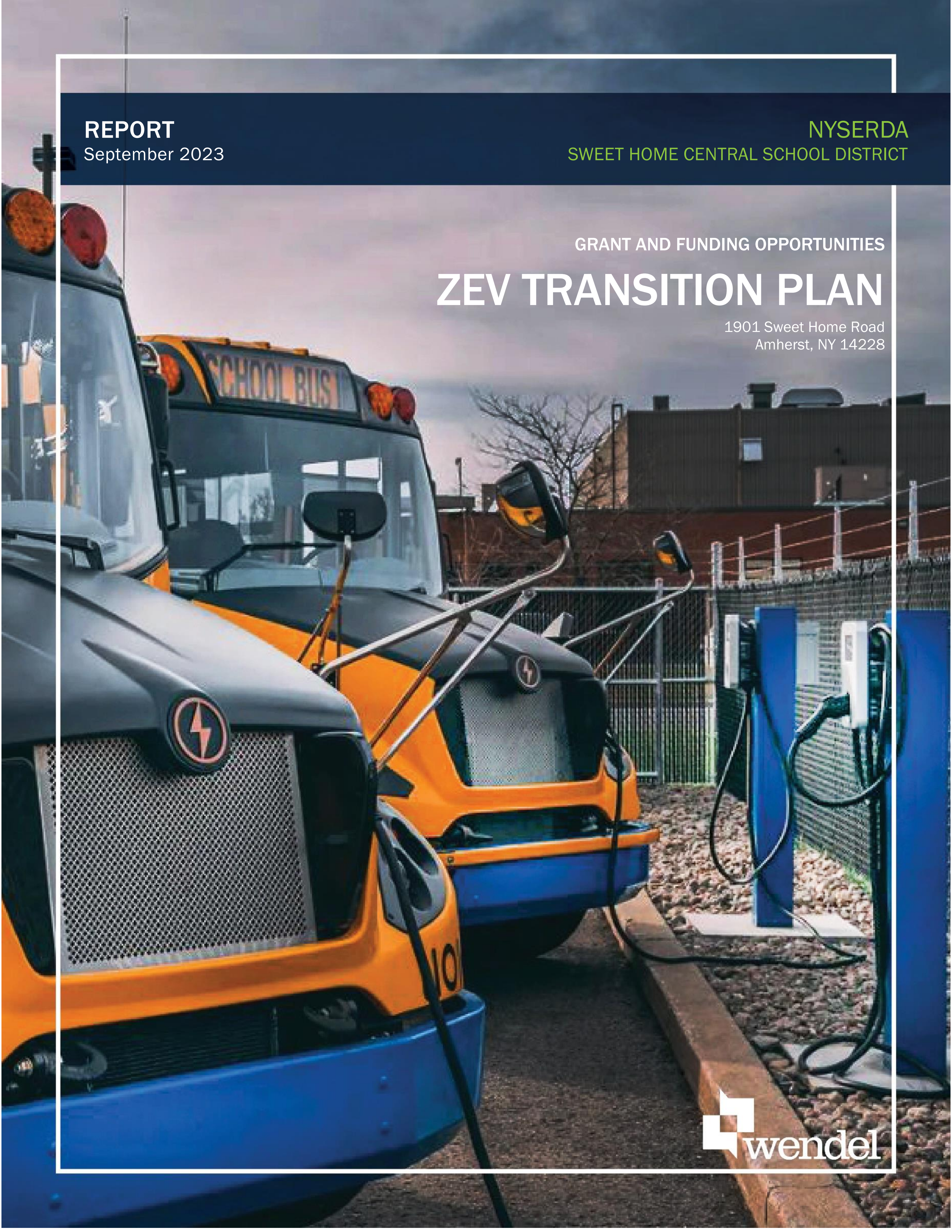
REPORT
September 2023

NYSERDA
SWEET HOME CENTRAL SCHOOL DISTRICT

GRANT AND FUNDING OPPORTUNITIES

ZEV TRANSITION PLAN

1901 Sweet Home Road
Amherst, NY 14228



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Introduction

Introduction

Sweet Home Central School District and NYSERDA have obtained Wendel's services to conduct a study regarding the transition of the district's current diesel school bus fleet to battery electric buses by 2035. The deliverables of the study include a transition plan providing the district a guide to transitioning the fleet based on current NYS mandates. Should the current mandates change, this plan will provide the necessary information for the district to adjust the plan accordingly.

Background

In April 2022, New York State's enacted 2022-2023 State Budget included a zero-emission mandate for NYS school buses. The mandate requires, in part, that by July 1, 2027, all new school bus purchases and leases must be zero-emission and that by July 1, 2035, all school districts must only operate and maintain zero-emission school buses. This mandate defines zero-emission school buses as a school bus that "is propelled by an electric motor and associated power electronics and draws electricity from a hydrogen fuel cell or battery; or otherwise operates without direct emission of atmospheric pollutants." Zero-emission school buses are primarily battery electric at this time. Other zero-emission buses such as hydrogen fuel cell are in development but are not readily available commercially.

Sweet Home Central School District elected to prepare for these requirements by developing a transition plan that would provide the district with the planning tools and flexibility necessary to ensure a seamless transition to zero-emission. In September of 2022, Sweet Home Central Schools contracted with Wendel and NYSERDA through PON 4157 – P12 Schools: Green and Clean Energy Solutions in developing a transition plan that provides a path towards a zero-emission bus fleet by 2035. The program goal is to provide districts with a study that evaluates and recommends infrastructure upgrades that can be used to make informed decisions regarding design and implementation to reduce energy loads and assist in conversion to carbon free fuels. This transition plan can be used as a guide to the district in transitioning and implementing battery electric buses.

Scope of Work

The detailed scope of work can be found in Appendix C and include the following major tasks:

TASK 1 – Project Kickoff and Status Meetings
TASK 2 – Data Collection
TASK 3 – Route Analysis
TASK 3a – Optional Route Analysis
TASK 4 – Conceptual Charging Strategy
TASK 5 – Electric Utility Analysis
TASK 5a – Optional Analysis – Vehicle-to-Grid Charging Analysis
TASK 6 – Concept Development and Phasing Plan
TASK 7 – Phasing Plan Estimates
TASK 7a – O&M Costs

A memo was submitted as a deliverable for each task above detailing the results and findings of the task. These memos are included in the appendices. This report is a summary of the findings of the individual letter reports generated from each task.

Note on Technology

Battery electric bus technology is emerging and rapidly changing. Electric bus battery capacities are increasing as this technology grows while battery sizes and weights continue to decrease due to charge density improvements. Supporting equipment, such as chargers, are also evolving in terms of charger sizes, an increase in features and improving energy efficiencies. As battery capacities increase, the need for larger chargers also increases to enable fully charging a larger battery in the same amount of time.

The recommendations in this report regarding bus battery capacities and charger sizes are based on the route analysis and charger strategies developed in Tasks 3 through 4 utilizing technology that is currently available as well as manufacturers recommendations. As battery electric bus and charger technology evolves, superior bus capacities and charger configurations may become available. This superior equipment may be substituted for the equipment proposed in this report in order to increase efficiency or bus performance. If an increase in charger size is desired, Sweet Home School District should confirm compatibility and capacity with the vendor and their utility provider, National Grid, prior to purchasing.

It should also be noted that at the time of this report, fire and building codes have not been updated to include recommendations for preventing or managing battery electric fires. Although the frequency of battery electric bus fires are no greater than their diesel counterparts, Lithium-Ion batteries burn much hotter than a diesel fire and are extremely difficult to extinguish. Wendel has developed a fire protection protocol for battery electric bus fires and, working with insurance agencies and various state fire marshals, has obtained approval for implementation of this protocol where battery electric buses are stored and maintained. It is important to note that the local Authority Having Jurisdiction (AHJ) is the primary authority for approval of fire protection protocols. As the codes are updated to address battery electric fires the recommendations of this report should be reviewed and updated as necessary and/or required.

Executive Summary

Executive Summary

Strategy, Goals & Constraints

Wendel developed a transition plan to provide the district with the planning tools and flexibility necessary to ensure a seamless transition to a zero-emission fleet. The goal of the transition plan is to provide a path towards a zero-emission bus fleet by 2035 by providing Sweet Home Central School District with a study that evaluates and recommends infrastructure upgrades that can be used to make informed decisions regarding design and implementation to reduce energy loads and assist in conversion to carbon free fuels. This transition plan can be used as a guide to the district in transitioning to a BEB fleet and implementing battery electric buses.

While Sweet Home school district's goal is to transition to zero-emission vehicles (ZEV) by 2035, Wendel utilized the following guiding principles to develop ZEV transition plans:

- No impact on student experience
- Limit constraints on operations
- Reduce implementation cost and complexity
- Minimize impact on workforce

Wendel has identified the following constraints to transition to a zero emissions fleet:

- Vehicle range limitations
- Charging duration requirements
- Utility demand requirements
- Demand on facilities and operations
- Maintenance knowledge

Analysis Results

Wendel analyzed current bus route data and determined the anticipated energy requirements per route. The anticipated energy requirements per route determine minimum battery size requirements, charging requirements and charging durations necessary for each route. Wendel established that all routes provided by the district could be driven by 56 buses (67 buses in the current fleet, including 11 buses as spare capacity). The anticipated energy requirements per route determined the maximum energy usage is 285.8 kWh. Wendel recommends that 62 Thomas Built 220 kWh buses and five IC 321 kWh buses be utilized to complete Sweet Home's routes.

The analysis of the bus routes determined that multiple bus battery sizes could be used to complete the Sweet Home CSD bus routes. Wendel chose the Thomas Built 226 kWh bus as the basis for the Sweet Home fleet. This choice is based on the following:

1. Sweet Home has a majority of Thomas Built Buses in their fleet and are comfortable with the Thomas Built Bus and the local dealer.
2. The 226 kWh battery in the Thomas Built Bus is large enough to complete a majority of the routes.
3. There are some longer routes that will require a larger bus battery. On these routes, Wendel is recommending the IC 315 kWh bus. Five larger battery buses would be required to complete all of the current Sweet Home CSD bus routes. The IC 315 kWh battery has a usable energy of 252 kWh when new.
4. Smaller battery buses, such as the Blue Bird 155 kWh bus could be used on some routes if desired, but these buses would be very limited in the routes that they could be placed on, complicating bus scheduling operations. The Blue Bird 155 kWh battery has a usable energy of 124 kWh when new.

Wendel recommends that Sweet Home CSD utilize Sixty (60) of the Proterra 60 kW chargers and seven (7) 120 kW chargers. The Proterra 60 kW chargers were selected as the basis of design for the following reasons:

1. The Thomas Built Bus utilize a Proterra drive train and battery system. Although not required, it is recommended that Proterra chargers be used with the Proterra batteries. This will limit issues between the bus manufacturer and the charger manufacturer if problems should arise during start-up and operations.
2. The Proterra 60 kW charger is the only Proterra charger that is V2G capable at this point in time.
3. Other charger manufacturers have chargers comparable to the Proterra 60 kW charger and can be utilized if desired.

The maximum demand from bus charging when all buses are converted to BEBs during the least efficient month is 1,319.22 kW.

Phases & Costs

Wendel has estimated the capital cost to purchase battery-electric buses and supporting charging infrastructure to achieve 100% zero-emissions bus operations by 2035. Transition plan phases were determined by the bus implementation/procurement schedule provided by Sweet Home. The bus implementation schedule below determines when infrastructure is required per phase. All components of phase 1 will be required to charge battery electric buses. If Sweet Home adjusts their procurement schedule, the timing of phases can be impacted. Based on this transition plan and bus implementation schedule, Sweet Home is fully transitioned to a zero emission battery electric fleet by 2031 – 2032 (56 operational buses by 2031 and 67 total buses including spares by 2032).

During the study, Sweet Home CSD entered into an agreement with their bus supplier to take advantage of the NY TVIP (Truck Voucher Incentive Program). Under TVIP, Sweet Home is procuring three Thomas Built electric buses for delivery in late summer 2024. The implementation of the transition plan, including the upgrades of the National Grid feeders will not be ready in time to provide charging power for the three buses purchased under TVIP. Wendel was asked to develop a feasibility study to determine if the three buses could be charged utilizing the existing Sweet Home CSD electrical infrastructure.

The feasibility study concluded that charging the three buses could be accomplished utilizing a charger/battery combination, such as the Freewire Boost Charger. This charger allows for fast charging while minimizing utility demand and allowing for charging from the existing Sweet Home CSD 208v distribution system.

	Existing	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	Total
Battery Electric Buses Procured	0	0	3	8	9	9	8	6	6	6	4	4	4	0	0	0	0	0	0	67
Battery Electric Bus Fleet Size	0	0	3	11	20	29	37	43	49	55	59	63	67	67	67	67	67	67	67	67

Temporary Charging Phase – Phase 0 of implementation will require electrical upgrades and charging infrastructure for temporary charging of three buses. The total estimated cost of phase 0 is $960,960

Phase 1 of implementation will require electrical upgrades including a new National Grid primary transformer, new power distribution equipment, primary cable trench from new service to power distribution equipment, power feeds and charging equipment for up to 34 additional chargers, and fire protection upgrades. The total estimated cost of phase 1 is $5,242,300 - $5,690,540.

Phase 2 of implementation will require power feeds and charging equipment for up to 20 additional chargers. This phase will bring total number of bus charging positions to 54. The total estimated cost of phase 2 is $2,123,152 - $2,346,641.

Phase 3 of implementation will require power feeds and charging equipment for up to eight (8) additional charging positions. This phase will bring the total number of bus charging positions up to 62. The estimated cost of phase 3 is $796,888 - $880,771.

Phase 4 of implementation requires power feeds and charging equipment for up to five (5) additional chargers. This phase will bring the total number of bus charging positions to 67. The estimated cost of phase 4 is $1,112,283 - $1,229,365.

The total estimated cost of all phases is $10,235,592 - $11,108,277.

Utility Requirements & Impacts

The projected power requirements for the charging of battery electric buses requires a new utility service feed from National Grid and an additional transformer. The utility has completed the feeder study and determined that they can support the project's anticipated required power to charge the electric fleet. The utility is in process of working through the estimate of utility side construction costs.

Environmental Impacts

The transition to battery electric buses from diesel buses would remove 407 MT CO2e, reduce energy consumption by 8,248 MMBtu's and reduce energy costs by $137,900 per school year.

