BSOOB Transit SMART Grid Transition Stage 1 Implementation Report -

Recipient: Biddeford Saco Old Orchard Beach Transit
Year Awarded: FY22
Period of Performance: August 1, 2023- February 1, 2025
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Acronym	Definition	Acronym	Definition
AC	Alternating Current	ISO	Independent System Operator
AHJ	Authority Having Jurisdiction	ITC	Investment Tax Credit
BABA	Build America Buy America	IRA	Inflation Reduction Act
BEB	Battery Electric Buses	kVA	Kilovolt-Amps
BESS	Battery Energy Storage System	kW(h)	Kilowatt (-hour)
CMP	Central Maine Power	L2	Level 2 EVSE
CO2e	Carbon Dioxide Equivalent	L3	Level 3 EVSE
DCFC	Direct Current Fast Charger	MDEP	Maine Dept. of Enviro. Protection
DER	Distributed Energy Resource	MCC	Maine Climate Council
DOE	Department of Energy	MPUC	Maine Public Utility Commission
DOT	Department of Transportation	NEB	Net Energy Billing
EPA	Environmental Protection Agency	NPV	Net Present Value
EV	Electric Vehicle	NREL	National Renewable Energy Laboratory
EVCS	Electric Vehicle Charging Station	OEM	Original Equipment Manufacturer
GEO	Governor’s Energy Office	O&M	Operation and Maintenance
FTA	Federal Transit Authority	SLR	Sea Level Rise
GHG	Greenhouse Gas	SOC	State of Charge
GPCOG	Greater Portland Council of Governments	V	Volt

Part 1: Introduction & Project Overview

Project Description

Biddeford Saco Old Orchard Beach Transit (BSOOB) has begun the process of transitioning to an electrified transit fleet. As it continues to transition from fossil fueled buses to electricity, resiliency becomes an increasingly important consideration to maintain operations, particularly as Maine has continued to experience a greater frequency of natural disasters and power outages as a result[1]. Public transit is a core public utility, particularly during environmental disasters when other modes of transportation may be constrained. BSOOB was awarded a Stage 1 Strengthening Mobility and Revolutionizing Transportation (SMART) to conduct a feasibility assessment and a preliminary design of a depot microgrid. Utility outages in this region are significantly longer than most areas with a lasting impact on the community. The microgrid solution would support BSOOB's local fixed route fleet in the event of an extended power outage. The BSOOB microgrid design serves as an example for other transit agencies throughout the nation that are in the midst of electrifying transit fleets due to a combination of local regulatory requirements, a desire for reducing operating costs, and aiming to reduce air pollution in the communities they serve. They too will be subject to the same resiliency challenges that BSOOB faces. This project is intended to act as a model for other smaller transit agencies on how they can develop resilient zero-emission transit operations.

Smart Grid Technology

This project falls primarily under SMART's *Smart Grid* category and also includes project elements from intelligent sensors and system integration. The key technologies deployed for the proposed microgrid include:

- 450kW of solar photovoltaic panels and inverters
- 653kW/2611 kWh Tesla MegaPack Battery Energy Storage System & Controls
- 625 kW Natural Gas Generator & Controls
  Smart EVCS
  Microgrid Controller
- Data Analysis and software
- Smart Circuit Breakers
- Smart Relays
- Energy monitoring & metering
- Weather Station

The microgrid would support two (2) ABB HVC 150 power cabinets each with two dispensers and one (1) ABB HVC 360 power cabinet with 4 dispensers. This provides enough charging ports for up to 8 buses, though only 5 buses typically operate in a single day. When microgrid is capable of providing approximately one full day of backup based on typical operations of the existing transit service, without utilizing the natural gas generator. Actual backup duration will vary by season. Multiday backup without the generator is feasible in summer months when the daily solar PV generation exceeds the daily bus energy demand. For example, in 2029 when all buses are assumed to be electrified, the average daily load is 1.7 MWh in winter months (December through February), and 1.2 MWh in summer months (July and August). The average daily solar output is 1.3 MWh in the winter and 1.9 MWh in the summer. Assuming a worst case scenario when an outage occurs when the BESS was depleted and only charges from solar during the day, the battery capacity of 2.6 MWh could last BSOOB approximately 0.8 days in winter, meeting 80% of the average daily load, and 1.5 days in summer, meeting 150% of the average daily load.

[1] https://themainemonitor.org/weather-related-power-outages-on-the-rise/

BSOOB has historically experienced its longest outages in the winter months when solar production is low and bus charging load is high to meet heating needs. Since it is unlikely that the solar and BESS system alone could provide more than one day of full back up in winter months, a secondary generation source is required to guarantee multi-day resiliency. For this reason, a natural gas fired generator is incorporated to provide extended backup. The generator will only be used when the BESS is depleted to minimize the carbon emissions from operating the microgrid.

The microgrid includes new electronic breakers that function as control switches instead of traditional automatic transfer switches (ATS). The microgrid will also incorporate the maintenance facility into the EV service so it can be powered daily by the microgrid. BSOOB will continue to operate ICE transit commuter and trolley buses for at least the next 15 years. Providing reliable backup power to the existing maintenance facility will allow BSOOB to continue to operate, fuel, and maintain all of its fleet in the event of an outage. If an outage is widespread and other fleets in the region have lost power to their own fueling and maintenance facilities, this microgrid will allow BSOOB to act as a local community resource.

