from the existing conditions assessment, charging analysis, and utility assessment, a preliminary charging design was developed for Brewster CSD's parking lot. The proposed layout for all electrical equipment is illustrated in the site map below, with equipment placement optimized for spatial efficiency and minimized conduit and wire lengths to reduce overall costs. This site map can also be found in **Appendix 9**.

Figure 13: *Proposed Charging Layout at 40 Farm to Market Road*

As noted previously, there is 500 kW of spare utility capacity available to electrify a small number of buses before requiring a larger substation and feeder upgrade. This 500 kW of spare capacity should be used for an initial learning phase of bus electrification. Based on the site and utility assessment, there are 14 parking spots near the utility transformer with a mix of Type A and Type C buses. As such, it is recommended that the 12 buses with the lowest route demand, and 2 spares, should be electrified first. Based on the route and charging analysis, these 14 buses can be supported by 6 dual port 40 kW chargers and 1 dual port 60 kW charger, totaling 300 kW total.

This 300 kW of upgraded service should be requested from NYSEG at a new location in the northwest corner of the lot approximately 90 feet from the nearest pole mounted transformer. This service should be requested at 480V to serve the expected DC fast chargers that will be installed. If 480V service cannot be delivered, a customer side step-up transformer will need to be installed, along with the other new service equipment which includes a service end box, meter, 600A/480V switchgear, and sub-panel. As noted above, this equipment will feed the initial 7 dual port chargers installed via conduit and wire trenched through soil and asphalt at the western side of the lot. A single line diagram for this initial service request can be found in **Appendix 10**.

Simultaneously, Brewster CSD should work with NYSEG to provide the additional 2640 kW service (2940 kW service total) needed to electrify the full lot, which will require a substation and feeder upgrade. Since the substation and feeder upgrades have a long lead time, it is important to start this coordination as soon as possible. Once the substation and feeder upgrades are completed, it is expected that NYSEG will provide a 3-megawatt (MW) transformer to cover the additional service. Brewster CSD will need to install supporting 4000A/480V service and distribution equipment to feed future charger installations. It is recommended that this new service equipment is placed between parking spaces along the northern perimeter of the lot to reduce costs and serve as a central point for the remainder of the lot electrification.

5. Phased Implementation Plan

This section outlines a phased approach to electrifying Brewster CSD's fleet based on the route and charging analyses. Each phase is designed to optimize fleet operations while minimizing disruptions and ensuring alignment with operational goals and state requirements. This plan is designed to optimize the amount of work, time, and money spent on each phased charger installation.

5.1 Summary

The phased implementation of Brewster CSD's fleet electrification plan, outlined in **Table 11** and depicted in **Figure 14**, aims to balance operational reliability with long-term sustainability. Each phase builds upon the previous, incorporating vehicle replacement plans, electrical infrastructure upgrades, future proofing plans, and training recommendations to prepare the district for comprehensive electrification.

The order of bus electrification was prioritized using two main factors: proximity to the utility transformer and power demand of the route. When transitioning to electric buses and scrapping old ICE vehicles, it is important to note that the vehicles were chosen based on the power demand of their routes, not their age. To maximize efficiency, it is recommended to scrap the oldest vehicles first. If a newer vehicle is selected for electrification, the ICE vehicle should be reassigned to an older vehicle's route to facilitate the retirement of the older vehicle. If Brewster CSD is going after the New York Bus Incentive Program (NYSBIP) scrapping bonus, the retired vehicle must meet the usage and/or age requirements, as detailed further in **Appendix 8.**

Table 11: *Overview of Phased Implementation Plan*

Phase	Year(s)	Buses Electrified	Routes Electrified	Dual Port Chargers Installed	Installed Charger (kW)	Cumulative Charger (kW)
Phase 1	2026-2027	14	*Type A*: 263, 347, 316, 390 327, 315 *Type C*: 287, 302, 357, 358, 394, 378, 379, 340	7	300	300
Phase 2.1	2028-2029	20	*Type A:* 286, 385, 369, 374, 324, 368 *Type C:* 301, 367, 396, 304, 359, 312, 386, 398, 349, 341, 360, 364, 377, 366	10	600	900
Phase 2.2	2030-2031	20	*Type A:* 323, 372, 322, 317 *Type C:* 361, 309, 376, 351, 350, 331, 375, 311, 382, 365, 330, 303, 383, 342, 397, 381	10	600	1500
Phase 3.1	2032-2033	19	*Type A:* 336, 389, 355, 352, 345, 353 *Type C*: 380, 310, 388, 319, 318, 362, 348, 343, 346, 356, 384, 395, 387	10	600	2100
Phase 3.2	2034	8	*Type A*: 392, 344, 333, 393, 332, 354, 337, 371	4	240	2340
Phase 4	2035	10	*Type A:* 285, 326, 325, 373, 321, 391, 363, 334, 370 *Type C:* 399	5	600	2940

Figure 14: *Spatial Design of Phased Implementation Plan*

Phase 1: Electrification of Low-Demand Routes

Phase 1 focuses on deploying an initial set of ESBs on low-demand routes to evaluate their performance and operational impacts while utilizing the spare capacity on the Tilly Foster substation feeding the lot. During this phase, a total of 14 buses (8 Type A, 6 Type C) are recommended for electrification. These routes were selected due to low mileage and their ability to meet both morning and afternoon routes without needing a midday charge (with the exception of bus 315, which does require a midday charge).

- **Type A**: 347, 316, 390 327, 315, and 263 (spare)
- **Type C**: 302, 357, 358, 394, 378, 379, 340, and 287 (spare)

Infrastructure upgrades during Phase 1 include requesting an upgraded service sufficiently sized to support the anticipated 300 kW charging demand of the electric buses and the existing parking lot service. The upgraded service is expected to be provided via a 500 kVA padmount transformer, which should be requested approximately 90 feet from the closest existing pole mounted transformer in the northwest corner of the lot. The service is recommended at this location rather than where the existing service is in the lot to serve as a central location for all phases of charger installation and minimize costs. This padmount transformer will feed new equipment including a service end box, meter, and main distribution panel. From the distribution equipment, Phase 1 will consist of trenching through both asphalt and soil to the furthest parking spot in the western part of the lot and running conduit and wire to install 6 dual port 40 kW chargers and 1 dual port 60 kW charger. This distribution equipment will also re-feed the existing parking lot equipment.

Training is a key component of this phase, with drivers and maintenance staff receiving comprehensive instruction on ESB operation, including regenerative breaking and servicing. Supporting resources and guidelines are detailed in the appendices to ensure effective knowledge transfer.

This initial phase is expected to gather baseline data on range, charging performance, and costs, while also building operational confidence in the district's transition to ESBs. As such, electrifying one spare Type A and Type C bus is recommended in this phase for additional flexibility, and other spares are distributed evenly across all phases.

Further, given NYSEG's constraints on providing power to the site, Brewster CSD should work with NYSERDA during this initial phase to file a 2-year extension on the 2027 deadline for purchasing electric buses. This extension would provide Brewster CSD with additional time while major utility upgrades are underway to enable future phases of electrification.

Figure 15: *Spatial Design of Phase 1*

Phase 2: Electrification of Low- to Medium-Demand Routes

Phase 2, broken down into subphases 2.1 and 2.2, expands implementation by electrifying additional low- to- medium-demand routes. During this phase, a total of 40 buses (10 Type A, 30 Type C) are recommended for electrification. These routes were selected based on the route and charging analyses where the Type C vehicles are considered straightforward and do not require a midday charge, while the typically longer Type A routes do.