56 Diesel Bus Energy Analysis		
Route Data	640,673	Miles
Bus Efficiency	6.1	Mpg
Total Gallons	105,028.35	Gallons
Energy Used	14,428.90	MMBtu
Diesel Cost	$ 3.6404	Per Gallon
Total Cost	**$ 382,347.00**	

56 Electric Bus Energy Analysis		
Route Data	640,673	Miles
Bus Efficiency	2.83	kWh/Mile
Total kWh	1,811,362.55	KWh
Energy Used	6,180.94	MMBtu
Electric Cost	$ 0.1350	Per kWh
Total Cost	**$ 244,444.00**	

Data Collection

DATA COLLECTION

Data collection plays a vital role in understanding, optimizing, and managing battery electric bus transitions. It enables evidence-based decision-making, facilitates operational efficiency, and supports the successful integration of BEBs into existing school district systems.

Wendel submitted an RFI to Sweet Home School District on 1/11/23 to gather key data required to perform proper analyses. The requested data included:

- Bus Fleet Information – Fleet size (current and projected), bus replacement plan/schedule, bus types/size
- Bus Schedules and Route Data – Detailed bus routes, departure and return times, operational hours, mileage, fuel consumption, operational contingency/resiliency plans.
- Bus Parking/Storage Arrangements – Indoor/Outdoor, location
- Fueling – current operational requirements for fueling
- Utility Data – Name of local utility, existing service size (kVA) and voltage, Utility contact
- Existing School Electrical Distribution Information – existing capacity, condition, expansion capability. Any as-built electrical site drawings (one-line distribution drawings)
- Existing Site Plan – CAD file of overall site plan
- Fleet maintenance data and historical cost

Bus Fleet Information

Bus fleet information is vital for effective planning, replacement strategies, and financial planning related to the transition of battery electric buses. It forms the foundation for a well-informed and successful BEB transition plan. Sweet Home provided a bus list containing 67 buses with their associated age, make, model, trim, etc. See information below:

Vehicle Types & Quantities	
Make/Model/ Trim	**Quantity**
IC Convec	1
Dodge MiniVan	1
Blue Bird Vision Conv.	13
Thomas Saf-T-Liner C2	41
Chevy 4500 Microbird	2
Chevy 3500 Microbird	2
Ford 4500	1
Ford 350 Corb	1
Chevy 4500 Minitour	2
Dodge MiniVan Caravan	1
Chevy Van Minitour	2
Ford Van E-150	0
Ford Pickup 5-350	0
Total	**67**

Vehicle	Year	Make/Model/Trim	Type	Fuel Type	Vehicle	Year	Make/Model Trim	Type	Fuel Type
289	2008	IC Convec	Bus	Diesel	350	2015	Thomas Saf-T-Liner C2	Bus	Diesel
295	2008	Dodge Minivan	Minivan	Unleaded	351	2016	Chevy 3500 Microbird	Bus	Unleaded
306	2009	Bluebird Vision Conv	Bus	Diesel	354	2017	Thomas Saf-T-Liner C2	Bus	Diesel
307	2009	Bluebird Vision Conv	Bus	Diesel	355	2017	Thomas Saf-T-Liner C2	Bus	Diesel
308	2009	Bluebird Vision Conv	Bus	Diesel	356	2017	Thomas Saf-T-Liner C2	Bus	Diesel
310	2009	Bluebird Vision Conv	Bus	Diesel	357	2017	Thomas Saf-T-Liner C2	Bus	Diesel
311	2011	Bluebird Vision Conv	Bus	Diesel	358	2018	Thomas Saf-T-Liner C2	Bus	Diesel
312	2011	Bluebird Vision Conv	Bus	Diesel	359	2018	Thomas Saf-T-Liner C2	Bus	Diesel
313	2011	Bluebird Vision Conv	Bus	Diesel	360	2018	Thomas Saf-T-Liner C2	Bus	Diesel
316	2011	Bluebird Vision Conv	Bus	Diesel	361	2018	Thomas Saf-T-Liner C2	Bus	Diesel
317	2011	Bluebird Vision Conv	Bus	Diesel	362	2018	Chevy 4500 Minitour	Bus	Unleaded
318	2011	Bluebird Vision Conv	Bus	Diesel	363	2019	Chevy 4500 Minitour	Bus	Unleaded
319	2011	Bluebird Vision Conv	Bus	Diesel	364	2019	Thomas Saf-T-Liner C2	Bus	Diesel
323	2013	Bluebird Vision Conv	Bus	Diesel	365	2019	Thomas Saf-T-Liner C2	Bus	Diesel
324	2013	Thomas Saf-T-Liner C2	Bus	Diesel	366	2019	Thomas Saf-T-Liner C2	Bus	Diesel
325	2013	Thomas Saf-T-Liner C2	Bus	Diesel	367	2019	Thomas Saf-T-Liner C2	Bus	Diesel
326	2013	Thomas Saf-T-Liner C2	Bus	Diesel	368	2018	Dodge MiniVan Caravan	MiniVan	Unleaded
329	2015	Thomas Saf-T-Liner C2	Bus	Diesel	370	2020	Thomas Saf-T-Liner C2	Bus	Diesel
330	2015	Thomas Saf-T-Liner C2	Bus	Diesel	371	2020	Thomas Saf-T-Liner C2	Bus	Diesel
331	2015	Thomas Saf-T-Liner C2	Bus	Diesel	372	2020	Thomas Saf-T-Liner C2	Bus	Diesel
332	2015	Thomas Saf-T-Liner C2	Bus	Diesel	373	2020	Thomas Saf-T-Liner C2	Bus	Diesel
333	2013	Chevy 4500 Microbird	Bus	Diesel	374	2021	Thomas Saf-T-Liner C2	Bus	Diesel
334	2013	Chevy 4500 Microbird	Bus	Diesel	375	2021	Thomas Saf-T-Liner C2	Bus	Diesel
336	2015	Thomas Saf-T-Liner C2	Bus	Diesel	376	2021	Thomas Saf-T-Liner C2	Bus	Diesel
337	2015	Thomas Saf-T-Liner C2	Bus	Diesel	377	2021	Thomas Saf-T-Liner C2	Bus	Diesel
338	2015	Thomas Saf-T-Liner C2	Bus	Diesel	378	2021	Thomas Saf-T-Liner C2	Bus	Diesel
339	2015	Thomas Saf-T-Liner C2	Bus	Diesel	379	2022	Thomas Saf-T-Liner C2	Bus	Diesel
342	2014	Chevy 3500 Microbird	Bus	Diesel	380	2022	Thomas Saf-T-Liner C2	Bus	Diesel
343	2016	Ford 4500	Bus	Diesel	381	2022	Thomas Saf-T-Liner C2	Bus	Diesel
344	2016	Thomas Saf-T-Liner C2	Bus	Diesel	382	2022	Thomas Saf-T-Liner C2	Bus	Diesel
345	2016	Thomas Saf-T-Liner C2	Bus	Diesel	383	2022	Thomas Saf-T-Liner C2	Bus	Diesel
346	2017	Thomas Saf-T-Liner C2	Bus	Diesel	384	2022	Thomas Saf-T-Liner C2	Bus	Diesel
347	2016	Thomas Saf-T-Liner C2	Bus	Diesel					

Sweet Home has 12 smaller Type A buses/vans which are shown below:

Sweet Home Type A Bus List						
Vehicle	Year	Make	Model	Trim	Type	Fuel Type
295	2008	Dodge	MiniVan		MiniVan	Unleaded
333	2013	Chevy	4500	Microbird	Bus	Unleaded
334*	2013	Chevy	4500	Microbird	Bus	Unleaded
342	2014	Chevy	3500	Microbird	Bus	Unleaded
343*	2016	Ford	4500		Bus	Unleaded
351*	2016	Chevy	3500	Microbird	Bus	Unleaded
352	2004	Ford	350	Corb	Bus	Diesel
362*	2018	Chevy	4500	Minitour	Bus	Unleaded
363*	2019	Chevy	4500	Minitour	Bus	Unleaded
368*	2018	Dodge	Minivan	Caravan	Minivan	Unleaded
383	2022	Chevy	Van	Minitour	Bus	Unleaded
384	2022	Chevy	Van	Minitour	Bus	Unleaded

**Vehicle numbers that are starred are currently assigned to a route*

Bus Schedules and Route Data

Vehicle schedules and route data for all buses was provided by Sweet Home school district. The data provides specific information on each individual route that is driven by Sweet Home's fleet of school buses. This data included departure and arrival times, total duration, and milage for each route. The duration and distance of the routes are essential to determine the energy requirements of each route and the size bus battery required.

The routes were combined by vehicle name and then broken up into "am" and "pm" routes. Each route group has a cumulative start and finish time, total duration, and total distance. The following two tables show an example of combining the routes:

AM & PM Route Schedule							
Vehicle Name	AM/PM	Distance	Deadhead Miles	Start Time	Finish Time	Duration	Stops
100	AM	7.07	3.22	7:59:00AM	8:25:00AM	26	35
100	AM	6.47	3.21	6:50:00AM	7:13:00AM	23	9
100	AM	11.23	3.81	8:30:00AM	9:05:00AM	35	10
100	PM	11.7	1.17	2:50:00PM	3:32:00PM	42	36
100	PM	10.85	3.82	3:55:00PM	4:33:00PM	38	9
100	PM	5.38	2.01	2:00:00PM	2:13:00PM	13	8

Combining of the Routes					
Vehicle Name	AM/PM	Total Distance	Total Deadhead Miles	Start Time	Finish Time
100	AM	24.77	10.24	6:50:00AM	9:05:00AM
100	PM	27.93	7	2:00:00PM	4:33:00PM

The following additional metrics were calculated to improve the accuracy of the analysis portion of the plan. Wendel calculated the % deadhead miles, Total active duration and "resting" duration, the average speed, and average active speed. Deadhead reflects the bus is driving with no students onboard which will yield higher driving efficiencies.

Total Distance Traveled (mi)
Total Deadhead (mi)
Deadhead %
Total Duration (Minutes)

Active Duration (Minutes)
Resting Duration "On" (Minutes)
Average Speed (mph)
Average Active Speed (mph)

Additional Data

The items from the request for information which are listed at the top of this section and below add key pieces of information needed to perform and high-quality data driven study and are shown in appendix A “Additional Information”.

- Bus parking/storage arrangements – Indoor/Outdoor, location
- Fueling- current operational requirements for fueling
- Utility Data – Name of local utility, existing service size (kVA) and voltage, Utility contact
- Existing School Electrical Distribution information – existing capacity, condition, expansion capability. Any as-built electrical site drawings (one-line distribution drawings)
- Existing Site Plan – CAD file of overall site plan
- Fleet maintenance data and historical cost

Data from previous studies was utilized to enhance the depth and comprehensiveness of the analysis. By leveraging the valuable insights and findings from these earlier investigations, Wendel was able to build upon existing knowledge and establish a stronger foundation for their own study.

Route Analysis

ROUTE ANALYSIS

Wendel analyzed the available bus route data for each route to determine the time and distance required for a bus to complete the routes. The analysis developed energy requirements per route and determined the minimum battery size requirements, charging requirements, and charging durations necessary per route.

Route Adjustments and Process

- Sweet Home school district provided 283 routes.
- The 24 routes below were removed per discussions with Sweet Home School District because they were old routes that are no longer driven.

Name	Schools	Vehicle Name	Desc	Number Stops	Distance	Deadhead Miles	Start Time	Finish Time
114 AM - Mikey to HS - T, Th, F	HS	114	334	4	4.4	3.42	9:10:00 AM	9:35:00 AM
114 PM - Mikey from HS - T, Th, F	HS	114	334	4	2.74	1.28	1:30:00 PM	1:53:00 PM
114 PM GLENDALE (Copy A)	GL	114	334	11	15.61	15.61	2:50:00 PM	3:38:00 PM
121 PM MIDDLE SPORTS	MS	121	345	5	7.397751	7.397751	3:55:00 PM	4:18:00 PM
125 Brunetto pick up	MS	125		3	31.87362	31.87362	8:05:00 AM	9:05:00 AM
136 PM IDT TIBBS	IDT	136		4	9.11	6.8	1:52:00 PM	2:30:00 PM
147 AM Work Program 8:00 AM M - Th - to WEGMANS ALBERTA	WEG	147	376	4	5.04	5.04	8:10:00 AM	8:31:00 AM
148 PM ST. JOHNS BAPTIST, (with JoAnn Fabric)	STJTB	148	377	8	14.39	14.39	1:40:00 PM	2:28:00 PM
BAND & ORCH - MONDAY22 - BUS A - NORTH	HS			14	10.96346	10.96346	4:30:00 PM	5:05:00 PM
BAND & ORCH - MONDAY22 - BUS B - HH/WR	HS			14	12.74816	12.74816	4:30:00 PM	5:10:00 PM
BAND & ORCH - MONDAY22 - BUS C - TONA	HS			16	11.2164	11.2164	4:30:00 PM	5:07:00 PM
BAND & ORCH - MONDAY22 - BUS D - SOUTH	HS			14	14.06861	14.06861	4:30:00 PM	5:14:00 PM
Exam Ready Tues MIDDAY D/O - P/U	READY			13	18.61	18.61	9:53:00 AM	11:01:00 AM
Exam Ready Tues MIDDAY Take In	READY			9	9.97	9.97	10:43:00 AM	11:24:00 AM
Exam Ready WED MIDDAY Take Home	READY			12	12.192	12.192	9:53:00 AM	10:41:00 AM
Exam Ready Wed MIDDAY Take In	READY			8	9.968662	9.968662	10:43:00 AM	11:24:00 AM
McKinney Vento - 8860 Disney Drive PM	HS,MS			5	30.25951	16.68181	3:30:00 PM	4:46:00 PM
McKinnney Vento - 1184 East Lovejoy St - AM	HS,MS			4	18.4475	9.0437	9:10:00 AM	9:55:00 AM
MIDDAY 204 TUESDAY - Return Students to Ready	GL,HH,MM,MS	307		5	9.75	9.75	1:00:00 PM	1:30:00 PM
MIDDAY 205 FAITH HOME FROM HS	HS	375		4	5.9	3.15	12:41:00 PM	12:59:00 PM
MIDDAY 206 12:30 READY TO HOME T, TH	READY			10	19.36034	19.36034	12:18:00 PM	1:23:00 PM
MIDDAY 206 WED	HS			4	4.673689	4.673689	11:30:00 AM	11:44:00 AM
Middle School Late Run WR and North End	MS			14	11.97399	11.97399	4:35:00 PM	5:13:00 PM
Middle School Late Run GL and South	MS			11	13.82977	13.82977	4:35:00 PM	5:18:00 PM

- The following 48 routes below had the deadhead miles adjusted because after review with Sweet Home the deadhead miles listed were incorrectly listed.