Building the microgrid will involve a significant upfront expense. The upfront capital cost of the microgrid is $9.3M, plus additional expenditure to replace some equipment at the end of their useful lives over the 20-year planning horizon. Potential Inflation Reduction Act (IRA) tax credits could reduce the upfront cost to roughly $7.5M, and over 20 years the microgrid is expected to provide an additional $13M in benefits through increased resiliency, reduced operating costs, and GHG emissions savings. These benefits allow the project to approximately breakeven after accounting for equipment replacement costs and a 7% discount rate to cover the cost of capital and risk premium (effectively the microgrid provides a 7% return on investment over 20 years).

The planned microgrid cost would also include additional charging infrastructure to better enable and provide backup for BSOOB's planned fleet electrification. All of these advantages that the microgrid will provide directly to BSOOB will also be compounded in sharing them with the local community. Public transit offers a range of significant benefits that enhance the quality of life, economic efficiency, and environmental sustainability in communities that can be sustained when resiliency is added to operations. Reliably maintaining operations becomes even more critical when individuals may have lost their primary modes of transportation during a disaster. BSOOB is obligated to provide additional support services in the event of a local natural disaster. During natural disasters, BSOOB may be expected to provide efficient and reliable transit operations that are crucial for evacuating residents, transporting first responders, delivering essential supplies, or providing other emergency services. By providing reliable transit even in emergencies, BSOOB can foster trust and demonstrates its commitment to community safety and well-being. This reliability is particularly critical for individuals without access to personal vehicles or for those that may have lost their personal vehicle during a natural disaster.

Community Impact

When implemented at scale, the microgrid will support BSOOB's overall transit operations. BSOOB Transit provides transit service in Biddeford, Saco, Old Orchard Beach, Scarborough, South Portland, and Portland; all part of the Metropolitan Statistical Area of Greater Portland. The population of these communities totals 170,000, with nearly 76,000 residents located within ¾ of a mile of a bus stop. BSOOBs service map is shown in Figure 1 and serves the following census tracts: 6, 10, 13, 15, 30.01, 30.02, 52, 53.01, 53.02, 61.03, 61.04, 61.06, 173.03, 173.05, 173.07, 173.08, 251, 252.03, 252.04, 252.06, 253, 254. Several of these census tracks are classified as Historically Disadvantaged Communities per the Climate and Economic Justice Screening Tool. The microgrid will support these Historically Disadvantaged Communities by helping BSOOB provide reliable transit service even when natural disasters create power outages.

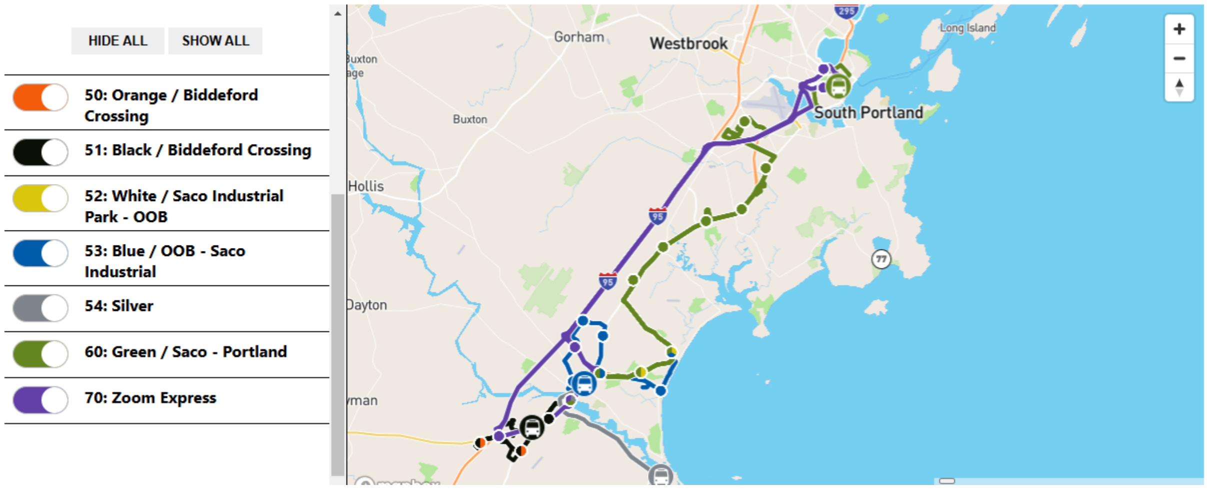


Figure 1. BSOOB Service Map

Community-Wide Impact and Resiliency

The impact of this microgrid will extend beyond BSOOB's own operations. BSOOB's bus depot currently acts as a significant maintenance hub for other fleets in the region, such as school districts and city support fleets. BSOOB has agreements in place to provide maintenance on these vehicles, both preventive and upon request.. As these surrounding community fleets begin to electrify their own vehicles, they too will need resilient charging infrastructure during outages. BSOOB's microgrid could be leveraged to support other public fleet vehicles in the event of extended outages to preserve critical community operations, especially medium and heavy-duty vehicles that are essential in community restoration activities post weather related events Coastal Maine is expected to see future sea level rise (SLR) of 4 feet by 2100, with storm surges requiring intermittent evacuation. BSOOBs bus depot is 100 feet above sea level and is unlikely to experience flooding from storm surges and therefore remain accessible to other fleets in the region if needed.

BSOOB has historically acted as a primary learning center for other local public agencies. BSOOB was the first fleet in the region to deploy heavy duty battery electric vehicles and has acquired many lessons learned on maintaining electric vehicle and charging infrastructure. Other fleets look to BSOOB for guidance on how to best incorporate new technologies. As BSOOB builds out its microgrid and incorporates new technologies into its operations, BSOOB will again act as a local knowledge base for other fleets that may want to incorporate distributed energy resources into their own future electric fleets.