Phase 2.1:

- **Type A**: 385, 369, 374, 324, 368, and 286 (spare)
- **Type C**: 301, 396, 304, 359, 312, 386, 398, 349, 341, 360, 364, 377, 366, and 367 (spare)

Phase 2.2:

- **Type A**: 323, 372, 322, and 317 (spare)
- **Type C**: 361, 309, 376, 351, 350, 331, 375, 311, 382, 365, 330, 303, 383, 342, 397, and 381

As noted previously, NYSEG does not have sufficient capacity to serve Phase 2 onward and will require an upgraded substation and feeder. To facilitate this infrastructure upgrade, an additional 2640 kW utility service (2940 kW service total for the project) should be requested to serve the remainder of the lot's electrification. It is expected that NYSEG will provide a 3 MVA padmount transformer for this service upgrade which will feed the chargers installed in Phase 2 onward. Aligned with the utility service upgrade, new service equipment will need to be installed and should be placed within the space between the buses electrified during Phase 3.2 and Phase 4 to centrally serve all future phases.

Infrastructure upgrades for Phase 2.1 consist of trenching from the new service equipment through asphalt to the furthest parking spot within the middle parking lane, running conduit and wire to the 20 farthest spots to install 10 dual port 60 kW chargers, and running empty conduit within the trench for the remaining chargers to be installed in Phase 2.2. Phase 2.2 will use the future-proofed conduit from Phase 2.1 to run wire to install 10 dual port 60 kW chargers. A total of 20 dual port 60 kW chargers will be installed across Phase 2.

This phase aims to expand the electric bus fleet while maintaining operational consistency across the district. Operational schedules should be optimized to align with charging times, ensuring efficiency and minimizing service disruptions.

Figure 16: *Spatial Design of Phase 2*

Phase 3: Electrification of Medium- to High-Demand Routes

Phase 3, broken down into subphases 3.1 and 3.2, further expands implementation by electrifying additional medium-demand Type C routes, and some of the fleet's higher-demand Type A routes. During this phase, a total of 27 buses (14 Type A, 13 Type C) are recommended for electrification.

Phase 3.1

- **Type A**: 389, 355, 352, 345, 353, and 336 (spare)
- **Type C**: 310, 388, 319, 318, 362, 348, 343, 346, 356, 384, 395, 387, and 380 (spare)

Phase 3.2

- **Type A**: 344, 333, 393, 332, 354, 337, 371, and 392 (spare)

Infrastructure upgrades for Phase 3.1 consist of trenching from the new service equipment installed in Phase 2 through soil to the furthest parking spot in the eastern part of the lot and running conduit for all Phase 3 installations, including future proofed conduit for Phase 3.2, and running wire to install 10 dual port 60 kW chargers. Phase 3.2 will utilize the future-proofed conduit from Phase 3.1 and run wire to install 4 dual port 60 kW chargers. A total of 14 dual port 60 kW chargers will be installed across Phase 3.

Figure 17: *Spatial Design of Phase 3*

Phase 4: Electrification of High-Demand Routes

Phase 4 of this plan completes the district's transition to an all-electric fleet. During this phase, the remaining 10 high-demand buses (9 Type A, 1 Type C) are recommended for electrification. These buses have been saved for last due to long routes and the subsequent need for higher powered chargers. Some buses in this phase have routes that cannot be met with current battery technology, so it is assumed that by the time of electrification at the end of this phasing plan, technology will have improved and these routes will be feasible.

- **Type A**: 326, 325, 373, 321, 391, 363, 334, 370, and 285 (spare)
- **Type C**: 399

Infrastructure upgrades for Phase 4 consist of trenching through soil from the service installed in Phase 2 and running conduit and wire to install 5 dual port 120 kW chargers.

By this point, advanced fleet management tools should be implemented to monitor performance, energy usage, and costs to ensure the fleet is operating efficiently and cost-effectively.

Figure 18: *Spatial Design of Phase 4*

Phasing Plan Flexibility

To maintain adaptability, the following proactive measures should be integrated:

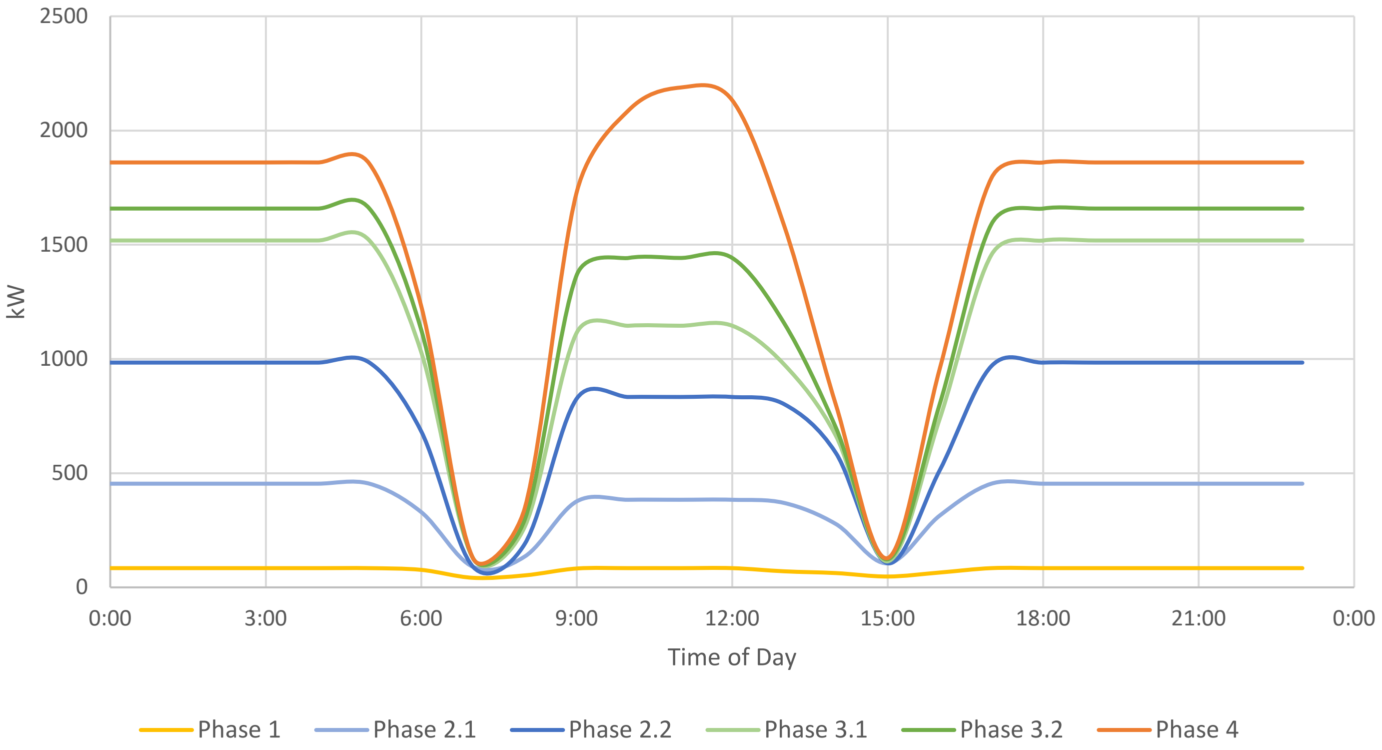
- **Energy Management Systems:** Advanced software will optimize charging schedules and minimize energy costs as the fleet grows.
- **Emerging Technology Integration:** Continuous alignment with advancements in battery and charging technology will ensure infrastructure remains cutting-edge.
- **Resilience Planning:** Backup power solutions and high-power chargers will enhance system reliability during unforeseen disruptions.

This phased strategy, underpinned by future-proofing and systematic infrastructure upgrades, ensures the district's successful transition to a sustainable and efficient electric fleet.