Name	Bus #	AM/PM	Schools	Vehicle Name	Desc	Number Stops	Distance	Deadhead Miles	Start Time	Finish Time	Start Time	Finish Time	Line #	Deadhead %	Comments
100 PM HERITAGE HEIGHTS	100	PM	HH	100	380	36	11.69958	1.169958	2:50:00 PM	3:32:00 PM	14.8333333	15.5333333	4	0.1	Revised to 10% deadhead.
104 AM MIDDLE SCHOOL	104	AM	MS	104	316	21	7.558608	0.7558608	8:37:00 AM	9:06:00 AM	8.61666667	9.1	21	0.1	Revised to 10% deadhead.
105 PM WILLOW RIDGE	105	PM	WR	105	317	29	5.847554	0.5847554	2:50:00 PM	3:12:00 PM	14.8333333	15.2	30	0.1	Revised to 10% deadhead.
107 PM WILLOW RIDGE	107	PM	WR	107	324	38	7.53	0.753	2:50:00 PM	3:19:00 PM	14.8333333	15.3166667	42	0.1	Revised to 10% deadhead.
108 PM GLENDALE	108	PM	GL	108	325	22	8.781784	0.8781784	2:50:00 PM	3:20:00 PM	14.8333333	15.3333333	46	0.1	Revised to 10% deadhead.
111 PM HERITAGE HEIGHTS	111	PM	HH	111	330	30	6.835407	0.6835407	2:50:00 PM	3:15:00 PM	14.8333333	15.25	64	0.1	Revised to 10% deadhead.
113 AM MAPLEMERE	113	AM	MM	113	332	31	5.32	0.532	8:00:00 AM	8:23:00 AM	8	8.38333333	74	0.1	Revised to 10% deadhead.
114 AM MIDDLE SCHOOL	114	AM	MS	114	334	4	22.85	2.285	8:30:00 AM	9:17:00 AM	8.5	9.28333333	82	0.1	Revised to 10% deadhead
117 AM HERITAGE HEIGHTS	117	AM	HH	117	357	26	19.19	1.919	7:35:00 AM	8:28:00 AM	7.58333333	8.46666667	91	0.1	Revised to 10% deadhead.
120 PM - Brunetto Take Home	120	PM	MS	120	368	3	43.26	21.63	3:50:00 PM	4:59:00 PM	15.8333333	16.9833333	102	0.5	Revised to 50% deadhead
121 PM GLENDALE	121	PM	GL	121	345	24	12.34063	1.234063	2:35:00 PM	3:25:00 PM	14.5833333	15.4166667	106	0.1	Revised to 10% deadhead.
122 AM GLENDALE	122	AM	GL	122	346	45	11.0016	1.10016	7:53:00 AM	8:34:00 AM	7.88333333	8.56666667	108	0.1	Revised to 10% deadhead.
126 AM JEWISH HERITAGE	126	AM	JHER	126	353	8	12.31	1.231	8:00:00 AM	8:37:00 AM	8	8.61666667	127	0.1	Revised to 10% deadhead.
126 PM ST. GREGORYS	126	PM	STGRE	126	353	6	21.99	2.199	1:40:00 PM	2:51:00 PM	13.6666667	14.85	131	0.1	Revised to 10% deadhead.
127 AM MAPLEMERE	127	AM	MM	127	354	33	13.45561	1.345561	7:49:00 AM	8:35:00 AM	7.81666667	8.58333333	134	0.1	Revised to 10% deadhead.
131 AM MIDDLE SCHOOL	131	AM	MS	131	358	19	7.046865	0.7046865	8:35:00 AM	9:01:00 AM	8.58333333	9.01666667	148	0.1	Revised to 10% deadhead.
131 PM MIDDLE SCHOOL	131	PM	MS	131	358	18	6.614384	0.6614384	3:55:00 PM	4:18:00 PM	15.9166667	16.3	151	0.1	Revised to 10% deadhead.
134 AM MAPLEMERE	134	AM	MM	134	361	33	10.89369	1.089369	7:43:00 AM	8:18:00 AM	7.71666667	8.3	164	0.1	Revised to 10% deadhead.
134 PM MAPLEMERE	134	PM	MM,MS,WR	134	361	33	14.92592	1.492592	2:50:00 PM	3:53:00 PM	14.8333333	15.8833333	167	0.1	Revised to 10% deadhead.
138 AM READY (T & TH)	138	AM	READY	138	365	11	12.58	3.33	8:30:00 AM	9:09:00 AM	8.5	9.15	174	0.264705882	Revised deadhead to match M/W/F routes
138 PM READY	138	PM	READY	138	365	8	13.29377	1.329377	1:52:00 PM	2:32:00 PM	13.8666667	14.5333333	176	0.1	Revised to 10% deadhead.
138 PM WILLOW RIDGE	138	PM	WR	138	365	32	7.020746	0.7020746	2:28:00 PM	2:55:00 PM	14.4666667	14.9166667	177	0.1	Revised to 10% deadhead.
139 AM GLENDALE	139	AM	GL	139	366	30	7.8	0.78	8:04:00 AM	8:35:00 AM	8.06666667	8.58333333	179	0.1	Revised to 10% deadhead.
139 PM GLENDALE	139	PM	GL	139	366	29	13	1.3	2:35:00 PM	3:27:00 PM	14.5833333	15.45	181	0.1	Revised to 10% deadhead.
140 AM READY (NORTH) (T, TH)	140	AM	READY	140	367	21	14.33961	1.7425	8:28:00 AM	9:12:00 AM	8.46666667	9.2	182	0.121516554	Revised deadhead to match M/W/F routes
143 PM WILLOW RIDGE	143	PM	WR	143	372	24	9.09	0.909	2:30:00 PM	3:15:00 PM	14.5	15.25	201	0.1	Revised to 10% deadhead.
144 PM GLENDALE	144	PM	GL	144	373	27	12.51	1.251	2:25:00 PM	3:24:00 PM	14.4166667	15.4	204	0.1	Revised to 10% deadhead.
146 PM HERITAGE HEIGHTS	146	PM	HH,HS	146	375	12	15.90394	1.590394	2:45:00 PM	3:37:00 PM	14.75	15.6166667	215	0.1	Revised to 10% deadhead.
147 AM FRIDAY TRI - MAIN	147	AM	TRI-M	147	376	3	12.39	6.195	8:30:00 AM	9:14:00 AM	8.5	9.23333333	218	0.5	Revised to 50% deadhead.
148 PM ST. JOHNS BAPTIST,	148	PM	STJTB	148	377	6	14.37	1.437	1:40:00 PM	2:26:00 PM	13.6666667	14.4333333	223	0.1	Revised to 10% deadhead.
251 MCKV AM Middle School	251	AM	MS	251		7	27.62	2.762	8:15:00 AM	9:29:00 AM	8.25	9.48333333	236	0.1	Revised to 10% deadhead.
251 MCKV PM High School	251	PM	HS	251		5	24.12	2.412	2:00:00 PM	2:36:00 PM	14	14.6	239	0.1	Revised to 10% deadhead.
Band A Bus A 2023	Ban	PM	HS			10	14.17489	1.417489	4:35:00 PM	5:19:00 PM	16.5833333	17.3166667	245	0.1	Revised to 10% deadhead. Best potential bus.
Band A Bus B 2023	Ban	PM	HS			14	9.73	0.973	4:35:00 PM	5:06:00 PM	16.5833333	17.1	246	0.1	Revised to 10% deadhead. Best potential bus.
Band A Bus C 2023	Ban	PM	HS			11	11.7	1.17	4:35:00 PM	5:12:00 PM	16.5833333	17.2	247	0.1	Revised to 10% deadhead. Best potential bus.
Band B Bus A 2023	Ban	PM	HS			10	10.63576	1.063576	4:35:00 PM	5:08:00 PM	16.5833333	17.1333333	248	0.1	Revised to 10% deadhead. Best potential bus.
Mc Vento 78th st AM	Mc	AM	HS			4	26.36575	13.182875	6:18:00 AM	7:11:00 AM	6.3	7.18333333	254	0.5	Revised deadhead to 50%. Best potnetial bus.
McKinney Vento - 8860 Disney Drive PM	McK	PM	HS,MS			5	30.25951	3.025951	3:30:00 PM	4:46:00 PM	15.5	16.7666667	256	0.1	Revised to 10% deadhead. Best potnetial bus.
MIDDAY 204 PM 12:00 KTON TO HIGH SCHOOL	204	PM	KENTO	307		2	8.51	4.255	12:21:00 PM	12:43:00 PM	12.35	12.7166667	264	0.5	Revised deadhead to 50%
MIDDAY 206 12:30 READY SENIORS TO HOME	206	PM	READY			8	16.2	1.62	12:35:00 PM	1:25:00 PM	12.5833333	13.4166667	269	0.1	Revised to 10% deadhead
MIDDAY 206 BINNER TO HARK 12:15	206	AM	HARKN			4	20.635	10.3175	11:50:00 AM	12:30:00 PM	11.8333333	12.5	271	0.5	Revised to 50% deadhead
MIDDAY 207 - Work Programs	207	AM	TOPSB			8	17.21619	8.608095	10:52:00 AM	12:38:00 PM	10.8666667	12.6333333	273	0.5	Best potential Bus. Revised to 50% deahead.
MIDDAY 209 TRI - MAIN FRIDAY	209	AM	TRI-M	352		4	12.53293	6.266465	10:40:00 AM	11:16:00 AM	10.6666667	11.2666667	276	0.5	Revised to 50% deadhead
MIDDAY 209 Work Program - From TGI Fridays	209	AM	TGIF			4	5.275328	2.637664	9:15:00 AM	9:38:00 AM	9.25	9.63333333	277	0.5	Revised to 50% deadhead
MIDDAY 209 Work Program M-TH From Wegmans - Alberta	209	AM	WEG			3	4.599909	2.2999545	10:45:00 AM	11:16:00 AM	10.75	11.2666667	278	0.5	Revised to 50% deadhead
MS Late Run (Wed/thurs)	MS	PM	MS			12	22.87421	2.287421	4:30:00 PM	5:37:00 PM	16.5	17.6166667	281	0.1	Best potential Bus. Revised to 10% deadhead.
Band B Bus B 2023	Ban	PM	HS			14	9.73	0.973	4:35:00 PM	5:06:00 PM	16.5833333	17.1	282	0.1	Best potential Bus. Revised to 10% deadhead.
Band B Bus C 2023	Ban	PM	HS			11	11.7	1.17	4:35:00 PM	5:12:00 PM	16.5833333	17.2	283	0.1	Best potential Bus. Revised to 10% deadhead.

- The following 11 routes can be assigned to any available bus

Name	Bus #	AM/PM	Schools	Vehicle Name	Desc	Number Stops	Distance	Deadhead Miles	Start Time	Finish Time	Start Time	Finish Time	Line #	Deadhead %	Comments
Band A Bus A 2023	Ban	PM	HS			10	14.17489	1.417489	4:35:00 PM	5:19:00 PM	16.5833333	17.3166667	245	0.1	Revised to 10% deadhead. Best potential bus.
Band A Bus B 2023	Ban	PM	HS			14	9.73	0.973	4:35:00 PM	5:06:00 PM	16.5833333	17.1	246	0.1	Revised to 10% deadhead. Best potential bus.
Band A Bus C 2023	Ban	PM	HS			11	11.7	1.17	4:35:00 PM	5:12:00 PM	16.5833333	17.2	247	0.1	Revised to 10% deadhead. Best potential bus.
Band B Bus A 2023	Ban	PM	HS			10	10.63576	1.063576	4:35:00 PM	5:08:00 PM	16.5833333	17.1333333	248	0.1	Revised to 10% deadhead. Best potential bus.
LATE 220 TWILIGHT	LAT	PM	TWLGH	362	220	4	21.1237	8.7935	5:15:00 PM	6:22:00 PM	17.25	18.3666667	253	0.416285973	Best potnetial bus.
Mc Vento 78th st AM	Mc	AM	HS			4	26.36575	13.182875	6:18:00 AM	7:11:00 AM	6.3	7.18333333	254	0.5	Revised deadhead to 50%. Best potnetial bus.
McKinney Vento - 8860 Disney Drive PM	McK	PM	HS,MS			5	30.25951	3.025951	3:30:00 PM	4:46:00 PM	15.5	16.7666667	256	0.1	Revised to 10% deadhead. Best potnetial bus.
MIDDAY 207 - Work Programs	207	AM	TOPSB			8	17.21619	8.608095	10:52:00 AM	12:38:00 PM	10.8666667	12.6333333	273	0.5	Best potential Bus. Revised to 50% deahead.
MS Late Run (Wed/thurs)	MS	PM	MS			12	22.87421	2.287421	4:30:00 PM	5:37:00 PM	16.5	17.6166667	281	0.1	Best potential Bus. Revised to 10% deadhead.
Band B Bus B 2023	Ban	PM	HS			14	9.73	0.973	4:35:00 PM	5:06:00 PM	16.5833333	17.1	282	0.1	Best potential Bus. Revised to 10% deadhead.
Band B Bus C 2023	Ban	PM	HS			11	11.7	1.17	4:35:00 PM	5:12:00 PM	16.5833333	17.2	283	0.1	Best potential Bus. Revised to 10% deadhead.

After the above changes were made, Wendel converted the 259 individual routes (bus drives multiple routes) into 117 routes by summing together routes that would be driven by the same bus (still separating routes by AM and PM since most buses have an AM and PM routes). Of the 117 routes, 11 were assigned as a third group of routes to the best available buses.

Utilizing the provided information from Sweet Home with battery electric bus data from previous studies[1] a route analysis was performed to determine the minimum and maximum kWh usage to satisfy each route. Wendel determined the energy associated with the routes utilizing two different methods, one used duration of the routes and the other utilizes distance of the routes. The reason both analyses are performed is to ensure the recommended bus and battery recommendations meet the requirement of shorter routes with more complex operations and longer more efficient routes without oversizing batteries.

Calculations and Assumptions

The duration and distance inputs are shown below and are derived from battery electric bus performance data analyzed in previous studies that Wendel conducted as referenced in the paragraph above. The min and max battery usages were determined by graphing the kW per hour and kWh per mile data against outside air temperatures (OAT). The data at the lowest OAT was utilized to determine max battery usage and the data at moderate OAT (60F) was utilized to determine the min battery usage. The resting battery usage is associated with time when a bus is "on" while waiting for its next route (A maximum of 15 minutes between routes was utilized). The resting battery usage is attributed primarily to keeping the heater on. Heater data from previous studies was also graphed against OAT, data at the lowest OAT along with 10% of min battery usage per hour was utilized to determine resting battery usage. Deadhead battery usage was determined by analyzing the weight of a full bus compared to an empty bus (Estimated full bus adds 10,000 lbs) along with an understanding that a bus with no students on it will not be making stops therefore will have improved efficiency.