Lastly, BSOOB's goal is not just to support its own transit fleet but to serve as a replicable model for other small urban and rural transit agencies on how to incorporate resiliency into their electrified transit fleets. small sized transit agencies across the country provide critical transportation options to low-income populations that may not have a personal vehicle. As other transit agencies begin to electrify their fleets they will need to consider how to provide resilient operations. The technologies deployed in this microgrid are readily available but combined in newer innovative ways to best support transit specific operations. This project also seeks to quantify the benefits of this resilience, which other transit agencies can learn from to justify the high upfront costs of a microgrid in their own applications.

When the microgrid is deployed, BSOOB's bus depot can serve as a crucial FEMA staging facility during widespread power outages caused by natural disasters. This resilient power system, designed to operate independently of the main grid, ensures continuous and reliable electricity for essential base operations, command, and control responses. In the face of a disaster, the microgrid can power critical communication systems, lighting, heating, and cooling, enabling efficient coordination and support for emergency services. By providing a stable power source, the microgrid enhances BSOOB's capability to support the community, maintain transit operations, and facilitate rapid response and recovery efforts, ultimately improving overall disaster resilience.

Goals and Desired Outcomes

The transit fleet electrification and microgrid has tangible benefits to the community in line with several of the SMART program goals and desired outcomes.

Safety - Battery electric buses, compared to traditional diesel, include investments in advanced technologies and will increasingly be connected vehicles with driver assistance technologies, such as collision warning and blind spot warning[2]. This increases safety by reducing potential harm to riders and pedestrians. The microgrid will increase the overall uptime of these safer vehicles by ensuring continuous, reliable power to increasingly energy intense vehicles.

Equity & Access – BSOOB mission statement is 'To provide safe, clean, reliable and affordable local public transportation for all.' BSOOB's service territory contains historically disadvantaged communities. The microgrid will increase the reliability of deploying zero-emission buses so the disadvantaged communities can better realize the public health benefits of zero-emission public transportation.

Fleet Resiliency & Climate Adaptation – When BSOOB transitions from diesel buses to battery electric buses, reliability of the electrical grid becomes a heightened concern to sustain operations. There has been an increase in power outages in recent years, and the microgrid will mitigate potential transit service disruption by decoupling from a sole reliance on the grid. This is exceedingly imperative given BSOOB serves a coastal community, increasingly susceptible to storm surge during extreme weather events. The transit center is located inland at an elevation of approximately 90 ft above MSL, allowing it to remain operational even if the coast is inundated, providing critical transportation services. The microgrid facility could serve as a staging or charging area for anticipated electric fleets within York and Cumberland County; including:

Biddeford Schools
Dayton Consolidated
Portland Public Schools
Greater Portland Metro (Bus Electrification Transition Plan)
South Portland Bus Service (Bus Electrification Transition Plan)
York County Community Transportation (Bus Electrification Transition Plan)

Community Partnerships – This project will enable BSOOB to contribute to an emergency response plan in which there could be a protocol during electrical grid outage at the distribution/low voltage level to allow emergency vehicles, diesel or electric, to refuel/recharge; including:

Biddeford Police & Fire Department
Secco Police & Fire Department
Northeast Mobile Health Services[3]

Technology Domain Integration – The project is a culmination of mature along with new technologies to establish a synergy in which the whole is greater than the sum of its parts, showcasing a systems approach to more sustainable, resilient public transit. While this project centers on a smart grid domain, enabling the electrification of the fleet will enable adoption of connected, and intelligent vehicles to continue to deliver outcomes.

[2] https://www.nhtsa.gov/vehicle-safety/driver-assistance-technologies
[3] https://www.nemhs.com/

Workforce Development – The electrification of the transportation sector and development of distributed energy resources are emerging industries that will transform our built environment, and the pace at which this occurs is intrinsically tied to workforce adaptation. This project will serve as a knowledge center for the region for the public and private sector to converge with continuing education programs to promote a skilled and inclusive workforce. As a public entity, BSOOB can expand on its experience as an early adopter of BEBs to be a leader with an obligation to serve the community in perpetuity. Reference the Workforce Training section to delve into further details.

Scaling Up

Currently BSOOB operates only 2 electric buses on a single route per day. This planning grant was used to evaluate and complete preliminary design of a microgrid that could support all of BSOOBs fixed route operations, up to 8 buses operating all 5 fixed local routes. The 30% design set is considered the prototype from the Stage 1 grant. BSOOB is planning this by installing on-route chargers separately from this microgrid which will allow them to operate a route with a single bus instead of two. In the event that a power outage occurs at the on-route chargers the microgrid will be able to support enough buses to maintain full operations with the spare electric vehicles, accounting for midday vehicle swaps and charging.

The proposed design strategically mounts the charging dispensers to ceiling of the solar canopy, and between two rows of parking stalls. Four dispensers will be installed under the canopy that can reach a total of 8 different parking stalls, providing additional flexibility to operations.

There will be some challenges BSOOB will need to overcome as it builds out the microgrid for at-scale implementation including:

- Ensuring Uptime of BEBs & EVCS. The existing BEBs and EVCS have had issues with extended downtime. Charger redundancy (8 ports needed to operate 5 buses on a typical day) will reduce downtime due to EVCS issues.
- Skills training. BSOOB staff will need to be training to maintain the various microgrid components or procure ongoing maintenance agreements from vendors or local service technicians.
- Utility coordination. BSOOB will need to work closely with CMP to complete the design and review grid capacity and available to meet the forecasted loads during normal operations.