5.2 Charge Management & Load Prediction

Effective charge management is essential for ensuring the seamless operation of an electrified school bus fleet. Without proper planning, uncoordinated charging can lead to excessive energy costs, increased strain on depot infrastructure, and reduced fleet availability during critical operational periods. Charge management helps optimize energy usage, align charging schedules with bus availability, and prevent costly peak demand charges. The graph below shows the expected load profile of Brewster CSD's ESB fleet, assuming charge management is utilized to maintain minimum required charging output.

Graph 13*: Predicted Hourly Load Profile for Brewster CSD*



Key benefits of charge management are:

1. **Operational Efficiency:** Charge management ensures buses are charged and ready for service when needed, minimizing delays and disruptions to routes.
2. **Cost Control:** By limiting charger output, staggering charging sessions, and therefore reducing peak demand, districts can decrease energy costs and avoid penalties from demand charges. **Table 12** below shows how charge management can be utilized to evenly spread charging during your dwell periods and decrease peak demand.
3. **Infrastructure Longevity:** Reducing simultaneous charging sessions prevents overloading depot infrastructure and extends the life of charging equipment.
4. **Scalability:** Charge management ensures infrastructure can handle a growing fleet without requiring excessive upgrades.
5. **Integration with Renewable Energy:** Advanced systems can align charging schedules with on-site solar production or energy stored in batteries, reducing dependency on grid power and lowering carbon emissions.

Table 12: *Projected Peak Demand With and Without Charge Management*

Phase	Daily Peak Demand Without Charge Management (kW)	Midday Peak Demand with Charge Management (kW)	Overnight Peak Demand with Charge Management (kW)	Daily Peak Demand with Charge Management (kW)
Phase 1	300	84	84	84
Phase 2.1	900	384	454	454
Phase 2.2	1500	834	984	984
Phase 3.1	2100	1145	1519	1519
Phase 3.2	2340	1442	1658	1658
Phase 4	2940	2188	1860	2188

6. Transition Plan Cost Estimates

This section provides a detailed schedule of capital expenditures (CapEx) required to complete each phase of the transition, along with the ongoing operational expenditures (OpEx) incurred throughout the duration of each phase. This comprehensive breakdown is designed to facilitate accurate budgeting for each stage of the planned transition. The analysis spans from 2025 to 2035, encompassing the entire EV transition period. By including both upfront investment needs and recurring costs, this schedule ensures that all financial aspects of the transition are accounted for, enabling effective financial planning and resource allocation. Additionally, the phased approach allows for adjustments based on real-time operational data and funding availability, ensuring a sustainable and scalable transition over the long term. This structured plan provides stakeholders with a clear understanding of the financial trajectory, supporting informed decision-making and alignment with funding opportunities, such as grants and incentives, to optimize cost efficiency.

6.1 Inputs

Capital and Operating Expenditures

When estimating transition plan costs, both capital and operating expenses must be considered. A significant portion of capital costs include the purchase of ESBs and the necessary charging infrastructure. These expenses can be partially offset through utility, state, and federal grant programs, which are further described below. Operational costs primarily consist of energy requirements for each route and the associated energy replenishment costs, and ongoing maintenance costs on the ESBs and EV charging stations. Additionally, annual software costs for the EV charging stations and bus depreciation must be factored in.

Key assumptions underpinning these calculations include an estimated ESB maintenance rate of $0.05 per mile and an EV charging station maintenance rate of $0.046 per mile. Another important assumption includes the cost of utility upgrades. These costs are extremely variable and are dependent on an official utility ruling, which is only obtained after a formal load request submission. The utility assessment determined feeder and substation upgrades are necessary for Phases 2-4, so a $200/kW rule of thumb was applied for the cost of the new utility service in Phase 1 and $1,000/kW in Phase 2.

To ensure accuracy in forecasting, a year-over-year escalation schedule was applied to both energy and maintenance rates, accounting for inflation and the expected increase in maintenance needs as the internal components of vehicles and equipment age. A discount rate of 6% and a utility escalation rate of 2% are included. A comprehensive breakdown of the annual cost projections is available in **Appendix 11**, offering detailed insight into the financial aspects of the transition plan.

Funding Opportunities

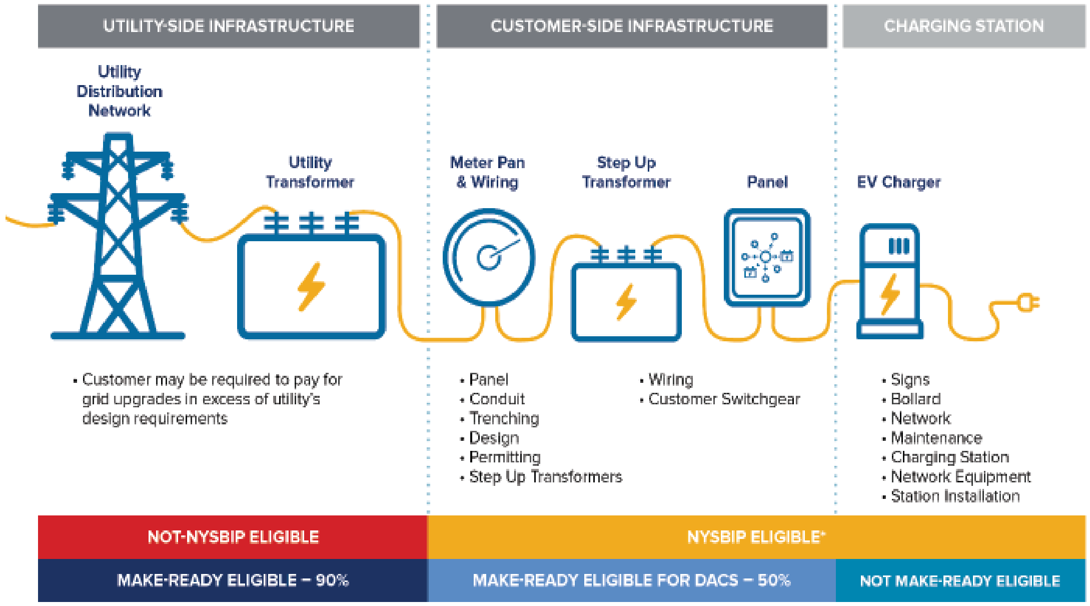
Transitioning to an electric fleet involves significant expenses, but various funding programs and models can help offset costs. In New York, NYSBIP, administered by NYSERDA, offers vouchers to reduce costs for electric bus acquisitions and charging infrastructure, accelerating clean vehicle adoption. The current cap to the NYSBIP charging vouchers is set to expire in December of 2025. The cost projections below assume that the current caps of $2 million per district for charging vouchers and 10% of the fleet for the vehicle voucher will be renewed each year. Cost projections without incentives are included since they frequently fluctuate and are not guaranteed.

In addition to the baseline NYSBIP charger and vehicle vouchers, there are additional add-ons that can increase funding amounts. Some of these add-ons are detailed below, and it is encouraged to become familiar with the NYSBIP manual which outlines the various requirements of the program[5]. Add-ons were not considered in the projected cost calculations.

Table 13: *NYSBIP Voucher and Bonus Voucher Amounts*

School Bus Type	Percentage of Incremental Cost Covered	Base School Bus Voucher Dollar Amount	Priority District Bonus Amount	Scrappage Bonus Amount	V2G Add-On Amount	Wheelchair Add-On Amount
New Type A	60%	$114,000	$28,500	$47,500	$9,500	$8,000
New Type C	60%	$147,000	$36,750	$61,250	$12,250	$8,000
New Type D	60%	$156,000	$39,000	$65,000	$13,000	$8,000
Repowered Type A	75%	$105,000	$21,000	N/A	$7,000	N/A
Repowered Type C	75%	$135,000	$27,000	N/A	$9,000	N/A

Figure 19: *NYSBIP Eligibility*



*NYSBIP covers bondable items. Signs, bollards, network, maintenance, etc. are not eligible.