Duration Analysis Inputs:

- Min battery usage per hour: 34.125 kW
- Max battery usage per hour: 70.875 kW
- Resting battery usage per hour: 33.075 kW
- Min deadhead battery usage per hour: 27.3 kW
- Max deadhead battery usage per hour: 45.3 kW

[1] Previous studies include CT Transit Hamden Charging Model and CT Greater Bridgeport Transit Low/No Grant which aided in assessment of charging scenarios to lead to better informed decisions on charging infrastructure, strategies, and operations.

Distance Analysis Inputs:

- Min battery usage per mile: 2.1 kWh
- Max battery usage per mile: 4.36 kWh
- Resting battery usage per hour: 33.075 kW
- Min deadhead battery usage per mile: 2.47 kW
- Max deadhead battery usage per mile: 45.3 kW

Analysis Assumptions:

- Maximum resting time with the bus "on" is 15 minutes between routes[2]
- Heater energy usage is roughly 30 kW at very low outside air temperatures.
- Weight differential between a full bus and an empty bus is roughly 10,000 lbs

Utilizing the route data, inputs and assumptions described in the paragraphs above Wendel was able to calculate the maximum kWh used for each route group with the following formulas:

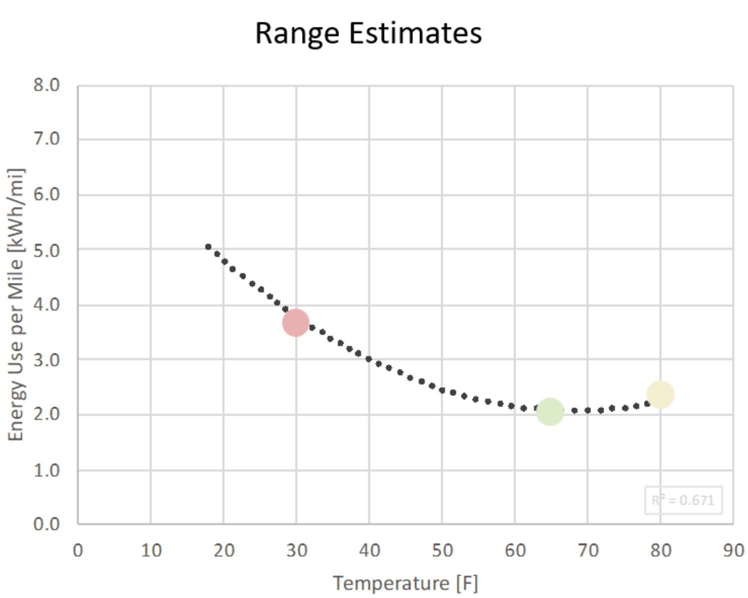
Duration Analysis Max kWh Used Calculation:

$$(Active\ Duration * \%\ Deadhead * Max\ Deadhead\ usage) + (Active\ Duration * (1 - \%\ Deadhead) * Max\ usage) + (Resting\ Duration * Resting\ Battery\ Usage)$$

Distance Analysis Max kWh Used Calculation:

$$(Active\ Distance * Max\ usage) + (Deadhead\ distance * Max\ deadhead\ usage) + (Resting\ Duration * Resting\ Battery\ Usage)$$

The graph below shows average battery electric bus efficiencies at certain outside air temperatures and was developed from a project Wendel worked on at Greater Bridgeport Transit. The analysis described above algins with the graph shown below:



Temp [°F]	Tolerance [±°F]	Est. Eff. [kWh/mi]	Est. Range [mi]
30	2	4.0	80
65	5	2.1	155
80	2	2.4	135

Notes:
- Based on 320 kWh "safe range", i.e. 90% of total usable battery
- Battery size estimate comes from Viriciti data
- Using on temperature ranges shown and ViriCiti data, the above efficiencies and daily ranges can be expected
- Actual data from Greater Bridgeport Transit Low/No Grant
- Proterra 440 kWh battery electric bus

Source: Center For Transportation and the Environment

[2] Route groups (AM/PM) consist of multiple routes that are driven sequentially (A bus may conduct routes for three schools in the morning and three schools in the evening).

Energy Requirements of Bus Routes

The analysis based on the duration of the 117 routes shows that the max energy usage per route is 195.8kWh which requires a minimum battery size of 220kWh to complete the routes. The analysis based on distance shows that the maximum energy usage is 285.8kWh and requires a minimum battery size of 317kWh to complete the routes. Wendel broke out the routes into three groups based on the energy usage of each route. The first group are routes that use less than 100 kWh, second group are routes that use between 100 kWh and 140 kWh, and the third group are routes that use more than 140 kWh. Wendel utilized 100 kWh and 140 kWh as dividers because 100 kWh is the usable battery size of many smaller type A battery electric buses and 140 kWh is the usable battery of the current Bluebird battery electric buses.

Duration Analysis Results:

- Max battery usage: 195.8 kWh
    - 44 routes use under 100 kWh
    - 50 routes use over 100 kWh and under 140 kWh
    - 23 routes use over 140 kWh

Distance Analysis Results:

- Max battery usage: 285.8 kWh
    - 39 routes use under 100 kWh
    - 44 routes use over 100 kWh and under 140 kWh
    - 26 routes use over 140 kWh

Charging Requirements

The charging analysis shows that a combination of charger sizes will be required as roughly 6 routes will require over 4 hours to charge even with a larger 60 kW DC charger. The specific charger sizes and quantities will be shown in the charge modelling section of this report due to the additional detail on each buses recharge duration between their “AM” and “PM” routes and the energy usage associated with each route.

Charging Requirements			
	Required Charging Duration Hrs (120 kW)	Required Charging Duration Hrs (60kW)	Required Charging Duration Hrs (30kW)
Max Charging Rate kW (95%)	114	57	28.5
Max Duration for Full Charge	2.5	50	10.0
Min Duration for Full Charge	.3	.6	1.2
Average Duration for Full Charge	1.1	2.1	4.2
# of routes requiring <1 hr charge at max rate	67	10	0

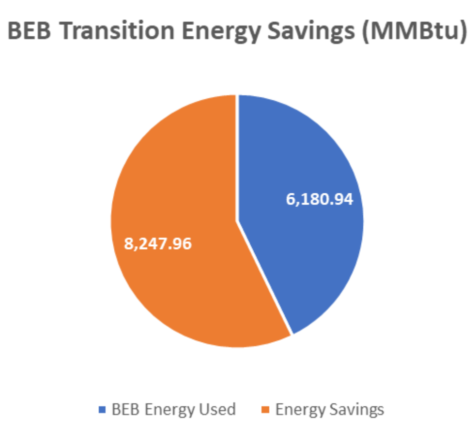
# of routes requiring >1 and <2 hr charge at max rate	44	57	10
# of routes requiring >2 and < 4 hr charge at max rate	6	44	57
# of routes requiring >4 and <6hr charge at max rate	0	6	34
# of routes requiring >6 hr charge at max rate	0	0	16
Total Routes	117	117	117

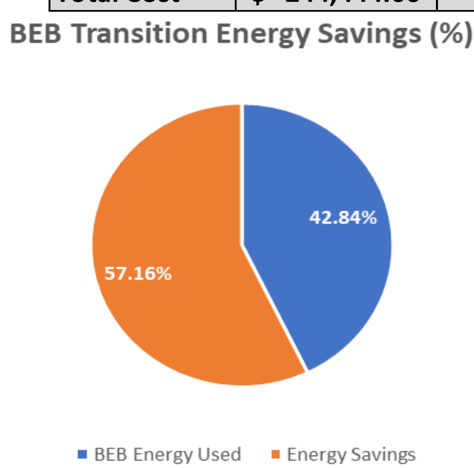
Energy and Environmental Impact:

The total annual milage for all the Sweet Home School District bus routes was 640,673 miles which at 6.1 MPG and $3.64 per gallon of diesel equates to 14,428 MMBtus[3] of associated energy usage and $382,347 annual fuel cost. Based on the route modeling analysis and a review of the existing diesel bus performance, the switch to battery electric buses from diesel buses would save approximately 8,247 MMBtu of energy or a 57.16% reduction in energy consumption. This would also result in a reduction in energy costs of approximately $137,903.00 per school year.

56 Diesel Bus Energy Analysis		
Route Data	640,673	Miles
Bus Efficiency	6.1	Mpg
Total Gallons	105,028.35	Gallons
Energy Used	14,428.90	MMBtu
Diesel Cost	$ 3.6404	Per Gallon
Total Cost	**$ 382,347.00**	

56 Electric Bus Energy Analysis		
Route Data	640,673	Miles
Bus Efficiency	2.83	kWh/Mile
Total kWh	1,811,362.55	KWh
Energy Used	6,180.94	MMBtu
Electric Cost	$ 0.1350	Per kWh
Total Cost	**$ 244,444.00**	





[3] MMBtu is Metric Million British Thermal Unit, measurement of heat content or energy

Battery Electric Bus Selection

BLUE BIRD

Standard Battery: 155 kWh
Operating Range: 120 miles
Battery Type: Li-NMC-G
Charge Options: AC Level 2&3
Drive Train: Cummins
Price Range: $250 – $350k

THOMAS BUILT

Standard Battery: 226 kWh
Operating Range: 138 miles
Battery Type: Li-NMC-G
Charge Options: AC Level 2&3
Drive Train: Proterra
Price Range: $325 – $400k

IC BUS

Standard Battery: 210 kWh
Operating Range: 155 miles
Battery Type: Lithium-ion
Charge Options: AC Level 2&3

Optional 315 kWh Battery
Optional diesel heater
Price Range: $325 – $400k

LION

Standard Battery: 126 kWh
Operating Range: 100 – 155 miles
Battery Type: Li-NMC-G
Charge Options: AC Level 2&3

Optional 168 kWh Battery
Optional 210 kWh Battery
Price Range: $340 – $370k

Each school bus manufacturer has a different bus battery and charge configuration that they offer. Wendel analyzed four manufacturers and bus types based on the existing routes to determine performance of each bus configuration.

Wendel evaluated the Blue Bird, Thomas Built, IC Bus, and Lion battery electric buses based on their available battery sizes, vehicle to grid capabilities, and existing relationship with the district. Sweet Home school district currently utilizes Blue Bird (17 buses) and Thomas Built (41 buses) for a majority of their fleet. Wendel utilized the 220 kWh Thomas Built Jouley (see appendix for cutsheets) as the basis of design due to larger battery size which better accommodate the longer routes, potential for vehicle to grid capabilities, and existing relationship with the district. For routes which require more than the 220 available battery capacity, Wendel utilized the IC 321 battery electric bus. This manufacturer had the largest battery capacity and overall range of the bus. The specific bus types and quantities will be shown in the charge modelling section of the report.

Conceptual Charging Study

CONCEPTUAL CHARGING STRATEGY

Wendel developed a conceptual charging strategy for the fleet based on the bus route data collected and the route analyses developed in previous tasks. The goal of the conceptual charging strategy is to determine the smallest available battery size that meets the district's route needs. The charging strategy identified the following items:

- Number, types, and sizes of chargers required to charge the fleet in the allotted time frames – assuming a low limit of 15% state of charge and upper limit of 90 % state of charge
- Anticipated peak demand during both on-peak and off-peak utility periods
- Optimum charger size and configuration – 1 to 1 or 1 to many chargers to dispensers

Charging Model Development Process:

An overview of the process Wendel utilized for the charging strategy modelling process is shown below:

Step 1	Analyze the route data and organize the data into numerical vales that represent the times at which each bus that serves the associated route would depart and arrive at Sweet Home for a standard week.
Step 2	Develop a model reflecting when all buses (56) **arrive and depart** Sweet Home over a 5-week period of time with additional 15 minutes to pull into the bus garage before it starts charging and additional 15 minutes required to get off the charger early before leaving Sweet Home.
Step 3	Develop a model reflecting bus **charge hours** for each hour of a 5-week period of time. This shows how many hours the bus has left to charge at any hour.
Step 4	Develop a weekly model reflecting the **battery state of charge** throughout the 5 weeks. The 5-week period of time utilizes weather data for a colder month to simulate a worst case scenario.
Step 5	Develop a 5-week model utilizing the state of charge model to reflect the charging of the battery throughout the week. This model shows the charging **impact on the battery** each hour throughout the 5-week period.
Step 6	Develop a 5-week model utilizing impact on battery model to reflect the **impact on the facility (Facility Demand)** while charging. This model utilized a table of charging efficiencies to convert the impact on the battery to the actual impact on Sweet Home school district.

Battery Electric Bus Requirements

Wendel determined that all routes provided by the district could be driven by 56 buses (67 buses in the current fleet, 11 buses spare capacity). Using the route information and energy usage rates, Wendel created several models which determined the battery life at each hour throughout the month (using the least efficient time, a winter month), the amount of charge delivered to the bus batteries for each hour throughout the month, and amount of charge delivered from the district for each hour throughout the month. From these models Wendel was able to confirm the quantity and types of bus required. Wendel confirmed that 51 of the buses could be driven by the 220 kWh Thomas Built Jouley battery electric bus. Five buses have battery capacity requirements in excess of 220 kWh and would need to utilize the larger 321 kWh IC Bus, which is the only bus that meets the necessary capacity requirements. The five routes that required the larger IC Bus are shown below:

Routes Requiring 321 kWh IC Buses											
Line #	AM/ PM	Bus #	Total Duration (Hrs)	Distance AM (Miles)	Max Energy (kWH)	AM/ PM	Total Duration (Hrs)	Distance PM (Miles)	Max Energy (kWh)	Total Distance Miles	Total Energy (kWh)
31	AM	117	2.1	42.8	199.1	PM	1.9	36.7	178.3	79.5	377.4
35	AM	119	2.0	36.4	146.3	PM	2.8	47.3	208.0	83.8	354.4
63	AM	135	2.2	40.4	173.6	PM	2.9	46.3	191.5	86.6	365.1
93	AM	251	2.9	62.4	275.1	PM	3.1	62.6	285.8	124.9	560.9
108	AM	205	1.0	33	130.1	PM	2.9	63.2	270.6	96.2	400.7

Electric Vehicle Charger Requirements

The charging strategy focuses on charging for long periods of time at low charging speeds. The model shows the batteries' charging rate based on the duration of time to charge. The maximum single bus charging rate for any hour throughout the winter month was 92.5 kW. Some chargers can modulate below 10%, but the charging time required would be excessive. A minimum charging rate of 6kW (60 kW charger) would take roughly 36 hours to fully charge a Thomas Built Jouley. A breakdown of the charging requirements is shown below:

- 7 Buses charge over 60 kW
- 11 Buses charge over 30 kW
- 14 Buses charge over 20 kW
- 24 Buses charge under 20 kW

The breakdown above shows the variety of chargers that could be utilized by Sweet Home school district to charge their school bus fleet. Wendel only used two charger sizes to reduce the operational impact on the school district when transitioning to battery electric buses.