Changes from Initial Proposal

This planning project was generally completed in line with what was included in the initial grant application. A mix of generation and storage assets were considered including solar PV, battery storage, and a backup generator. Willdan has reached out to Central Maine Power (CMP) to review the preliminary design, though at the time of this report, we are still pending feedback on how the distributed energy resources may alleviate local grid stress. During the final design, additional follow up will be required to determine what costs, if any, CMP may pass on to BSOOB for any utility side upgrades that may be required. Further follow up will also be needed to determine if the DERs included in the microgrid may alleviate any potential upgrades.

Other Relevant Factors

State Policy

The project is aligned with the regional metropolitan planning organization - Greater Portland Council of Governments (GPCOG) and the 2030 Strategic Plan. Adopted May 2024, the relevant outcome is a Sustainable Future, to fund projects that increase resiliency to extreme weather, reduce greenhouse gases through decrease in private vehicle miles travelled, as well as investment in increasing electrification, including charging infrastructure and electric vehicles use.

The Maine Public Utilities Commission (PUC) succinctly laid out state policy goals related to this project, including the following:

Maine's PUC has goals of increasing local solar generation[4] with goals of "ensuring that solar electricity generation, along with electricity generation from other renewable energy technologies, meaningfully contributes to the generation capacity of the State through increasing private investment in solar capacity in the State." In furtherance of these and other goals, the Act creates a State policy of "encouraging the attraction of appropriately sited development related to solar energy generation, including any additional transmission, distribution and other energy infrastructure needed to transport additional solar energy to market for the benefit of all ratepayers.". The proposed microgrid is in line with these goals by increasing distributed solar generation in the State.

Maine has established ambitious climate change initiatives[5] including several greenhouse gas emissions reduction targets. The microgrid will result in significant GHG reductions from BSOOB's transit operations, supporting these statewide goals.

- 2030 annual emissions level. By January 1, 2030, the State shall reduce gross annual greenhouse gas emissions to at least 45% below the 1990 gross annual greenhouse gas emissions level.
- Interim emissions level. By January 1, 2040, the gross annual greenhouse gas emissions level must, at a minimum, be on an annual trajectory sufficient to achieve the 2050 annual emissions level in accordance with subsection 3.
- 2050 annual emissions level. By January 1, 2050, the State shall reduce gross annual greenhouse gas emissions to at least 80% below the 1990 gross annual greenhouse gas emissions level.

The Maine Governor's Energy Office is tasked with developing a plan (with input from stakeholders and in consultation with EMT - Efficiency Maine Trust) to achieve the targets of reducing the State's consumption of oil by at least 30% from the 2007 levels by 2030 and by at least 50% from 2007 levels by 2050[6]. The microgrid will better support BSOOB's fleet of electric buses to realize long-term reductions in local oil consumption.

Environmental Sustainability

The project has a multitude of benefits to environmental sustainability. The microgrid will supply most, if not all, of the energy needed to power the electric buses on an annual basis. This will reduce the need from local fossil fuel fired power plants and reduce regional air pollution. While not quantified in this report, the microgrid is expected to help improve local air quality and result in public health benefits. These were not quantified because an apples-to-apples emission value for the same diesel emission pollutants across different sources were not available during the course of this project. It is expected that local air quality benefits are relatively small, and lower than the carbon benefits which are quantified in this report and thus the exclusion is not expected to significantly impact the overall results. The microgrid will increase the reliability and resiliency of BSOOBs zero-emission transit operations which will sustain additional public health and environmental benefits by better supporting the transition away from diesel buses. This includes further public health benefits by avoiding pollution from diesel combustion in disadvantaged communities.

Supporting the transition away from diesel buses will also better protect local waterbodies. BSOOB's bus depot is located adjacent to local waterbodies, including a wetland onsite and the Saco River Watershed. BSOOB has an obligation to protect the Saco River Watershed which serves as a drinking water source for 40,000 residents. The Saco Watershed Collaborative was formed in 2016 with a goal to 'protect water quality, public health and the ecosystems…' Transitioning the BSOOB diesel fleet to BEBs will minimize the risk of diesel spills or maintenance fluids getting into the water bodies and therefore significantly reduce the risk of contamination.

[4] The Maine Solar Energy Act, 35-A M.R.S. § 3472 et. seq.
[5] Title 38 Chapter 3-A
[6] Title 2, Section 9(5)

Stage 1 Deployment & Milestones

Throughout the course of this project, Willdan reviewed BSOOB's existing transit operations and historical electric bus energy use to design a microgrid that could support all of BSOOB's fixed local routes with electric buses. While microgrids have been developed before, Willdan reached out to several different technology vendors looking for the latest innovations in controls, battery technology, and smart relays. Willdan also started outreaching to the local utility to understand potential grid impacts of the proposed microgrid.

One of the key benefits of microgrids is providing resilience to critical operations. Resiliency is notoriously difficult to quantify, however, this study considers utilizing the value of lost load to estimate the benefits of reduced downtime. This is a replicable strategy that other transit agencies can use to quantify the benefits of increasing resiliency into their own zero emission transit operations.

Part 2: Proof-of-Concept & Evaluation Findings

BSOOB previously completed a fleet electrification plan prepared by Hatch LTK, in conjunction with Maine DOT, on February 10, 2023. The plan included energy modelling of BSOOB's existing routes and proposed a charging strategy to support the long-term needs of the fleet. The plan includes preliminary layouts for potential solar PV arrays.

As part of the microgrid feasibility assessment, Willdan refreshed the previous analysis, accounting for the latest BEB options available and incorporating historical charging data from the two (2) battery electric buses (BEBs) BSOOB has been operating. This information was used to refine the load profiles that would need to be supported by the microgrid.