Similarly, NYSEG's Electric Vehicle Charging Station Make-Ready Program funds up to 50% of eligible sites of utility-side infrastructure costs, easing the financial burden of charging station installations. Both NYSERDA's NYSBIP vouchers and NYSEG's Program funds are accounted below and can be seen in the comprehensive breakdown of the annual cost projections in **Appendix 11**.

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[5] https://www.nyserda.ny.gov/-/media/Project/Nyserda/Files/Programs/Electric-School-Bus/NYSBIP-Implementation-Manual.pdf

Another funding option is an Electrification-as-a-Service (EaaS) model which provides a streamlined approach by bundling vehicle procurement, maintenance, charging infrastructure, and energy management into a single service, minimizing upfront costs. Instead of requiring large, up-front expenditures for EVs and charging infrastructure, EaaS providers often operate on a subscription or service agreement basis. This shifts expenses to predictable operating costs, allowing organizations to electrify their fleets without significant budgetary strain. Additionally, EaaS providers manage the design, installation, and commissioning of charging stations, ensuring that the infrastructure is optimized for the fleet's specific needs. It is important to note that in an EaaS model, a third party will own the assets, not Brewster CSD.

Similarly, if pursuing alternative energy options, a Power Purchase Agreement (PPA) can reduce the upfront CapEx. Under a PPA, a third-party provider finances, installs, and maintains energy assets such as PV solar or BESS, while the district purchases the generated electricity at a fixed or variable rate over a specified period. This arrangement helps the district benefit from lower, predictable energy costs for EV charging, while avoiding the financial and operational burdens of ownership. Additionally, PPAs enable the district to leverage private investment and take advantage of available incentives, resulting in long-term cost savings and a more affordable transition to electric buses.

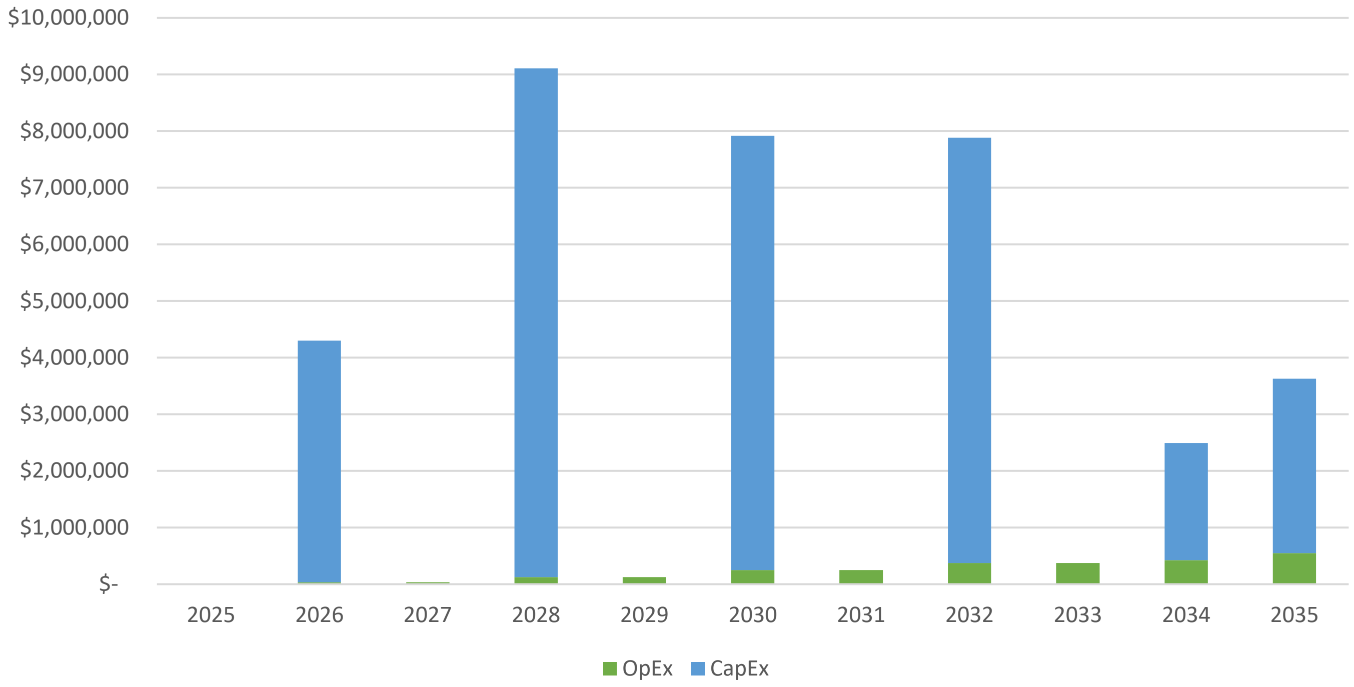
6.3 Results

The total projected CapEx and OpEx for Brewster CSD’s transition on an electrified fleet are summarized below. **Table 14** includes cost projections for the electrified fleet only, including costs related to the purchase of new buses, buying and installing chargers and electrical equipment, and the operational expenses of the fleet. With current incentives included, the cumulative CapEx by the final phase of electrification in 2035 is expected to be $33.5 million, and the annual OpEx of the fully electrified fleet is expected to be $548,000, each of which are broken down further in **Graph 15** and **Graph 16**. Finally, **Table 15** includes cost projections for the electrified fleet as well as costs associated with phasing out the remaining ICE vehicles over the 10-year electrification period.

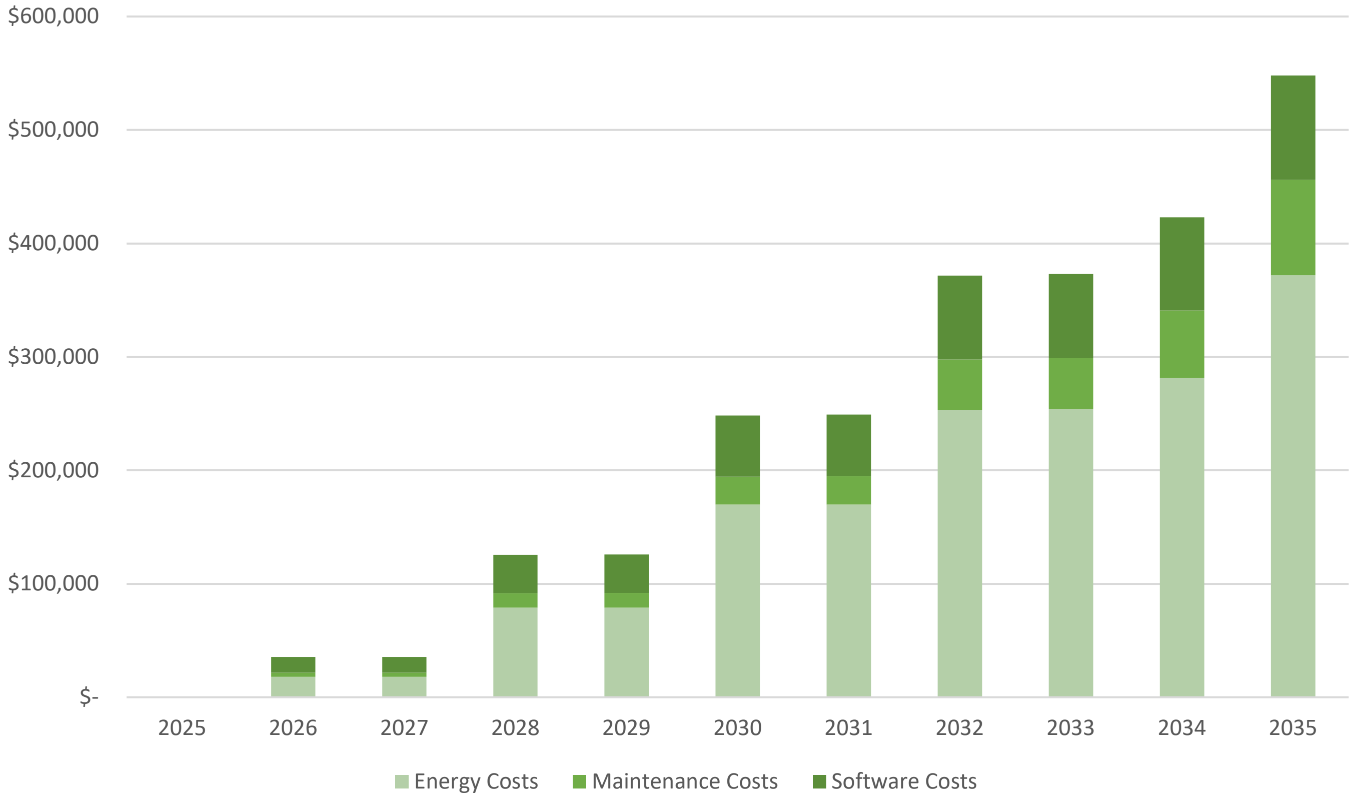
Table 14: *Phased Cost Projections for Electrified Fleet*