The models provide additional insights on the charger infrastructure required when converting to BEB's. Although many buses do not require a DC fast charger, the basis of the model utilized Proterra "fast" chargers which can charge up to 60 kW and are vehicle to grid capable.

The charging model shows that (7) of the routes have charging requirements above 60 kW and would need to utilize 120 kW Proterra chargers. The maximum number of buses charging at any one hour is all 56 buses, meaning Sweet Home would need the ability to charge all 56 buses simultaneously.

Basis of Design

- 62 – 220 kWh Thomas Built Buses & 5 – 321 kWh IC Buses
- 60 – 60kW Proterra Chargers (Cut sheets provided in appendix)
- 7 – 120 kW Proterra Chargers (Cut sheets provided in appendix)

Alternative

Wendel's basis of design utilized a 1:1 ratio of chargers to buses, primarily for operational efficiency and flexibility. There are 24 buses that charge under 20 kW. An alternative to the base charging strategy would be to utilize 2:1 charging for applicable buses. This would enable simultaneous charging of two buses at a maximum charge rate of 30 kW, thereby reducing the number of overall 60 kW chargers. There would still be a need for dedicated 60 kW chargers (1:1) for some buses. This alternative does not remove the need for the 120 kW chargers for buses running long routes. The charger count under this alternative would be:

- 11 – 60 kW Proterra Charger (1:1 charging)
- 25 – 60kW Proterra Chargers (2:1 charging)
- 7 – 120 kW Proterra Chargers

This alternative would reduce the upfront capital costs (from chargers only) by approximately $3,126,069.

Sweet Home can elect to purchase chargers from other manufacturers, such as ABB, Siemens, ChargePoint and others. Wendel is recommending the Proterra 60 kW chargers for the following reasons:

1. The Thomas Built Bus utilize a Proterra drive train and battery system. Although not required, it is recommended that Proterra chargers be used with the Proterra batteries. This will limit issues between the bus manufacturer and the charger manufacturer if problems should arise during start-up and operations.
2. The Proterra 60 kW charger is the only Proterra charger that is V2G capable at this point in time.
3. Other charger manufacturers have chargers comparable to the Proterra 60 kW charger and can be utilized if desired.

There are some disadvantages to going with this alternative and they include:

1. Using a 60 kW charger in a 2:1 configuration limits V2G capability.

2. Operations challenges arise from 2:1 charger configurations due to the need for certain buses to be parked in specific parking spots (Based on charger configurations: 1:1 vs 2:1).
3. Charger failure affects two buses. If a charger that is configured in a 2:1 configuration fails, two buses would fail to charge.

Demand Impact

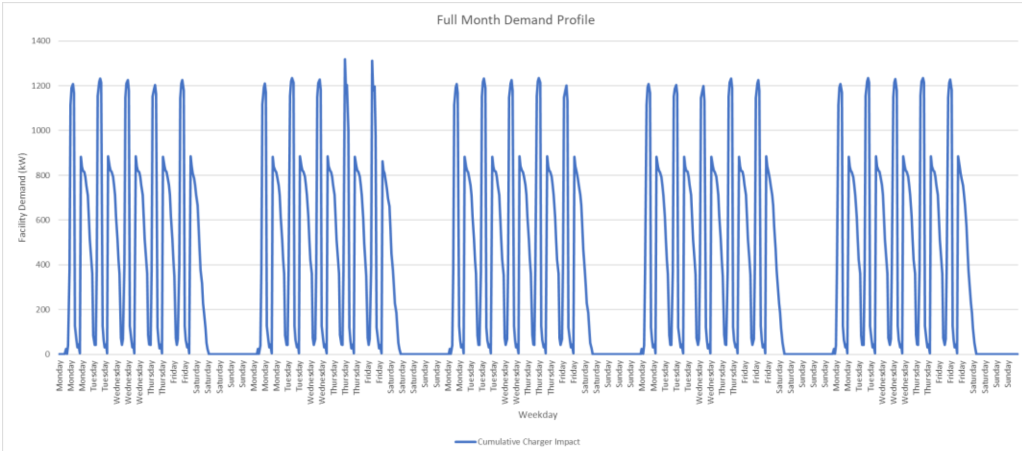
Demand is the power draw from the utility at any one point in time, measured in kW. Peak demand is the maximum demand required from the utility, during the utilities peak demand period, over a one month period and is also measured in kW. The peak demand is the cumulative demand of all loads connected to the utility transformer.

Not all buses will need a maximum charge rate from the charger to reach a full charge in the available time frame. Charging a bus at a reduced charge rate increases the life of the battery and reduces overall demand on the utility system. Demand reduction is evaluating the state of charge when the bus arrives back at the garage and determining the minimum charge level required to charge the bus in the allotted time, to ensure the bus is adequately charged when it needs to begin a new route. If this is done with every bus in the fleet, the overall utility demand will be greatly reduced, reducing utility demand charges and extending the life of the batteries.

The maximum demand from bus charging when all 56 buses are converted to battery electric buses during the coldest month (Least efficient month) is 1,319.22 kW which occurs at 10:00am on Thursdays. Wendel expects that an average months monthly demand would be roughly 850 kW which is 35% lower than the coldest month.

Coldest Month Demand with Charging Strategy	
Time	**Peak**
Thursday 10:00 am	1,319.22 kW

The overall demand profile shows the projected impact for each hour over the five-week period. The goal is to flatten demand as much as possible. A graph showing the demand profile over the entire month is shown below:



Charge Management

Charge management[1] is an essential part of a successful battery electric bus transition plan. Charge management will manage charging operations and energy management. An ideal charging strategy focuses on charging for long periods of time at low charging speeds while ensuring the buses are sufficiently charged to complete their routes. Lower charging rates help to keep a more consistent demand profile, a lower peak demand and longer battery life. Additional strategies like “on” and “off” peak charging can be added into the charging strategy as well to minimize the cost impact on the district.

A charge management system is a software system that provides real time demand reduction analysis and automatically manages the fleet of chargers based on each of the buses needs. Charge management systems utilize bus telemetric data, route data, and battery data to perform its analysis. Today’s systems can limit the overall utility demand to preset limits, based on the power distribution systems designed for charging.

Charge management systems are available through independent third-party suppliers, such as Mobility House, SYNOP, and BP Pulse. Some bus manufacturers such as Proterra also sell charge management systems.

Wendel strongly recommends implementing a charge management system for managing charging operations and energy management. Wendel has assumed charge management within the calculations, and it has been incorporated into the charging model.

Vehicle to Grid

[1] Charge Management System – end to end software solution to manage EV charging operations & energy management.

Wendel analyzed the periods when a bus is parked at the school and connected to the charger. Wendel evaluated the amount of time the bus must charge, the amount of charge required for the next route and the amount of energy that could be sent back to the grid, “Vehicle to Grid” while leaving enough energy for the buses to complete their next route.

Although vehicle to grid is the concept of sending extra power back to the utility, the optimal strategy for Sweet Home would be to send the available power to other buses (use the extra power on site – V2V). Using the extra power on site is more useful than sending it back to the grid because there is currently no time-of-day rate arbitrage opportunity[2], and significant savings can be recognized from demand savings.

By utilizing the extra available power from the battery electric buses to charge other buses, the overall demand profile can be reduced. Wendel calculated the cost per kW (specific to service class 3) which is $11.79 along with the V2G/V2V demand profile to get the projected monthly savings by implementing this strategy. The modelled energy that could be sent back to other vehicles and the associated cost savings are shown below:

Projected Monthly Savings		
Energy (kWh) Per Month (V2G/V2V)	Monthly Peak Demand Savings	Monthly Project Cost Savings
30837.08 kWh	297.53 kW	$3,507.92

Overall, Wendel is not recommending vehicle to grid or vehicle to vehicle charging strategies today due to the low revenue impact, lack of current incentive programs, the high design complexity, and high capital cost. With that said, there are several components of implementing V2G/V2V strategies such as having the proper charger hardware, charger V2G software, and having the proper electrical distribution infrastructure and utility feeds. Wendel recommends Sweet Home school district to purchase the charger hardware that is V2G/V2V capable, but not the software currently. This will allow Sweet Home to be prepared to efficiently deploy V2G/V2V when opportunities are more economically feasible.

It should be noted that the current utility incentives for V2G capability is based on existing utility tariffs for distributed generation. These tariffs are not the best structure for incentivizing V2G capability. The utilities in NYS are working with the NYS Public Service Commission to develop new V2G tariffs that will provide more benefit for this capability. The current thinking is that as electrification continues in the state, there will be more pressure on the utility grid at various times during the day. Having the capability to tap into connected batteries on the grid, V2G would enable the utility to ride through system events. This type of tariff would be economically favorable to V2G participants. National Grid, the utility serving Sweet Home, anticipates having a V2G tariff negotiated with the Public Utility Commission within the next twelve to eighteen months.

[2] Time of day rate arbitrage: The ability to buy power at off peak times and sell power back to the utility at a higher price during peak times.

Utility Analysis

ELECTRIC UTILITY ANALYSIS

Sweet Home CSD receives power from National Grid. The Sweet Home CSD site is fed from National Grid distribution feeder 36_03_22457 which is a 13.2 kV primary feeder rated at 7.48 MW. According to National Grid, the current feeder has approximately 3.93 MW of headroom, which indicates capacity available for EV charging on that feeder.

Based on the load profile developed as part of this study, the total connected [1] charger load at Sweet Home CSD at full battery electric bus implementation would be 4.662 MVA with an anticipated peak [2] demand load of 2.394 MVA.

Wendel is awaiting the full report from National Grid but they has completed the feeder study and have confirmed they can provide the anticipated power for the project. Per meetings with the utility on site on July 18, 2023, the power will be fed from the primary feeder on Sweet Home Road. The project will require installation of a new switch pole and 2500kVA pad mount transformer.

The project is in design with National Grid currently and will take up to three (3) additional weeks to complete. Once design is completed, the utility will provide an estimate for the project. In the meantime, Wendel has worked with the internal estimating team to provide an estimated allowance for the proposed work on from the utility. Wendel estimated the cost of the utility work while awaiting the estimate from National Grid. The cost of the utility work is anticipated to cost about $225,000. This estimate assumes adequate capacity at the pole location. Sweet Home can utilize the National Grid's Make Ready Program for incentives to assist in utility side infrastructure upgrades. The Make Ready Program incentives may cover up to 90% of the utility infrastructure upgrade costs.

[1] Connected load is the total load physically connected to the system and may be different than operating load

[2] Peak Demand is the anticipated maximum energy demand on the system

Electric and Diesel Utility Analysis

Wendel reviewed the electric and diesel utility information provided by Sweet Home school district in order to present accurate economics associated with their battery electric bus transition. Wendel utilized an average blended electric rate of $.13495/kWh and a diesel rate of$3.64/gallon. Charging is $137,903 less expense than fueling per year.

Support rate information is shown below:

Invoice Charge Detail							
Sub Group	Usage (kWh)	Commodity	CES	Mgmt	Total Supply	Utility Passthrough	Total Invoice
Sweet Home CSD	508,759	$65,254.34	$2,895.90	$508.77	$68,659.01	$0.00	$68,659.01
Sweet Home CSD Total	508,759	$65,254.34	$2,895.90	$508.77	$68,659.01	$0.00	$68,659.01
Rate ($/kWh)		$0.12826	$0.00569	$0.00100	$0.13495	$0.00000	$0.13495

Sweet Home CSD Fuel Costs				
Date	Gallons	Unit Price	Cost	Provider
12/14/22	7,504	3.0503	$22,889.45	Kurk Fuel Company
11/2/22	7,504	4.8623	$36,486.70	Kurk Fuel Company
9/26/22	6,500	3.6363	$23,635.95	Kurk Fuel Company
8/10/22	8,504	3.5716	$30,372.89	Kurk Fuel Company
4/12/22	6,512	3.7647	$24,515.73	Kurk Fuel Company
2/23/22	8,004	3.0394	$24,327.36	Kurk Fuel Company
2/27/22	4,392	2.3334	$10,248.99	Noco
8/15/88	1,303	4.0100	$5,225.08	Amherst Highway
7/22/22	4,889	4.6000	$22,930.10	Amherst Highway
TOTAL	**55,112**	**3.6404 average**	**$200,632.25**	

Concept Development & Phasing Plan

CONCEPT DEVELOPMENT & PHASING PLAN

The concept development and phasing plan is the culmination of the previous tasks in the study. The phasing plan incorporates several components and include:

1. Deadlines issued as part of the state mandate including:
    a. By July 1, 2027 all new school buses purchased and or leased must be zero-emission
    b. By July 1, 2035 all school buses on the road must be zero-emission
2. Sweet Home Central School District's preferred battery electric bus procurement schedule
3. On-site electrical distribution/charger equipment procurement and construction lead times
4. Utility service upgrade equipment and construction lead times
5. Availability of capital funding including state aide, school capital programs and grant funds

For the purposes of this report, we are assuming the following:

- The state mandated deadlines pertaining to zero-emission school buses will be upheld by the state.
- Funding will be available when required for capital improvements and bus purchases.

Sweet Home Bus Procurement Schedule

Sweet Home CSD currently has 67 diesel school buses. The projected battery electric school bus (BEB) procurement schedule for Sweet Home CSD is depicted in the following table:

Sweet Home CSD Anticipated Battery Electric Bus Procurement Schedule

	Existing	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	Total
Battery Electric Buses Procured	0	0	3	8	9	9	8	6	6	6	4	4	4	0	0	0	0	0	0	67
Battery Electric Bus Fleet Size	0	0	3	11	20	29	37	43	49	55	59	63	67	67	67	67	67	67	67	67

This proposed BEB procurement schedule is subject to change based on available funding.