Route Modelling Refresh

Duty Cycle Analysis

Willdan reviewed 12 months of historical BEB and EVCS telematic data for vehicle utilization, energy consumption, and charging data to refine the energy modelling needed to develop the microgrid. BSOOB would operate one BEB at a time, typically on either the Route 50-Orange/51-Bloack route or the Route 52-White/53-Blue route and ran until they reached 20% SOC, at which point the second BEB would be deployed to complete the route for the rest of the day. BEB performance is influenced by many factors including elevation, ridership load, driver behavior, and outside air temperature. Willdan reviewed the total miles driven and total energy consumption for each month in a year to understand how the ambient temperature impacted vehicle efficiency and overall performance. A summary of the average vehicle efficiency throughout 2023 is contained in Table 1.

Table 1 – 2023 Vehicle Efficiency

MONTH	AVERAGE			BUS 554			BUS 555		
	Average kWh Charged (kWh)	Average Distance Driven (mi)	Average kWh/mil	Average kWh Charged (kWh)	Average Distance Driven (mi)	Average kWh/mil	Average kWh Charged (kWh)	Average Distance Driven (mi)	Average kWh/mil
JAN	197.1	70	2.80	82.8	29	2.84	114.3	41	2.77
FEB	249.4	90	2.77	57.7	15	3.93	191.6	75	2.55
MAR	302.5	128	2.36	112.2	41	2.77	190.3	88	2.17
APR	300.1	138	2.18	118.3	52	2.30	181.8	86	2.10
MAY	312.5	169	1.84	95.3	49	1.93	217.2	120	1.81
JUN	324.5	180	1.80	153.8	85	1.82	170.7	95	1.79
JUL	315.3	166	1.90	82.4	42	1.98	232.9	124	1.87
AUG	265.3	150	1.77	2.6	0*	102.52	262.6	150	1.75
SEPT	250.6	141	1.78	137.1	75	1.82	113.5	65	1.73
OCT	328.1	173	1.90	166.8	87	1.92	161.3	86	1.89
NOV	332.7	131	2.54	208.6	82	2.55	124.1	49	2.51
DEC	297.8	111	2.69	227.0	86	2.64	70.8	25	2.86
AVG.	**289.7**	**137**	**2.11**	**120.4**	**53**	**2.25**	**169.3**	**84**	**2.02**

*Bus 554 was down in August 2023

These efficiency results for each month were then used to estimate the future energy consumption for operating the BEBs on the remaining routes, assuming a representative 35 foot BEB with a 450kWh battery. Buses are assumed to start each day with a fully charged battery and viability is determined if the bus can complete the route with a minimum 20% SOC. The microgrid is designed to support the charging needs for the following BSOOB fixed route operations:

- Route 50-Orange/51-Black
- Route 52-White/53-Blue
- Route 54- Silver
- Route 60- Green (multiple vehicles)

The commuter routes and trolley services are excluded from consideration and design of the microgrid. Route 70-Zoom Express is a commuter route and per BSOOB will not use BEBs in the next 10-15 years, thus has been excluded from consideration and design of the microgrid. While these vehicles may not be powered by the microgrid, they are still serviced by the maintenance facility, so ensuring resiliency to the overall facility is important to maintaining all the transit operations.

BSOOB is planning to install two 450kW on-route pantograph chargers at the Saco Transportation Center, and it is assumed that all future fixed local route BEBs will be equipped with pantograph charging capabilities. Based on existing route schedules and scheduled layovers Willdan was able to determine that the on-route chargers would allow a single bus to complete a route without dropping below 20% SOC. This avoids the need to swap buses midday, as is currently done.

The energy delivered in the duty cycle analysis summary (Table 2) accounts for not only the energy consumed by the buses, but the estimated losses during charging. Full duty cycle analysis results are contained in Appendix A. The energy delivered at the depot is the key data result to sizing the microgrid.

Table 2 – Duty Cycle Analysis Summary

Route	Metric	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Route 50-Orange/ 51-Black	Vehicle Daily Energy Consumption (kWh)	547	542	460	425	360	352	371	345	348	371	495	525
	On-Route Energy Delivered (kWh)	284	284	284	284	0	0	0	0	0	0	284	284
	Depot Energy Delivered (kWh)	363	357	261	219	426	416	439	409	411	439	302	337
Route 52-White/ 53-Blue	Vehicle Daily Energy Consumption (kWh)	620	614	522	482	409	399	421	391	394	421	562	595
	On-Route Energy Delivered (kWh)	348	348	348	348	348	348	348	348	348	348	348	348
	Depot Energy Delivered (kWh)	386	379	270	222	136	124	150	115	119	150	317	356
Route 54- Silver	Vehicle Daily Energy Consumption (kWh)	612	606	515	476	403	394	415	386	389	416	554	587
	On-Route Energy Delivered (kWh)	284	284	284	284	284	284	284	284	284	284	284	284
	Depot Energy Delivered (kWh)	440	434	326	279	193	182	207	173	177	208	372	411
Route 60-Green	Vehicle Daily Energy Consumption (kWh)	976	967	822	758	643	628	662	616	620	662	884	936
	On-Route Energy Delivered (kWh)	682	682	682	682	682	682	682	682	682	682	682	682
	Depot Energy Delivered (kWh)	473	462	291	215	79	61	102	47	52	102	364	427
Route 60-Green Seafood	Vehicle Daily Energy Consumption (kWh)	143	142	120	111	94	92	97	90	91	97	129	137
	On-Route Energy Delivered (kWh)	0	0	0	0	0	0	0	0	0	0	0	0
	Depot Energy Delivered (kWh)	169	168	142	131	111	109	115	107	108	115	153	162

Charging Strategy and Load Profile

Willdan's proposed charging strategy builds off the existing chargers and operations, and the plan previously developed. BSOOB currently operates two ABB HVC 150 charging cabinets each with one charging dispenser. The EVCS are on a separate service. To meet the long term charging needs, Willdan recommends that BSOOB plan for two (2) ABB HVC 150 power cabinets each with two dispensers and one (1) ABB HVC 360 power cabinet with 4 dispensers (Figure 2). One additional dispenser will be added to each of the two existing power cabinets, and one new cabinets four dispensers will be added to the site. This can support charging for up to 8 buses each night, though only 5 are typically expected to be in operation each day. The extra three ports will ensure that there are enough charging ports for all of BSOOBs future electric fixed route fleet so spares are always charged and available during unexpected downtime or power outages at the on-route chargers.