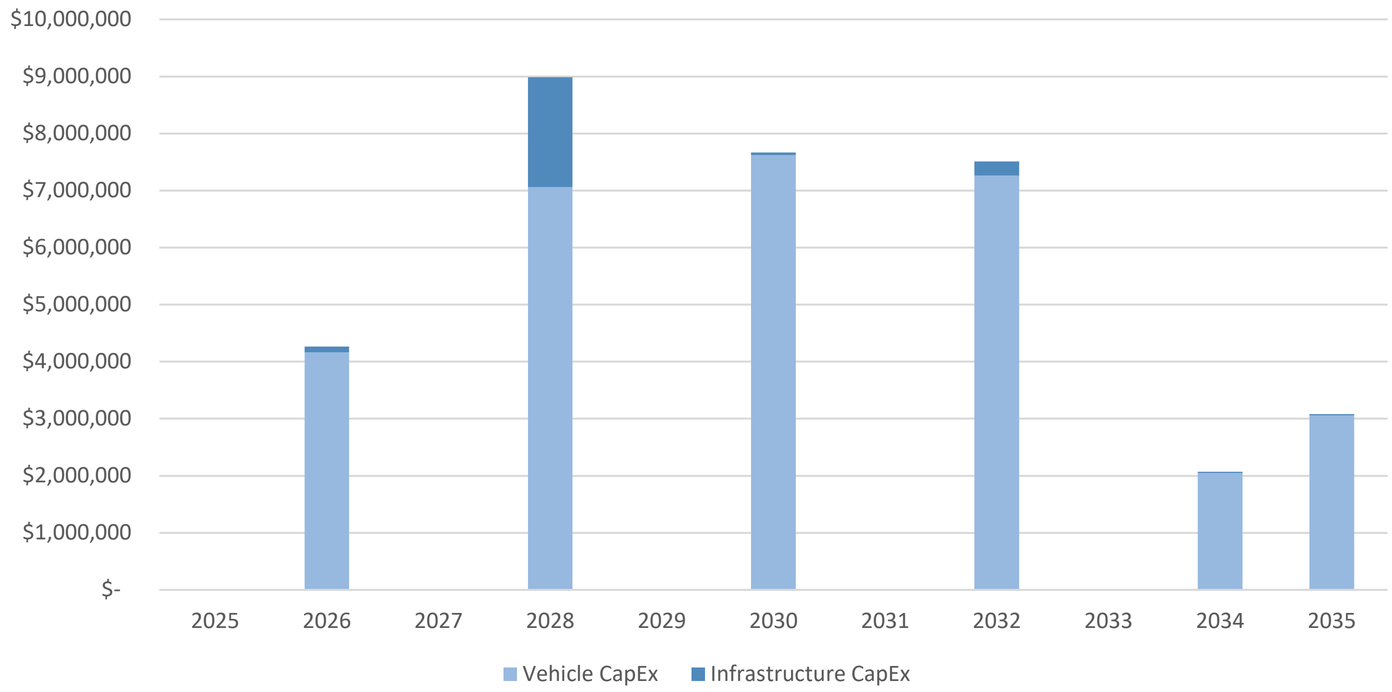
General						
Year(s)	2026-2027	2028-2029	2030-2031	2032-2033	2034	2035
Phase	1	2.1	2.2	3.1	3.2	4
ESB in Fleet	14	34	54	73	81	91
CapEx & OpEx						
CapEx Without Incentives	$6,004,910	$12,727,767	$9,586,596	$9,877,434	$3,388,447	$4,638,639
CapEx With Incentives	$4,264,585	$8,984,767	$7,669,355	$7,509,434	$2,068,251	$3,078,766
OpEx	$71,237	$251,487	$ 497,445	$744,575	$423,004	$548,040
Total Without Incentives	$6,076,147	$12,979,253	$10,084,041	$10,622,009	$3,811,451	$5,186,679
Total With Incentives	$4,335,822	$9,236,253	$8,166,800	$8,254,009	$2,491,255	$3,626,807
Cumulative Without Incentives	$6,076,147	$19,055,401	$29,139,442	$39,761,451	$43,572,902	$48,759,582
Cumulative With Incentives	$4,335,822	$13,572,076	$21,738,875	$29,992,884	$32,484,139	$36,110,946

Graph 14: *Cost Projections for Electrified Fleet (with incentives)*



Graph 15: *Electrified Fleet OpEx Breakdown*





Graph 16: *Electrified Fleet CapEx Breakdown (with incentives)*

Table 15: *Phased Cost Projection for Entire Fleet**

General						
Year(s)	2026-2027	2028-2029	2030-2031	2032-2033	2034	2035
Phase	1	2.1	2.2	3.1	3.2	4
ESB in Fleet	14	34	54	73	81	91
ICE in Fleet	77	57	37	18	10	0
CapEx & OpEx						
CapEx with Incentives	$4,264,585	$8,984,767	$7,669,355	$7,509,434	$2,068,251	$3,078,766
ESB OpEx	$71,237	$251,487	$497,445	$744,575	$423,004	$548,040
ICE OpEx	$1,609,556	$964,379	$821,274	$559,411	$182,256	-
Total OpEx	$1,680,793	$1,215,866	$1,318,719	$1,303,986	$605,260	$548,040
Total Cost	$5,945,378	$10,200,632	$8,988,073	$8,813,420	$2,673,511	$3,626,807
Cumulative	$5,945,378	$16,146,010	$25,134,084	$33,947,503	$36,621,014	$40,247,821