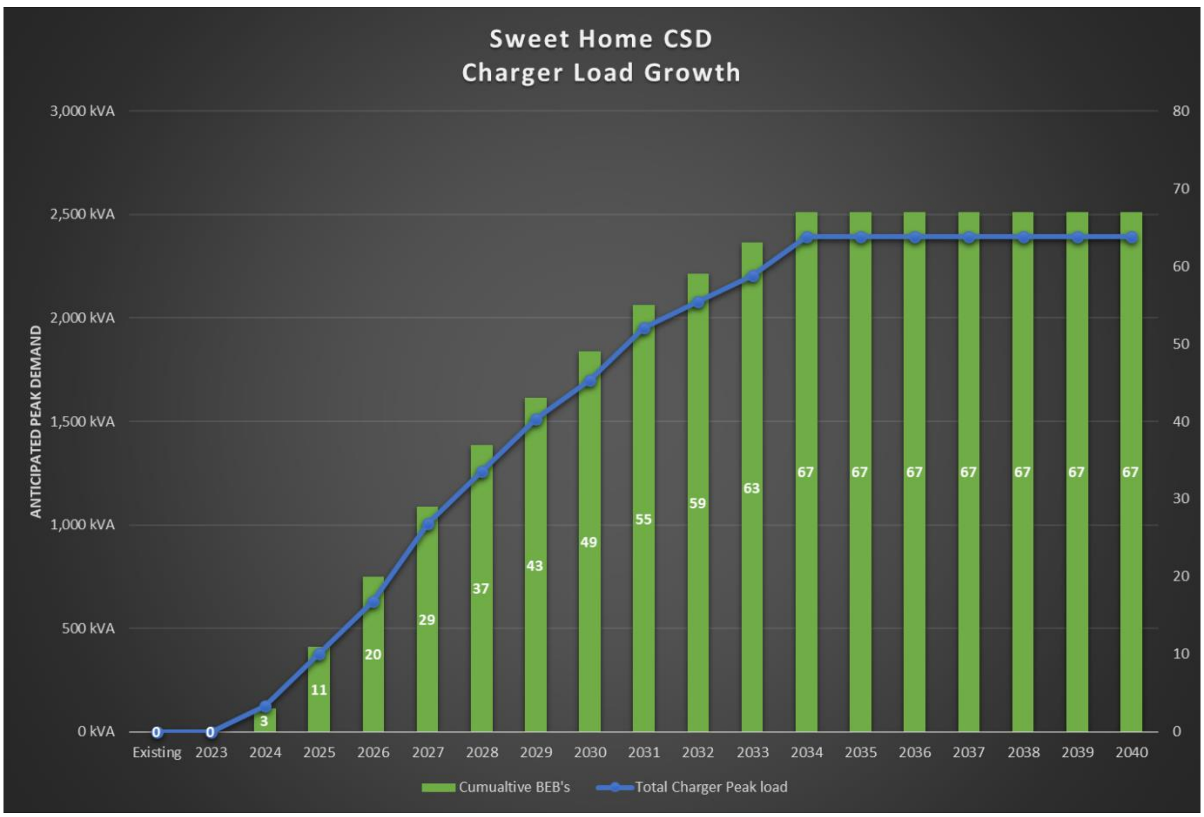
Sweet Home CSD anticipates procuring their first 3 BEBs through the NYS Truck Voucher Incentive Program (TVIP) in 2023 with delivery in mid to late 2024. The district has also applied for grant funding for additional school buses through the EPA 2023 Clean School Bus (CSB) Grants Program.

The proposed battery electric bus procurements will include a mix of different battery sizes. The majority of the fleet (62 out of the 67 proposed BEBs) will have 220 kWh batteries and the remainder of the fleet (5 out of the 67 proposed BEBs) will have 321 kWh batteries.

Wendel recommends 60 of the 220 kWh BEBs utilize 60 kW chargers, and two (2) will utilize 120 kW chargers. Wendel recommends 5 – 321 kWh BEBs utilize 120 kW chargers. The proposed procurement plan calls for one charger per BEB resulting in 60 – 60 kW chargers and 7 – 120 kW chargers.

Based on the proposed procurement schedule, the route analysis and the charging strategy developed for Sweet Home CSD, the projected charger load growth over time is as follows:

Sweet Home CSD Charger Load Growth



Phasing Plan

The proposed phasing plan for Sweet Home CSD consists of four phases, each phase building upon the previous phase. Equipment layouts for each of the four phases are included in Appendix E of this report.

Temporary Charging Phase – Phase 0

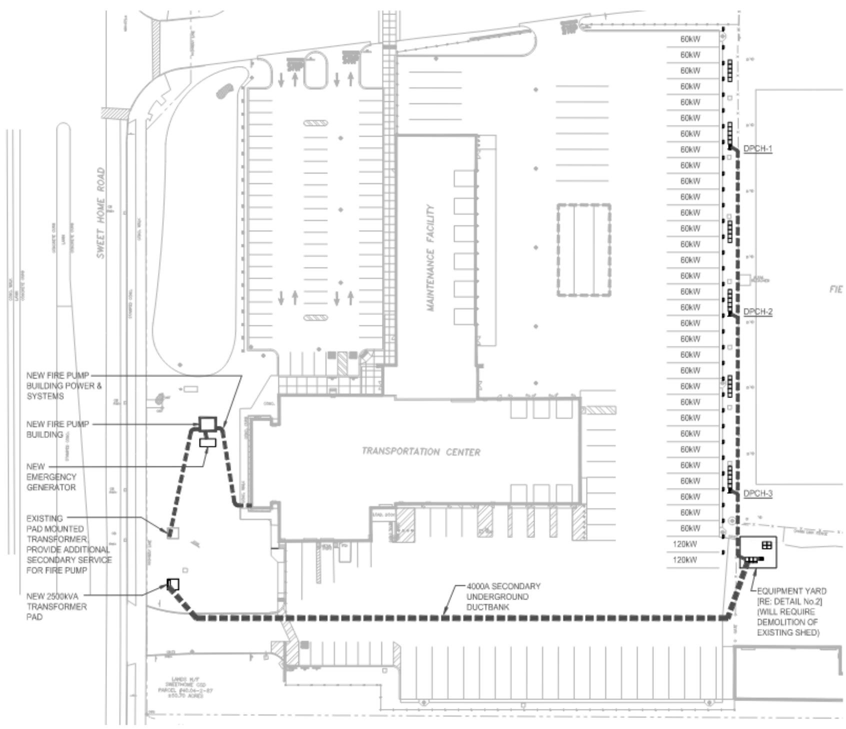
Phase 0 is the temporary charging phase for the three TVIP buses that are anticipated to be in use for the 2024 – 2025 school year. Adequate electrical distribution is not available for this temporary phase and the chargers need to work with the existing 208V electrical infrastructure. This phase requires a new 400A panel board and 150 kW FreeWire Charger, which limits the demand on the facility. This infrastructure will allow for the temporary charging of the three buses until the permanent infrastructure is implemented in Phase 1. The infrastructure implemented in this phase will be useful for additional capacity in the maintenance area once temporary charging is no longer required.

Costs

- Temporary charging infrastructure for Phase 0: **$960,960**

Phase 1

Phase 1 is the most robust of the four phases and incorporates several components necessary for the overall site development.



Phase 1 Implementation

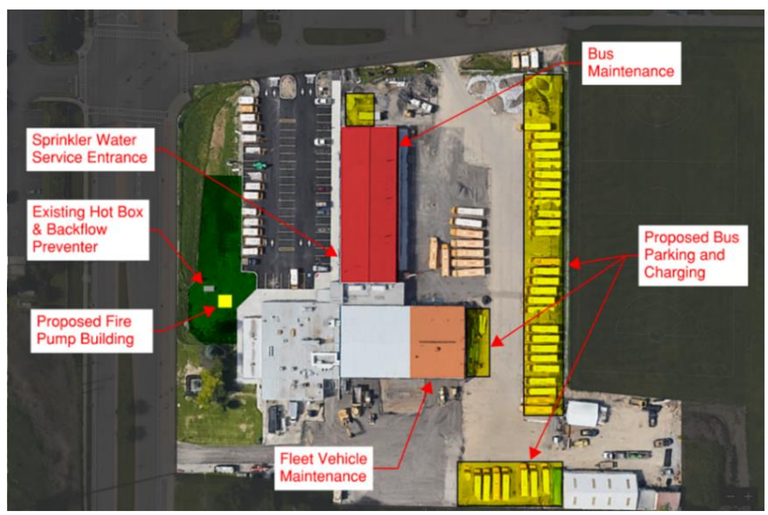
New National Grid primary transformer – The battery electric bus charging infrastructure for Sweet Home CSD should be powered through a new utility service feed from National Grid. The proposed location for the new transformer and service is on the side of the entrance to the Transportation Center Parking Lot from Sweet Home Road as seen on the Phase 1 Implementation layout in Appendix E of this report.

New power distribution equipment – The existing storage shed at the southeast corner of the Transportation Center Parking Lot is to be demolished to allow for the development of an electrical equipment area. This area will then be used for switchgears, switchboards and charging equipment which will be utilized throughout the remaining phases of the infrastructure development.

Primary cable trench from new service to power distribution equipment – An underground duct bank should be installed from the new National Grid transformer to the new electrical distribution equipment.

Power feeds and charging equipment for up-to 34 new chargers – New power feeds should be installed along the eastern property line between the new maintenance facility and the practice field. Thirty-two 60 kW chargers and two 120 kW chargers should be installed along the existing bus parking spaces on the eastern side of the lot.

Fire protection system upgrades Upgrades to the fire protection systems in the maintenance facility should be performed to increase protection against battery electric bus fires. These upgrades should include a new fire pump, back-up generator and new fire protection piping in the maintenance facility. The proposed fire pump would be located near the existing Hot Box & Backflow Preventer on the western side of the property between Sweet Home Road and the maintenance facility.



Fire protection upgrades

Costs

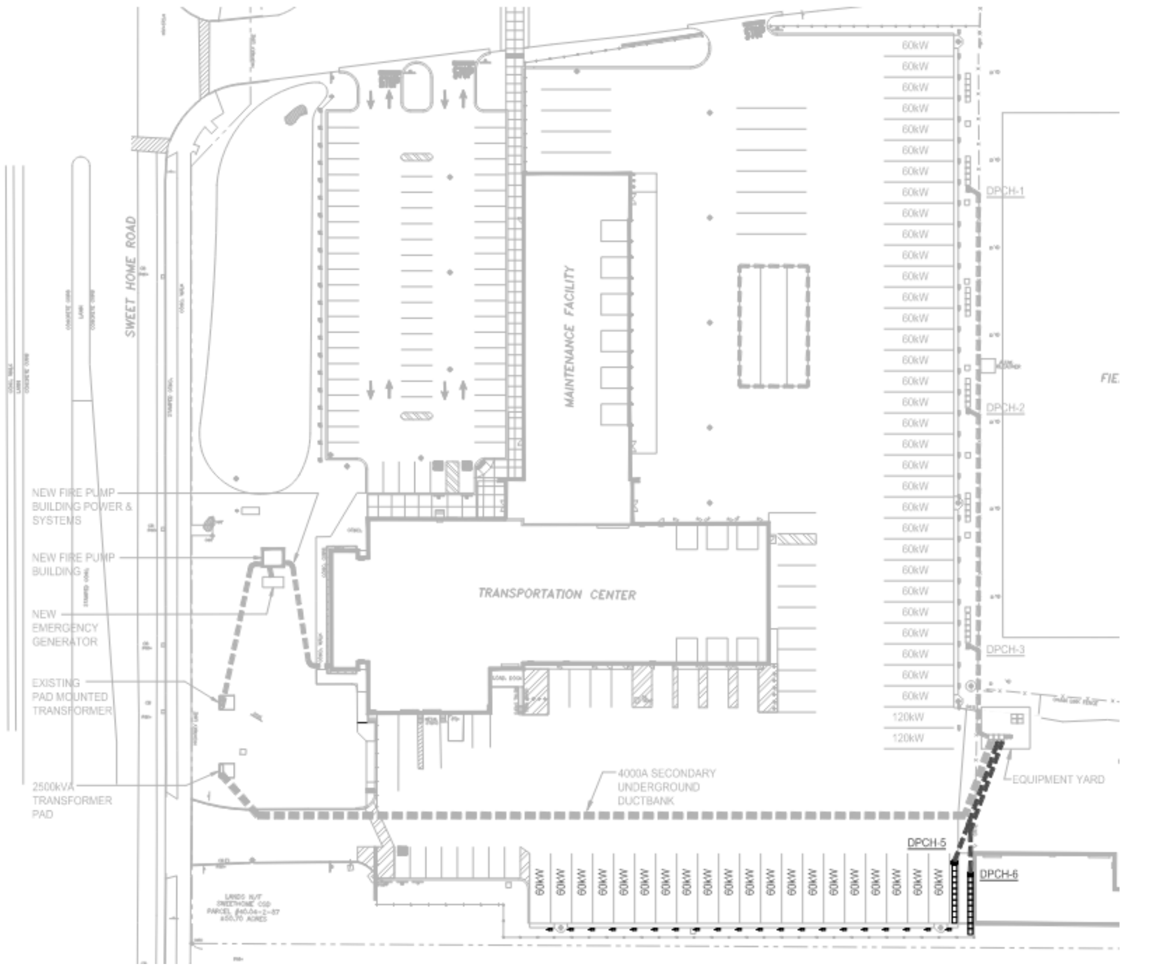
- Charging system infrastructure for Phase 1: **$4,258,274 - $4,706,514**
- Fire protection system upgrades for Maintenance building: **$984,026**
- **Total Phase 1 estimated cost: $5,242,300 - $5,690,540**

Detailed cost estimates are included in the appendix.
Cost estimates do not include bus purchases.

Phase 2

Phase 2 of the proposed phasing plan includes the procurement and installation of an additional 20 chargers, bringing the total number of bus charging positions up to 54.

Power feeds and charging equipment for up-to 20 new chargers – New power feeds should be installed along the southern property line. Twenty 60 kW chargers should be installed along the existing bus parking spaces on the southern side of the pavement.