Historical load profiles are illustrated in Figure 3. Historically, early morning charging loads were from vehicles that were not plugged in the night before and needed to be charged before morning deployments. Historical midday charging loads were from when vehicles returned midday once they reached 20% SOC during their route. When the on-route chargers are installed, BSOOB is expected to be able to operate without swapping vehicles midday during normal operations, so the current midday charging load is expected to shift to overnight charging load.

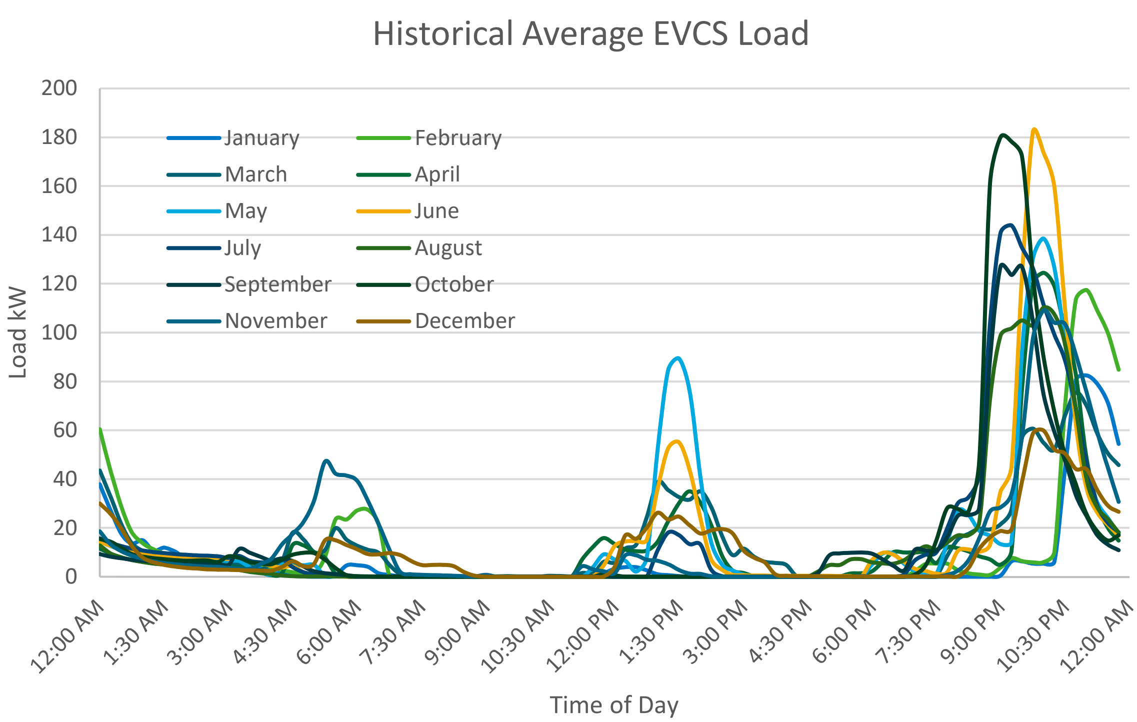


Figure 3. Historical Average EVCS Load at Bus Depot from January 2023 Through December 2023

The microgrid will need to support the charging needs of 5 buses on average each day. Buses are expected to partially recharge during the day at the Saco Transportation Cener via two on-route pantograph chargers. The solar PV and BESS components of the microgrid are sized assuming that the on-route chargers are not impacted by a local outage and buses partially recharge midday on-route. Even in the event of an outage at the Saco Transportation Center, BSOOB will maintain spare buses that can be swapped out and recharged midday at the depot via excess solar generation in summer months or the backup generator in winter months or cloudy days.

Based on when vehicles are expected to return to the depot and their estimated charge time, only 3 buses are generally expected to be charging at once. An example load profile at the bus depot for the month of January is shown in **Error! Reference source not found.**. Bus depot load profiles for the other months are contained in Appendix B. Appendix B also contains expected load profiles for the on-route chargers, which were used to estimate the remaining kWh each bus had to recharge at the depot by the microgrid. Since the microgrid will only serve the depot chargers, the depot load is the key input for designing the microgrid.