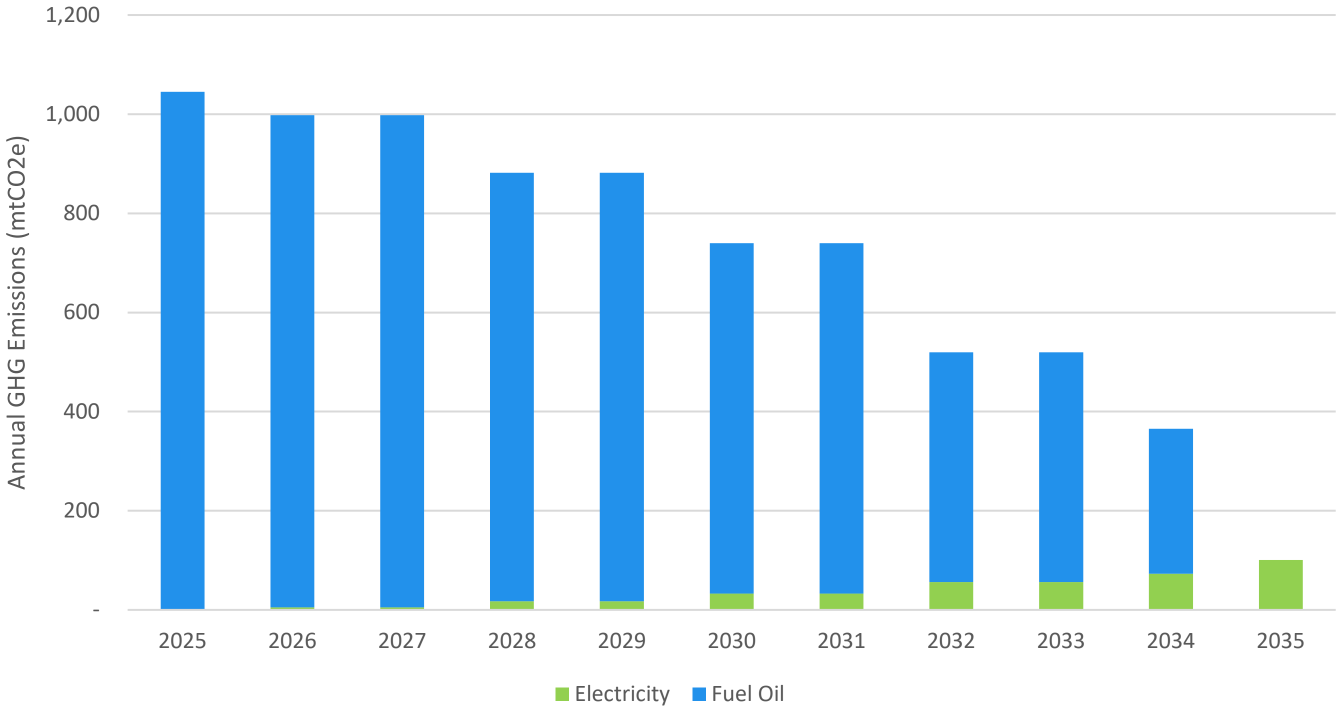
**Assumes all buses replaced are electric (no ICE vehicles purchased)*

7. Environmental Impact

Transitioning to an electric school bus fleet significantly reduces greenhouse gas (GHG) emissions and improves energy efficiency compared to diesel-powered vehicles. Electric buses produce zero tailpipe emissions, contributing to cleaner air quality for students and the community, while also aligning with state and federal sustainability goals. While the electric grid in NYSEG is mainly powered by natural gas[6], there are statewide efforts in creating cleaner power plants which will reduce emissions. Additionally, the transition lowers the district's reliance on fossil fuels, promoting long-term energy resilience and cost stability. This shift not only supports Brewster CSD’s environmental objectives but also positions the district as a leader in sustainable transportation.

As shown by **Graph 17** and **Graph 18**, implementation of the FEP strategy will reduce total fleet GHG emissions by a cumulative total of 3,707 metric tons of carbon dioxide equivalent (mtCO2e) through 2035 using the current and projected grid emission intensity. This is equivalent to the emissions from consuming 8,582 barrels of oil and the carbon sequestered by 61,296 tree seedlings grown for 10 years.[7] The New York Climate Leadership and Community Protection Act of 2019 (CLCPA) commits to a 100% zero-emission electricity by 2040, at which time the annual fleet emissions will drop to zero assuming successful implementation of the FEP.

Graph 17: *Annual Fleet GHG Emissions*



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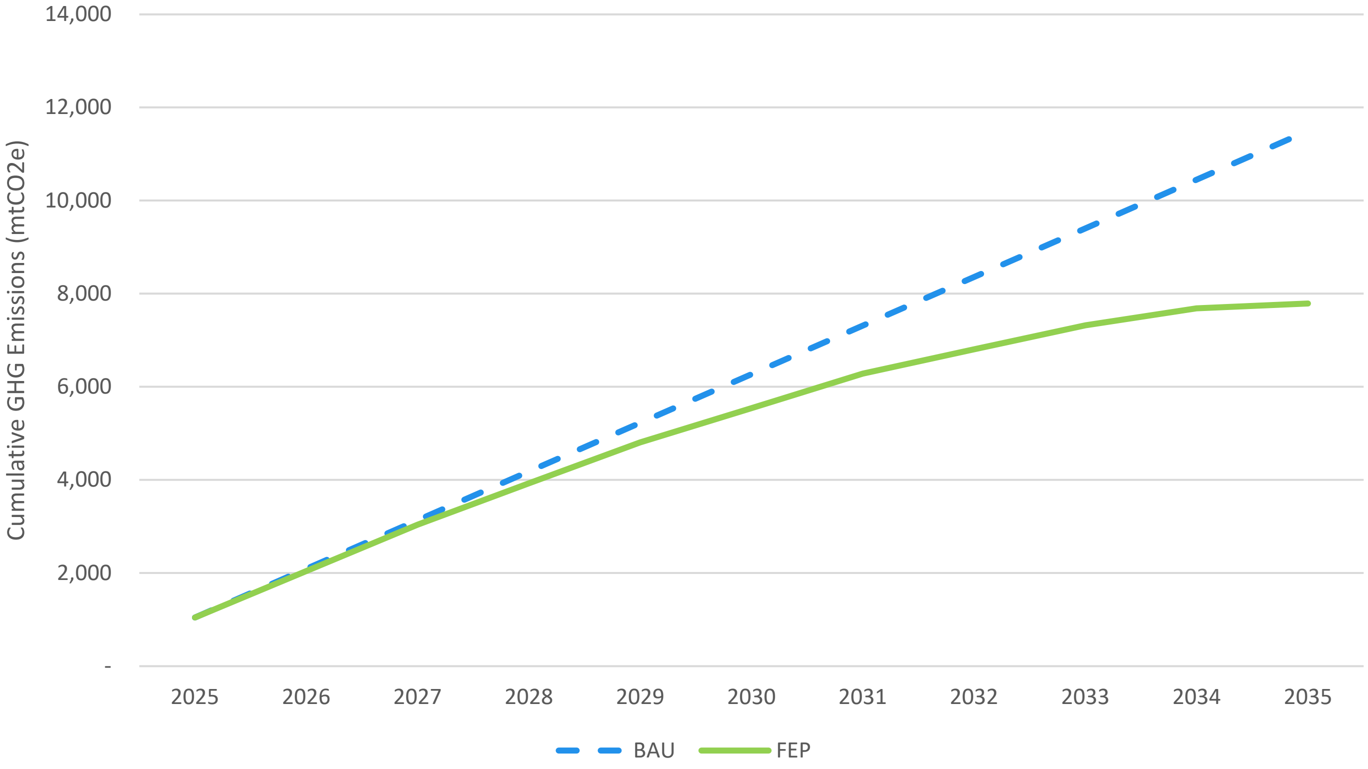
[6] https://www.nyseg.com/w/environmental-disclosure

[7] https://www.epa.gov/energy/greenhouse-gas-equivalencies-calculator

Graph 18: *Comparative Analysis of Projected Cumulative Fleet GHG Emissions - Business as Usual vs. Fleet Electrification Plan*



8. Alternative Energy Options

With a fleet of 91 buses, Brewster CSD will incur significant costs in the transition to electric vehicles, particularly in charging infrastructure and energy management. To mitigate these expenses, a suggested option is to explore distributed energy resources such as linear generators, battery energy storage systems (BESS), and solar photovoltaics (PV). These technologies can supplement grid capacity, provide backup power, and help manage demand charges, potentially reducing long-term operational costs. By incorporating on-site energy generation and storage, districts can improve energy resilience and optimize charging strategies while navigating the financial challenges of fleet electrification.