Phase 2 Implementation

Costs

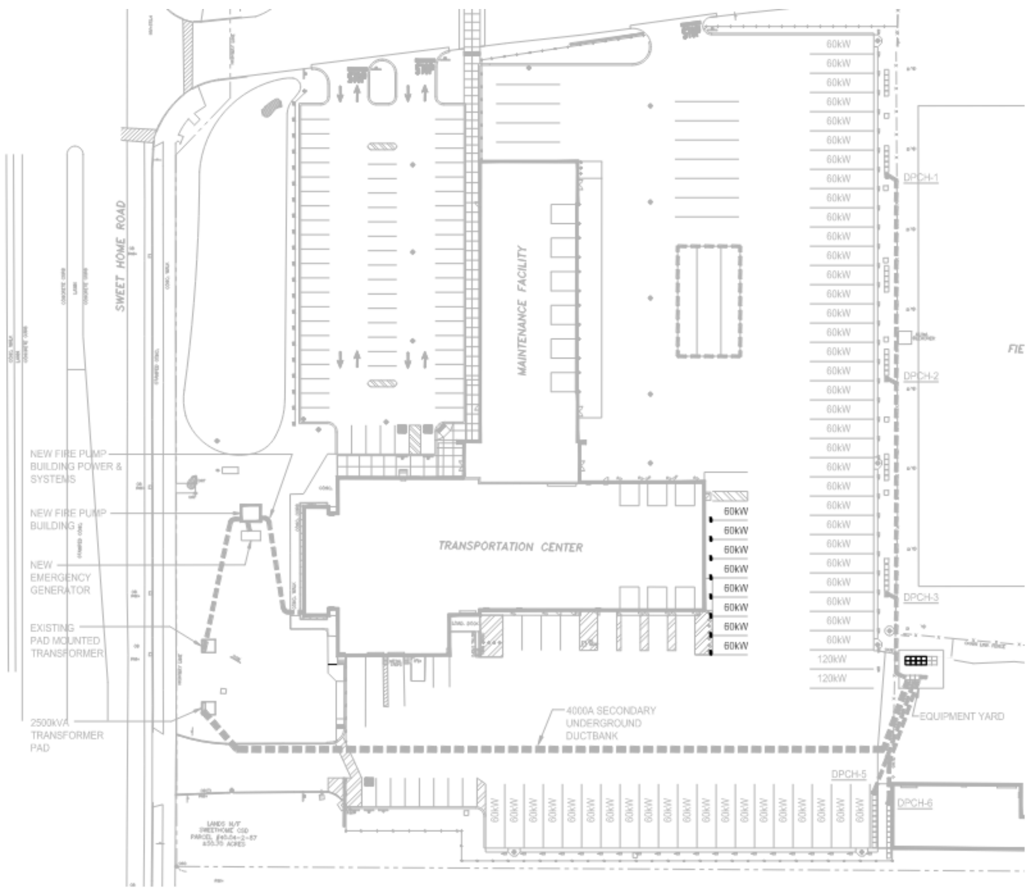
- Charging system infrastructure for Phase 2: **$2,123,152 - $2,346,641**
- **Total Phase 2 estimated cost: $2,123,152 - $2,346,641**

Detailed cost estimates are included in the appendix.
Cost estimates do not include bus purchases.

Phase 3

Phase 3 of the proposed phasing plan includes the procurement and installation of an additional 8 chargers, bringing the total number of bus charging positions up to 62.

Power feeds and charging equipment for up-to 8 new chargers – New power feeds should be installed along the eastern wall of the maintenance facility. Eight 60 kW chargers should be installed along the existing bus parking spaces on the eastern wall of the maintenance facility building.



Phase 3 Implementation

Costs

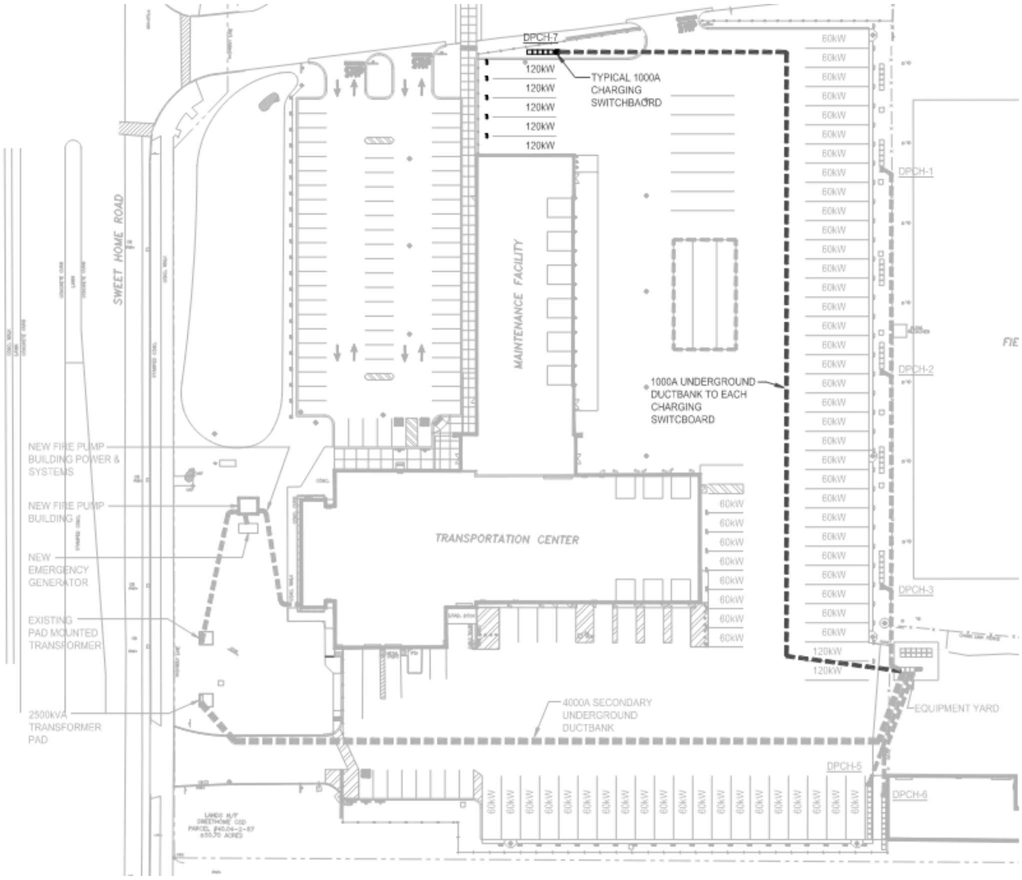
- Charging system infrastructure for Phase 3: $796,888 - $880,771
- **Total Phase 3 estimated cost: $796,888 - $880,771**

Detailed cost estimates are included in the appendix.
Cost estimates do not include bus purchases.

Phase 4

Phase 4 of the proposed phasing plan includes the procurement and installation of an additional 5 chargers bringing the total number of bus charging positions up to 67.

Power feeds and charging equipment for up-to 5 new chargers – New power feeds should be installed North of the maintenance facility. Five 120 kW chargers should be installed along the existing bus parking spaces.



Phase 4 Implementation

Costs

- Charging system infrastructure for Phase 4: $1,112,283 - $1,229,365
- **Total Phase 4 estimated cost: $1,112,283 - $1,229,365**

Detailed cost estimates are included in the appendix.
Cost estimates do not include bus purchases.

Total Costs for all four phases: $10,235,583 - $11,108,277

__Notes regarding Phasing Plan__

1. Phasing plan costs assume all equipment included in that phase are purchased and installed at the same time. Sweet Home CSD may elect to purchase and install all equipment except the chargers/dispensers and install chargers and dispensers as buses are purchased.
2. Other than the common equipment installed in Phase 1, the sequence of the installation of chargers can be modified. For example, Sweet Home CSD could elect to go to Phase 4 following Phase 1.
3. Sweet Home CSD has a fleet of 67 school buses. The district typically runs 56 buses on regular routes with 11 buses in reserve. Based on the usage of the fleet Sweet Home CSD could elect to modify the phasing plan as follows:
    a. Phase 2 brings the total fleet electrification up to 54 buses. Phase 3 could be optional or delayed until all reserve buses are retired from service or 2035.
    b. Phase 4 would still be required as this phase adds the 120 kW chargers that would be necessary to charge the larger IC buses.

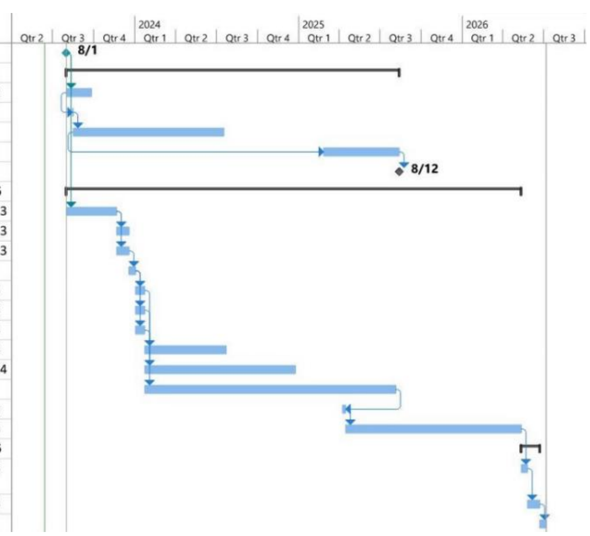
Schedule

A preliminary schedule was developed as a guide for the implementation of Phase 1 of the transition plan and potentially including the project into the District's next capital improvement plan. This preliminary schedule is heavily impacted by current supply chain issues associated with electrical equipment, particularly electrical switchgear. The current lead time for switchgears is estimated to be 20 months.

The preliminary schedule was created based on a start date for the project of August 1, 2023 and an estimated completion date of July 6, 2026 for Phase 1.

Phase 1 Preliminary Schedule

ID		Task Mode	Task Name	Duration	Start	Finish
1			Notice to Proceed	0 days	Tue 8/1/23	Tue 8/1/23
2			**Utility Service**	**531 days**	**Tue 8/1/23**	**Tue 8/12/25**
3			Utility Design	8 wks	Tue 8/1/23	Mon 9/25/23
4			Transformer Order	1 day	Tue 8/15/23	Tue 8/15/23
5			Transformer Delivery	12 mons	Wed 8/16/23	Tue 7/16/24
6			Utility Distribution Construction	6 mons	Wed 2/26/25	Tue 8/12/25
7			Utility Service Energized	0 days	Tue 8/12/25	Tue 8/12/25
8			**Site Design and Construction**	**725 days**	**Tue 8/1/23**	**Mon 5/11/26**
9			Phase 1 Detailed Design	4 mons	Tue 8/1/23	Mon 11/20/23
10			SED Review	4 wks	Tue 11/21/23	Mon 12/18/23
11			Bid Construction Package	4 wks	Tue 11/21/23	Mon 12/18/23
12			Award Construction Package	2 wks	Tue 12/19/23	Mon 1/1/24
13			Order Main Switchgear	3 wks	Tue 1/2/24	Mon 1/22/24
14			Order Switch Boards	3 wks	Tue 1/2/24	Mon 1/22/24
15			Order Chargers	3 wks	Tue 1/2/24	Mon 1/22/24
16			Charger Delivery	26 wks	Tue 1/23/24	Mon 7/22/24
17			Switch Board Delivery	12 mons	Tue 1/23/24	Mon 12/23/24
18			Switchgear Delivery	20 mons	Tue 1/23/24	Mon 8/4/25
19			Mobilization	1 wk	Tue 4/8/25	Mon 4/14/25
20			Construction	14 mons	Tue 4/15/25	Mon 5/11/26
21			**Start-Up and Commissioning**	**30 days**	**Tue 5/12/26**	**Mon 6/22/26**
22			Commission Switchgear and Switch Boards	2 wks	Tue 5/12/26	Mon 5/25/26
23			Commission Chargers	1 mon	Tue 5/26/26	Mon 6/22/26
24			Project Close-out	2 wks	Tue 6/23/26	Mon 7/6/26



Transition Plan Cost Estimates

(Not Included)

Operations & Maintenance Cost Comparison

OPERATIONS & MAINTENANCE IMPACT

The purpose of the operation and maintenance (O&M) and analysis is to identify, where feasible, changes in O&M costs as well as estimated energy costs for bus charging, fuel/diesel costs, and workforce training costs when switching from diesel school buses to battery electric buses.

Impact on Workforce

A properly trained workforce is essential to achieve Sweet Home's goal to transition to 100% battery electric buses by 2035. While many aspects of operating battery electric buses resemble existing practices, adapting to new battery electric systems will require adjustments to safety procedures, charging and fueling operations, and maintenance practices, as well as aspects of service management and depot operations.

Completing the transition to battery electric buses will require ongoing training and support to prepare and transition the Sweet Home facilities and operations staff. There are four major areas in which battery electric buses will change workforce knowledge and skill requirements: safety, bus maintenance, facilities maintenance, and operations.

Safety

Batteries on buses and charging equipment in depots are high voltage electrical systems that bring new safety requirements affecting maintenance, operations, and incident management. All staff need a baseline awareness and safety skill set. Wendel recommends Sweet Home engage in a service contract with bus/charger installers/vendors and incorporates several training sessions for their staff. See below for examples of safety training topics:

- Electrical Safety Training including high voltage training, lock-out tag-out procedures, and arc flash training
- Battery Technology and Handling Training
- Fire Safety Training
- First Aid and Emergency Response Training
- Vehicle Operation and Maintenance Training
- Hazardous Materials Handling Training

Training

- Arc flash training will be required after every phase. The cost of arc flash training ranges from $3,000 - $5,000 per training
- Bus manufacturer training is included in the cost of the bus and occurs upon commissioning of the buses
- Charger training is included in cost of charger
- Fire safety training – Fire protection training is provided by the contractor after the system is commissioned. The contractor will train staff directly on the equipment installed. This is standard and is included in the construction contract.

Bus Maintenance

Bus operators and service management staff will need awareness of battery electric bus components, how they might fail, and how to respond. Wendel recommends Sweet Home collaborate with vendor equipment manufacturers to allow for skills transfer to Sweet Home O&M staff. Standardized maintenance procedures for common battery electric bus repairs and diagnostics should be developed and incorporated into day-to-day operations.

In addition to normal maintenance, standard operating procedures should be developed for maintenance personnel in the event a battery electric bus is involved in an accident or returns to the depot with a battery alarm. Isolation of the bus, preferably outside, until the integrity of the battery can be confirmed should be part of the overall O&M standard operating procedures.

Facilities Maintenance

The installation of charging equipment and new power supply and distribution equipment is a significant expansion in the scale and complexity of facilities maintenance. New expertise will be required in troubleshooting and fixing charging equipment. This will require an expansion of existing facilities maintenance responsibilities and expertise. Close coordination with equipment manufacturers, installers, and hands-on troubleshooting will help Sweet Home manage this transition.

Operations

Charging requirements and range limitations mean new operational practices in various aspects of operations. Bus operators and managers will need to know how to deal with low-battery situations and incidents that may occur on the road as well as how to interface with charging infrastructure. Bus Fleet managers will need to understand how to coordinate charging operations to ensure buses are charged and available for the next day's service as well as which bus assignments are feasible for battery-electric buses to facilitate daily pull-out operations. Training is an essential component of a successful battery electric bus transition. See some example operational trainings below:

- Charging operations – Training would include training on any charge management system(s) as well as any bus analytics software. This would include interfaces with existing bus scheduling software to ensure proper scheduling of bus charging
- Low-battery management – Driver training is essential to the proper operation and optimization of battery electric buses. Part of the driver training should include driver training on low battery power management as well as operational procedures to handle a driver response to low battery issues while in route.
- Incident response – Procedures that are in place for existing diesel buses should be reviewed based on battery electric bus capabilities. For example, if an electric bus is involved in an accident, rather than pull the bus into a maintenance bay, an electric bus should be placed in a secure outside location due to the potential for fire risk related to a potentially damaged lithium ion battery.