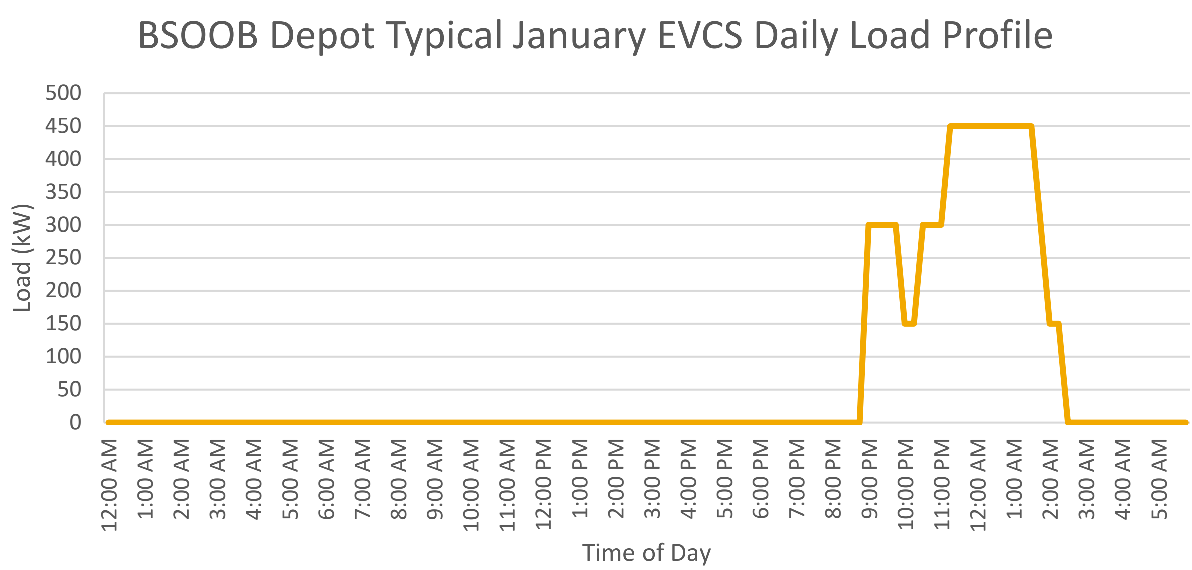


Figure 4. Example January Bus Depot Load Profile for Microgrid

Microgrid Basis of Design and Components

The proposed microgrid is designed to support the energy needs of the fixed route operations as previously described. The core of the microgrid is a solar PV system, a battery energy storage system, a natural gas fired generator, and a microgrid controller. The basis of design for sizing the key components are summarized below:

- The microgrid should generate approximately 550,000 kWh per year to meet the annual forecasted load of the BEBs (~490,000 kWh/yr) and the maintenance facility (~54,000 kWh/yr)
  - A solar system with a nameplate rating of ~450kW will meet this annual year 1 generation
- The BEBs are expected to consume between 1,000-2,000 kWh per day, depending on the season. The maintenance facility uses approximately 150kWh/day. The EVCS can output a maximum of 660kW and the maximum load of the maintenance facility is 20kW. These loads informed the sizing of the BESS and generator.
  - A 2.6MWh BESS starting at full charge can provide between 1 and 2 days of backup power for BSOOB depending on the season, before accounting for potential solar recharge, and assuming the buses can recharge partially at the Saco Transportation Center. The ability for the solar PV system to fully recharge the battery will vary based on the season.
  - In June through August, solar generation is expected to be greater than 2 MWh on most days. Some days in March, April, May, and September have generation above 2 MWh as well. Since

BSOOB's average daily load in these months ranges from 1.2 MWh – 1.5 MWh, the battery system charged from solar generation can provide multi-day backup.

- In winter months, solar generation is significantly lower due to weather and daily load is higher due to heating needs. Therefore, storage is not able to charge fully or support a full day worth of backup in winter.
- Given the intermittent nature of solar energy and the potential for multi-day outages, a 625kW natural gas generator is incorporated to provide lower carbon vs. diesel, long term resiliency option when the battery is depleted and solar PV is not able to fully recharge the BESS. This can power all the EVCS and the maintenance facility at once if needed.

A 30% engineering design set was completed under this project, which serves as the prototype under the Stage 1 grant. A copy of the design set is contained in Appendix C. Spec sheets for proposed components are contained in Appendix D.

This project falls primarily under SMART's *Smart Grid* category and also includes project elements from intelligent sensors and system integration. The key technologies deployed for the proposed microgrid include:

- 450kW of solar photovoltaic modules and inverters
- 653kW/2611 kWh Tesla MegaPack, Battery Energy Storage System (BESS) & Controls
- 625 kW Natural Gas Generator & Controls
- Smart EV Charging System
- Microgrid Controller (MGC)
- Data Analysis and software
- Smart Circuit Breakers
- Smart Relays
- Energy monitoring & metering
- Weather Station

While several microgrids have been designed and built before, each microgrid is unique in how it is designed and operates. This particular microgrid will rely on several new innovative components and heavily on new smart relays instead of a traditional automatic transfer switch to control the different distributed energy resources and integrate with the EVCS software. The following sections detail the proposed components and highlight the unique way they are designed to work together.

The Microgrid itself is a collection of energy assets, or DERs (Distributed Energy Resources). The utility, solar, battery storage, generator are all working together real-time to optimize energy efficiency and maintain facility operations even during the most demanding situations. Each component of the DER features cutting edge technology to optimize energy production, maximize efficiency, and increase safety. How these different components communicate with each other is how this microgrid is unique and innovative.

Technology has seen a rapid increase in products to interconnect, often referred to as the Internet of Things (IoT). Smart phones, wireless speakers, thermostats and appliances can be interconnected and monitored. Unfortunately, the Microgrid industry lacks standardized technology and hardware to quickly and easily interconnect. Unique to BSOOB is the use of digital switching and interconnectivity to build a localized 'Ethernet of Things' (EoT). This EoT optimizes control of the DERs to leverage energy storage strategies and maximize energy production.