8.1 Linear Generators

As fleet operators transition to electric vehicles, the challenge of reliable and scalable charging infrastructure remains a key concern. Linear generators offer a flexible and efficient solution by providing on-site power generation that can supplement grid capacity or serve as a primary energy source in areas with limited electrical infrastructure. Unlike traditional combustion engines or turbines, linear generators use a direct linear motion of magnets within coils to generate electricity, eliminating the need for rotating parts. This design improves efficiency, reduces maintenance, and allows for rapid response to fluctuating power demands.

One of the key advantages of linear generators for EV fleet charging is their fuel flexibility. They can operate on various fuels, including natural gas, hydrogen, biogas, and other renewable sources, making them adaptable to evolving clean energy goals. This capability enables fleet operators to implement charging solutions that align with sustainability initiatives while ensuring reliability, even in locations where grid expansion is costly or impractical. Additionally, linear generators can function as distributed energy resources, supporting microgrids or peak shaving strategies to mitigate demand charges and reduce overall energy costs.

For fleets operating in remote or off-grid environments, linear generators provide a dependable alternative to traditional diesel generators, offering cleaner and quieter power generation. Their modularity allows for scalable deployment, ensuring that charging capacity can grow alongside fleet electrification goals. By integrating linear generators into EV charging strategies, fleet operators can enhance energy resilience, optimize costs, and accelerate the transition to zero-emission transportation without being constrained by grid limitations.

8.2 Distributed Energy Resources

Solar-powered microgrids and/or BESS provide another scalable and sustainable solution for EV charging. By integrating solar PV with battery storage and intelligent load management, microgrids can generate and store renewable energy on-site, reducing reliance on the traditional grid while lowering operational costs. Solar energy offers a zero-emission power source that can be optimized for daytime charging when sunlight is abundant, while battery storage ensures energy availability during nighttime or cloudy conditions. When combined with other distributed energy resources, such as linear generators, solar microgrids enhance resilience by diversifying power generation sources and reducing exposure to fluctuating utility rates.

Battery energy storage systems provide a crucial solution for managing energy demand and ensuring reliable EV charging, especially in areas with grid constraints. By storing electricity during off-peak hours or when energy prices are low, BESS allows fleets to reduce demand charges and avoid costly peak-period electricity rates. Additionally, BESS enhances grid resilience by providing backup power during outages and stabilizing energy supply in the event of fluctuations. Whether used as a standalone solution or in combination with other distributed energy resources, battery storage enables fleet operators to optimize energy costs, improve charging reliability, and accelerate electrification without relying solely on grid upgrades.

While the benefits of BESS and solar-powered microgrids are clear, the upfront capital investment can be a significant barrier for fleet operators. Partnering with a third-party owner-operator can alleviate these costs by utilizing private capital to finance, build, and maintain the microgrid. PPAs or EaaS models, fleets can access clean and reliable charging infrastructure without the financial burden of ownership. This arrangement allows operators to focus on fleet management while benefiting from predictable energy pricing, reduced demand charges, and long-term sustainability advantages. By leveraging third-party ownership, fleet operators can accelerate their transition to solar-powered charging, ensuring a cost-effective and resilient electrification strategy.

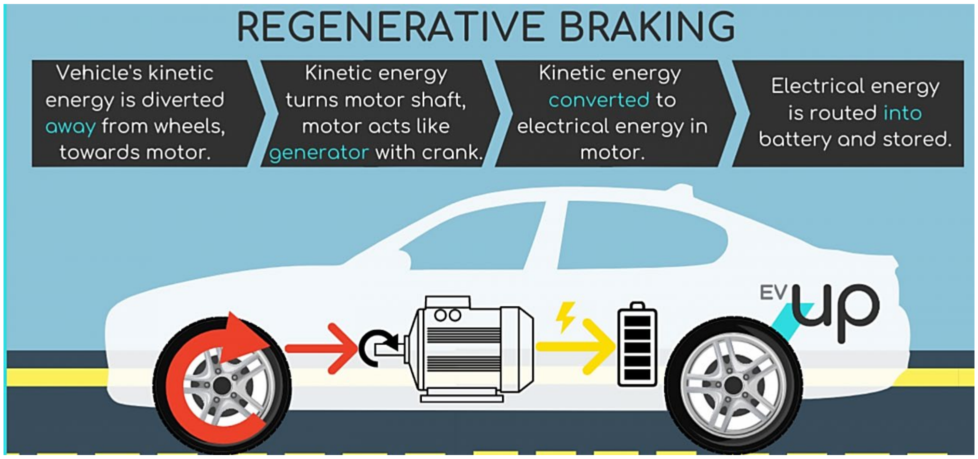
9. Maintenance and Training Considerations

Successfully integrating electric buses and charging infrastructure into fleet operations requires more than just the initial installation and deployment. To ensure long-term reliability, safety, and performance, a comprehensive approach to maintenance and training is essential. By prioritizing maintenance and training in the following areas, Brewster CSD can improve operational efficiency, reduce downtime, and enhance safety protocols, helping to maximize the benefits of their electric fleet investments. Guidelines and resources on workforce training can also be found in **Appendix 12**.

9.1 Driver Training

Training school bus operators in new driving habits is essential in increasing the efficiency of the electric school buses. There are certain driving behaviors that maximize the regenerative braking capabilities of the vehicle and minimize power demand, extending the range of the school bus. It is important to understand how regenerative braking works to properly operate the system. **Figure 20** below provides a high-level description of this process.[8]

Figure 20: *Regenerative Braking Technology*



Bus routes typically have many stops, causing drivers to brake frequently and therefore giving many opportunities to regenerate energy. The list below[9] includes driver habits that minimize power usage and allow for regeneration during braking:

- **Cabin pre-conditioning:** Heat or cool the interior of the vehicle before you get in while the vehicle is still plugged in to the charger. This draws power from the grid rather than the battery to condition the interior temperature, preserving battery health and maximizing range.
- **Minimize HVAC usage:** Avoid excessive heating or cooling of the vehicle, when possible. While HVAC use in extreme conditions is considered in the route analysis, range can be extended by combining pre-conditioning strategies with minimization of heating and cooling systems.