O&M Costs

Battery electric buses are different than their diesel counterparts in that they do not have a traditional drive train. The following table provides a comparison of the bus components of a diesel bus and an electric bus:

COMPARISON OF ELECTRIC AND INTERNAL COMBUSTION ENGINE VEHICLE COMPONENTS

Common
EV Only
Changed for EV
ICE Only

Body System	Body
	Doors
	Windows
	Head/all Lights
Suspension System	Springs
	Shocks
	Air leveling
	Front axle
	Control arms
Brake System	Brake calipers
	Air compressor
	Reservoir
	Brake pedal
Steering System	Steering wheel
	Gearbox
	Power steering pump
	Steering arm
	Tie rod
	Hydraulic system
Climate Control System	HVAC compressor
	Blower
	Ducts
	Vents
	Heat pump
	Burner/heater
	Controls
Electrical/Power Supply System	Battery
	Generator/alternator
	Inverter
	Wiring
	Voltage/current monitors
	Distribution module
	Outlets/connections
Engine System	Engine
	Radiator
	Turbocharger
	Oil filter
	Coolant hoses
Gauge & Warning System	Instrument cluster
	System monitor sensor
	Display/HMI
	Alert buzzer
Communications System	Transponder
	PA system
	Tracking
Lighting System	Control panel
	Lights (interior, overhead)
Interior System	Seats
	Flooring
	Luggage storage
Public Interface	Display signage
	Advertising
Chassis System	Frame
	Body mounts
	Engine mounts
	Suspension mounts
Driveline System	Transmission
	Driveshaft
	Shifter
	Rear axle(s)
	Differentials
	Wheels
	Tires
Exhaust System	SCR catalyst
	DEF tank
	DPF canister
	Muffler
	Exhaust pipes
	Exhaust brake
Fuel System	Tank
	Pump
	Hoses
	Filter
	Separator
	Injector
Power Unit	Motors
	Drive reduction
	E-axle
	Battery
	Inverter
	Charger

Source: World Resources Institute: Electric School Bus U.S. Market Study and Buyer's Guide

The elimination of the engine system, exhaust system and fuel system reduce the maintenance requirements for a battery electric bus. Additionally, the changes to the driveline systems, including the elimination of the transmission, driveshaft and differentials, also reduces maintenance requirements. The brake system on an electric bus requires less maintenance as the dynamic braking available on an electric bus reduces wear and tear on traditional brake components and extends their life.

The addition of the power unit to replace some of the diesel engine components adds some complexity over a traditional diesel bus, but these are less maintenance-intensive components. After the upfront cost, electric school buses could save districts an estimated $4,000–$11,000 per school bus every year on operational expenditures like fueling, maintenance, and repair costs according to the World Resources Institute's Electric School Bus U.S. Market Study and Buyer's Guide[1].

Sweet Home CSD provided the O&M costs of their existing diesel fleet for items that are exclusive to non-zero emission school buses and will be avoided costs when considering the O&M of battery electric school buses. These costs are identified in the following table:

Diesel Bus	Parts	Labor Hrs	Labor $	Parts & Labor	# Over 10 years	10 Yr. Mainenance Cost
VGT	$ 1,400	5.0	$ 200	$ 1,600	1	$ 1,600
Turbo	$ 3,500	10.0	$ 400	$ 3,900	1	$ 3,900
Radiator	$ 850	3.0	$ 120	$ 970	1	$ 970
Exhaust System	$ 2,000	3.0	$ 120	$ 2,120	1	$ 2,120
Oil Changes	$ 120	0.5	$ 20	$ 140	20	$ 2,800
Gas Tank	$ 2,000	12.0	$ 480	$ 2,480	1	$ 2,480
Fuel Filters	$ 100	0.5	$ 20	$ 120	5	$ 600
Water Pump	$ 150	1.5	$ 60	$ 210	2	$ 420
Belt Tensioner	$ 150	1.5	$ 60	$ 210	2	$ 420
Belts	$ 40	0.5	$ 20	$ 60	2	$ 120
Coolant Tank	$ 150	2.0	$ 80	$ 230	1	$ 230
NOX sensor	$ 425	2.0	$ 80	$ 505	1	$ 505
D.E.F. Dosing Unit/ Gaskets/Isolators	$ 1,000	2.0	$ 80	$ 1,080	4	$ 4,320
D.E.F. Sending Unit	$ 2,000	4.0	$ 160	$ 2,160	1	$ 2,160
Alternator	$ 500	1.5	$ 60	$ 560	1	$ 560
Starter	$ 319	4.0	$ 160	$ 479	1	$ 479
Total O&M Diesel	**$ 14,704**		**$ 2,120**	**$ 16,824**		**$ 23,684**
# of Buses in the Fleet	**67**				**Total Fleet Cost**	**$ 1,586,828**
Assumed Labor Rate	$ 40					

Switching to an all-electric fleet at Sweet Home CSD would save approximately $1,587,000 over a ten-year period, or roughly $158,700.00 per year on these maintenance items through avoided cost. The balance of maintenance cost items between the two vehicle types are similar except for the battery pack on the BEB.

In addition to the maintenance associated with the bus fleet, there are additional maintenance savings associated with the fuel system. Wendel has assumed an estimated fuel system maintenance savings of $15,000.

The life of today's battery electric bus battery packs are impacted by the quantity and depth of charges and discharges, vehicle to grid (V2G) usage, as well as environmental impacts such as temperature variations and wear and tear. The local Thomas bus representative indicated that the standard warranty on the battery for the Thomas Built bus is 8 years, 175,000 miles. They state that the battery will have approximately 80% of its original capacity at that time.

[1] *dependent on labor costs, local electric utility rates, and petroleum fuels prices*

Sweet Home CSD has an average bus mileage of 11,400 miles per year, or roughly 91,200 miles over the warranty period. With an average life span of 12 years for a school bus, there will be a four-year period where the battery is outside of its warranty period and is in a state of capacity decline. Wendel would recommend transferring older school buses, greater than eight years old, to shorter routes as newer school buses are purchased. This would allow for an older battery to still have enough capacity to complete the shorter routes as its capacity declines.

It is possible that with this strategy Sweet Home CSD may be able to avoid replacing a battery during the life of a bus.

Replacement batteries have a cost of roughly $76,000. Wendel is recommending that an allowance should be set aside for battery replacement for roughly 10% of the fleet batteries or roughly six (6) battery replacements starting nine (9) years out from the purchase of the first bus.

In addition to the bus maintenance costs, battery electric buses also have maintenance costs for additional ancillary equipment such as chargers and dispensers for the bus. These costs vary by type and size of charger with smaller level 2 charger averaging yearly maintenance costs of $536 per charger and up to $2,000 per year for DC Fast Chargers. Proterra provided maintenance cost estimates for the 60 kW and 120 kW chargers at $1,000 to $1,500 per year per charger. This would equate to $67,000 per year for charger maintenance.

There are several options available to Sweet Home CSD for maintaining the charging infrastructure. These include the following:

1. Hiring or training school maintenance personnel on the power electronics and controls in a bus charger.
2. Contract with a local firm that can provide on-call support and annual maintenance services for charger infrastructure.
3. Contract with the charger manufacturer for the same service in 2 above.

If Sweet Home CSD elected to maintain the charging equipment with in-house personnel (option 1) Wendel would still recommend contracting for services for a period of one to two years with a service provider to allow for the new technicians to shadow the service provider as they get up-to speed on the charging equipment. This may not be necessary if the in-house maintenance person is already versed in power electronics and high voltage equipment.

Based on the above components, the O&M savings without fuel cost consideration is:

Maintenance Costs Diesel VS Battery Electric School Bus				
		10 Yrs		Annual
Bus Maintenance Savings	$	1,586,828	$	158,683
Fuel System Maintenance Savings	$	150,000	$	15,000
Battery Replacement	$	(354,667)	$	(35,467)
EV Charger Maintenance	$	(536,000)	$	(53,600)
Charge Management	$	(448,000)	$	(44,800)
Total Savings	**$**	**398,161**	**$**	**39,816**
Diesel VS Battery O&M Cost Difference **Per Bus**	**$**	**7,110**	**$**	**711**

Diesel Fuel Consumption

Sweet Home CSD provided fuel consumption data and costs for 47 diesel school buses for the period from September 8, 2022, through March 28,2023. Diesel fuel procurement records were also obtained. A fuel analysis was performed utilizing this data and can be found below:

Sweet Home CSD

Fuel Analysis from 9/8/2022 - 3/28/2023

DIESEL BUSES				DIESEL BUSES			
Vehicle #	Quantity	Total Miles	MPG	Vehicle #	Quantity	Total Miles	MPG
306	127	1,253	9.9	350	997	7,342	7.4
307	150	816	5.4	352	193	2,153	11.2
308	82	674	8.2	354	1,087	6,268	5.8
309	339	2,101	6.2	355	673	3,887	5.8
310	557	3,901	7.0	356	1,268	7,936	6.3
311	129	829	6.4	357	662	5,709	8.6
312	425	2,373	5.6	358	879	4,574	5.2
313	347	2,099	6.0	359	1,225	7,773	6.3
316	777	4,253	5.5	360	1,081	5,869	5.4
317	540	2,466	4.6	361	977	6,584	6.7
318	620	3,356	5.4	364	1,013	6,095	6.0
319	801	5,243	6.5	365	827	5,437	6.6
323	1,008	5,113	5.1	366	815	4,859	6.0
324	984	5,251	5.3	367	741	4,670	6.3
325	956	4,890	5.1	370	983	6,244	6.4
326	870	4,662	5.4	371	640	3,284	5.1
329	1,028	7,058	6.9	372	684	4,199	6.1
330	817	4,466	5.5	373	902	5,597	6.2
331	1,067	7,027	6.6	378	578	3,490	6.0
332	962	5,054	5.3	379	864	5,838	6.8
344	716	4,184	5.8	380	921	6,294	6.8
345	951	5,665	6.0	381	1,009	6,103	6.0
346	1,043	6,671	6.4	382	713	4,595	6.4
347	933	5,468	5.9	**Totals**	**35,955**	**219,673**	**6.1**

Sweet Home CSD
Fuel Costs

Date	Gallons	Unit Price	Cost	Provider
12/14/2022	7,504	3.0503	$ 22,889.45	**Kurk Fuel Company**
11/2/2022	7,504	4.8623	$ 36,486.70	
9/26/2022	6,500	3.6363	$ 23,635.95	
8/10/2022	8,504	3.5716	$ 30,372.89	
4/12/2022	6,512	3.7647	$ 24,515.73	
2/23/2022	8,004	3.0394	$ 24,327.36	
2/27/2023	4,392	2.3334	$ 10,248.99	**NOCO**
8/15/2022	1,303	4.0100	$ 5,225.08	**Amherst Highway**
7/22/2022	4,889	4.6900	$ 22,930.10	
Totals	**55,112**	**3.6404**	**$ 200,632.25**	

Sweet Home CSD's average fuel cost during the period analyzed was approximately $3.64 per gallon with a total of $200,632.25.

Utilizing the route data and route milage from the Route Analysis section, it was determined that the total route mileage of the 56 routes is approximately 640,673 miles per year. With an average miles per gallon of 6.1 mpg and an average cost of $3.6404 per gallon of diesel, the annual diesel fleet fuel cost for a typical school year is estimated to be $382,347.00.

Battery Electric Bus Charging (Electrical) Costs

Based on the results of the route and charging analysis, Wendel was able to calculate the annual electrical costs associated with charging the battery electric fleet at Sweet Home CSD. The route analysis used a worst-case scenario week by utilizing the week with the lowest temperatures out of the year to determine how the battery electric buses would perform. This best-case scenario usage uses roughly 50% less energy than the worst-case scenario usage. A summary of the route analysis energy costs can be found below. For the detailed analysis please refer the Route Analysis section of this report.

Utilizing the total route mileage of the 56 routes, estimated to be 640,673 miles per year, an average electrical efficiency of 2.83 kWh per mile, and a blended electric cost of $0.1350 per kWh, the annual fleet electric cost for a typical school year is estimated to be $244,444.00.

Fuel Cost Comparison/Savings

Based on the route modeling analysis and a review of the existing diesel bus performance, the switch to battery electric buses from diesel buses would save approximately 8,247.96 MMBtu of energy or a 57.16% reduction in energy consumption. This would also result in a reduction in energy costs of approximately $137,903.00 per school year.

56 Diesel Bus Energy Analysis		
Route Data	640,673	Miles
Bus Efficiency	6.1	Mpg
Total Gallons	105,028.35	Gallons
Energy Used	14,428.90	MMBtu
Diesel Cost	$ 3.6404	Per Gallon
Total Cost	**$ 382,347.00**	

56 Electric Bus Energy Analysis		
Route Data	640,673	Miles
Bus Efficiency	2.83	kWh/Mile
Total kWh	1,811,362.55	KWh
Energy Used	6,180.94	MMBtu
Electric Cost	$ 0.1350	Per kWh
Total Cost	**$ 244,444.00**	

Total O&M and Fuel Cost Savings

The total O&M and fuel cost savings for Sweet Home CSD is estimated to be approximately $177,719.00 annually, or roughly $3,174.00 per operating school bus. This analysis is based on a conservative BEB driving efficiency of 2.83 kWh/mile which is significantly higher than manufacturer standard efficiencies of 1.9 kWh/mile. Actual maintenance cost savings could be higher than the conservative estimate provided.

Maintenance Costs Diesel VS Battery Electric School Bus

	10 Yrs	Annual
Bus Maintenance Savings	$ 1,586,828	$ 158,683
Fuel System Maintenance Savings	$ 150,000	$ 15,000
Battery Replacement	$ (354,667)	$ (35,467)
EV Charger Maintenance	$ (536,000)	$ (53,600)
Charge Management	$ (448,000)	$ (44,800)
Fuel Savings	$ 1,379,030	$ 137,903
Total Savings	$ 1,777,191	$ 177,719
Per Bus	**$ 31,736**	**$ 3,174**

In conclusion, transitioning to battery electric bus fleet will have significant impact on the operations and maintenance practices for Sweet Home Central School District, and will yield operations cost savings. Wendel recommends Sweet Home School district invest in workforce trainings for safety and operational process training along with utilizing service contracts for bus and charger maintenance until the O&M staff have the proper knowledge to bring specialty talent in house.