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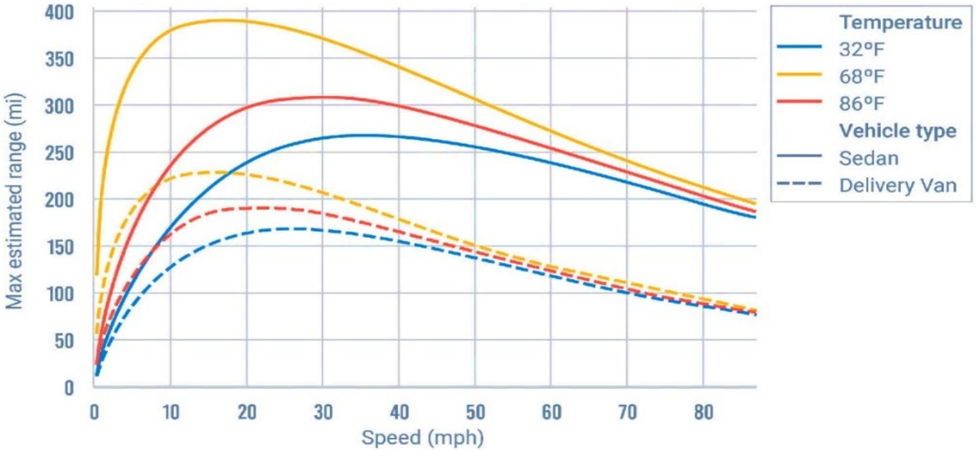
[8] https://www.evup.com.au/about-evup/ev-news/how-does-regenerative-braking-work

[9] https://driveelectric.gov/webinars/electric-school-bus-operators

- **Avoid excessive speed:** Where allowable, avoid driving at speeds over 60 mph and try to maintain speeds of under 20 mph. Driving at faster speeds drains battery faster, as displayed in **Graph 19** below[10].

Graph 19: *The Effect of Speed and Temperature on Range*



- **Minimize frequent and aggressive acceleration**: Reduce use of accelerator and coast on kinetic energy of the bus as much as possible, while still maintaining speed limit and safe driving practices. Ease into driving from stopped points, having a 'heavy foot' uses up the EV battery at an accelerated rate.
- **Modulate accelerator pedal:** Rather than hitting on the brake right away, lessen the pressure on the accelerator first to utilize the regenerative brake to slow down.
- **Use hilly routes to your advantage:** Drive over hills at a speed that will allow you to coast all the way down. This permits movement downhill at 'negative' energy, regenerating power the whole way down.

9.2 Bus Maintenance

While electric buses typically require less maintenance than diesel and gasoline-fueled buses, there are still routine maintenance considerations that school districts should be aware of to reduce maintenance costs, extend the lifetime of the vehicle, and maintain fleet operations. Currently, the New York State Department of Transportation (NYSDOT) has the same requirements for all buses, regardless of fuel type. **Appendix 13** is a NYSERDA resource which outlines the NYSDOT maintenance requirements and their importance to ESB operations.

It is important to highlight that any maintenance that engages high-voltage systems requires extra caution. Common practice includes disengaging battery connectors and waiting at least 15 minutes before performing any maintenance. If maintenance is conducted in-house, they should be trained in new practices and ensure that they reference the electric bus service manuals from the manufacturer.[11]

9.3 Charger Operations and Maintenance

In addition to charge management strategies, proper maintenance and operation of the charging equipment is an important consideration for electric school bus operators. When purchasing and installing charging equipment, bus

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[10] https://www.geotab.com/blog/ev-range-impact-of-speed-and-temperature/

[11] https://www.nyserda.ny.gov/-/media/Project/Nyserda/Files/Programs/Electric-School-Bus/Electric-School-Bus-Operations-and-Maintenance.pdf

operators should reference the charging station's operating manual. **Appendix 14** includes key details for a charger O&M plan.[12]

Preventative measures that can extend the lifetime of the charger include purchasing a charge management system with your charger as well as protective bollards. The bollards will block the charger from being hit and allow for proper storage of the charging cables, avoiding damage to the equipment.

9.4 Fire Safety

While the risk of electric school buses catching fire is significantly less than a school bus with a combustion engine, it is still important for bus operators to understand the risks associated with electric buses and the mitigation strategies for these risks. Engaging with the local fire department during the transition to electric school buses allows them to be familiar with the electrical layout of the facility. NYSERDA's Electric School Bus Guidebook contains a section on Fire Safety that details fire prevention measures and is included in **Appendix 15**.[13]

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[12] https://www.nyserda.ny.gov/-/media/Project/Nyserda/Files/Programs/Electric-School-Bus/Electric-School-Bus-Charging-Equipment-Operations-and-Maintenance.pdf

[13] https://www.nyserda.ny.gov/-/media/Project/Nyserda/Files/Programs/Electric-School-Bus/Electric-School-Bus-and-Charging-Safety.pdf

10. Final Summary

The Fleet Electrification Plan for Brewster CSD provides a structured approach to transitioning its school bus fleet to ESBs in alignment with New York State's zero-emission mandates. The plan outlines a phased strategy that addresses operational needs, infrastructure requirements, and financial considerations, tailored to the unique challenges of Brewster CSD's fleet operations.

The plan proposes a phased transition, beginning with electrification of 14 buses in 2026 and culminating in a fully electric fleet of 91 buses by 2035. Through detailed route and charging analyses, the study identifies operational demands, factoring in worst-case scenarios including a 30% reduction in battery efficiency during cold weather. The Micro Bird G5 Type A and International CE Type C buses were simulated for their compatibility with Brewster CSD's needs, offering usable ranges of 94.2 miles and 88 miles, respectively, in cold weather and hilly conditions. With these inputs, it was found that 9 routes cannot be met with current ESB models. If battery and bus technology continue to advance at the current predicted rate of 5% per year, it is predicted that there will be bus models capable of completing the currently infeasible routes.

Charging infrastructure recommendations include the installation of 46 dual port chargers over 4 phases. An upgraded utility service capable of handling up to 2940 kW of extra power will support these upgrades. Advanced charge management systems are expected to limit peak demand to roughly 2188 kW by 2035, reducing operational costs and grid strain, if utilized. Upgraded utility infrastructure for the local substation and feeder is needed should be planned in close coordination between NYSEG and Brewster CSD. Given the large infrastructure upgrades needed, Brewster CSD may be eligible for an extension to the electrification mandate.

Training programs for drivers and maintenance staff are highlighted as critical components to ensure operational readiness. Driver education focuses on optimizing ESB efficiency through practices such as regenerative braking and minimizing HVAC usage, while maintenance protocols address the unique requirements of ESBs and associated charging equipment. Safety considerations, including fire prevention measures and facility upgrades, are integrated into the report to inform on and mitigate potential risks.

The financial framework provides a comprehensive overview of both capital and operating expenses. The plan forecasts cumulative capital expenditures, including vehicle procurement and charging infrastructure, of approximately $33.5 million, cumulative ESB operational expenditures of $2.5 million by the end of the transition, and an annual OpEx of roughly $550,000 for the fully electrified fleet. It incorporates funding opportunities such as NYSERDA's New York School Bus Incentive Program, and NYSEG's Electric Vehicle Make-Ready Program to offset costs. The plan also mentions Electrification-as-a-Service models as an alternative funding mechanism, enabling fleet electrification through predictable operational expenses rather than upfront capital investments.

This plan equips Brewster CSD with a clear path to electrifying its fleet, addressing logistical and financial challenges while ensuring compliance with state mandates. By providing detailed analysis, phased implementation, and funding strategies, the plan supports a sustainable transition that is both practical and adaptable to future advancements in electric vehicle technology.

Appendix

1. Micro Bird G5 Type A Specifications
2. Phoenix Motorcars Z-600 Specifications
3. International CE Type C Specifications
4. Thomas C2 Jouley Type C Specifications
5. Route Analysis Results
    a. Type A Model 1
    b. Type A Model 2
    c. Type C Model 1
    d. Type C Model 2
6. Charge Analysis Results
7. NYSEG Utility Assessment
8. NYSBIP School Bus Voucher Requirements and Amounts
9. Phasing Plan Spatial Designs
10. Phase 1 Single Line Diagram
11. Annual Cost Projections
    a. CapEx
    b. OpEx
    c. Total
12. NYSERDA ESB Workforce Training Guide
13. NYSERDA ESB O&M Guide
14. NYSERDA ESB Charger O&M Guide
15. NYSERDA ESB Safety Guide