Solar Modules & Inverters

The microgrid will utilize the Sunny Tripower CORE1 inverter which is the world's first free-standing string inverter. Its innovative design significantly reduces installation costs for commercial rooftop, carport and ground mount PV systems. Combined with industry leading performance and safety features, CORE1 offers unmatched reliability, maximum return on investment, and lower total cost of ownership. Embedded within the electronics is a host of Smart Technology to enhance safety and optimize production including:

- SMA Shade Fix.
  - An industry leading solution, Shade Fix optimizes power production at reduced cost and complexity. SMA inverters with ShadeFix optimization produce the maximum power from PV modules. On typical designs, a shaded module produces less relative power and shuts down all the modules on the same circuit, or "string". For instance, if a tree or structure partially shades the solar array then all the modules wired on this circuit would be turned off. Similarly, if one of the solar modules malfunctions it shuts down the entire string of modules. The result is an underperforming system that produces less power, underutilized capacity. SMA inverters outperform other traditional module-based optimizers which require additional hardware.
- I-V Curve Function and Intelligent String Monitoring.
  - The built in telemetry provides advanced diagnostic tools to maintain optimal system performance. The inverters monitor Current (I) and Voltage (V) with onboard electronics that allow for real time adjustments to optimize performance. Each inverter has (6) inputs (MPPT) divided up across 12 strings so it can handle a wide quantity and variety of strings into it's inputs, allowing maximized performance. This helps with any dirty panels, or shading, or a string that's not performing well.
- Rapid Shutdown Compliance.
  - SMA's SunSpec certified rapid shutdown solution sends an emergency signal transmitted by the Sunny Tripower CORE1 inverter through the line voltage wiring to the module-level devices. The innovative technology reduces communication cable, installation time and delivers the simplest, most reliable module-level shutdown solution for complying with NEC 690.12 Rapid Shutdown of PV Systems on Buildings. This provides a simple, flexible, and safe solution for commercial rooftop systems.
- UL 3741 PV Hazard Control listed.
  - SMA inverters feature enhanced safety and Code Compliance without module-level shutdown. Sunny Tripower CORE1 are the first inverters listed to standard UL 3741 PV Hazard Control for NEC shutdown devices when CORE1 inverters are installed with co-listed array mounting systems – offering cost savings, faster installation and improved reliability versus traditional module-level shutdown solutions. This feature provides additional protection for fire fighters and first responders.

Battery Energy Storage System (BESS) & Advanced Controls

BSOOB's Microgrid will utilize a Tesla Megapack 2 XL (Megapack) which is an all-in-one utility-scale energy storage system optimized for cost and performance. The product includes a custom enclosure, batteries, bi-directional inverter, and thermal system. At the site level, a Tesla Site Controller with intelligent software allows the coordination and operation of the Megapack.

This turnkey system is designed to maximize savings and prolong battery life. Combined with the Tesla Site Controller, Megapacks have the most advanced battery technology and dispatch optimization software to quickly learn and predict a facility's energy patterns. Tesla's proprietary storage dispatch software can charge and discharge autonomously to maximize customer value

The Tesla Site Controller is the single point of interface for the utility, network operator, or customer ethernet systems to control and monitor the entire energy storage site. Inside, is a control algorithm that dictates the charge and discharge functions of the battery system units, aggregating real-time information and using the information to optimize the commands sent to each individual battery unit. The Tesla Site Controller allows the user to define battery operational data points, program control modes and associated setpoints, and assign protocols supported system monitoring and controls.

From a fire safety perspective, the Megapack is listed to the UL9540A large-scale fire testing standard, and is tested at the cell, module, and unit level. From the manufacturer's safety overview, "In the unlikely event of a fire, rigorous full-scale fire testing has shown that Megapack performs in a safe and controlled manner, consuming itself slowly and without explosive bursts, projectiles, or unexpected hazards. The vents are designed to direct all gases, smoke, and flame out of the top of the Megapack, minimizing risk to nearby response personnel and exposures. In the event of a fire at a Megapack site, the fire service will be able to manage the event with standard fire service response equipment."

Generac Genset & Controller

The natural gas generator was selected to provide a lower carbon and continuous fuel source to weather the severe and prolonged outages as compared to a diesel generator. BSOOB could also evaluate procuring renewable natural gas (RNG) to further reduce the carbon intensity of the generator. The generator is paired with control system that features a plethora of smart technologies:

- Power Zone® Pro Sync Controller
- NFPA 110 Level 1 Compliant
- Engine Protective Functions
- Alternator Protective Functions
- Digital Engine Governor Control
- Digital Voltage Regulator
- Multiple Programmable Inputs and Outputs
- Remote Display Capability
- Remote Communication via Modbus® RTU, Modbus TCP/IP, and Ethernet
- Alarm and Event Logging with Real Time Stamping
- Expandable Analog and Digital Inputs and Outputs
- Remote Wireless Software Update Capable
- BMS and Remote Telemetry
- Built-In Programmable Logic Eliminating the Need for External Controllers Under Most Conditions
- Ethernet Based Communications Between Generators
- Programmable I/O Channel Properties
- Built-In Diagnostics
- Arc Flash Maintenance Mode (When Correctly Equipped)

Microgrid Controller (MGC)

The MGC receives, organizes data, and monitors the real time operations by using current and historical data, makes decisions and sends instructions to the field. These decisions are based on user priorities and a user defined sequence of intent. This operational process outlines the informational steps that guide the MGC and its decision making. Unique to BSOOB is the collection of data points for historical analysis patterns and software based AI Tools to learn and make smarter decisions.

With time, the data set will expand allowing analysis of previous events to improve response times, readiness and overall planning. The MGC controller and its collective components are state of the art with field proven reliability. These components feature a host of smart technology.

- SEL3555 – Real time Automation Controller (RTAC)
  This is the core of the microgrid where decisions are made. Data from the DERs and field sensors are sent to the controller. The data is processed and evaluated within the controller, eliminating the need for additional computers. Ideal for the most demanding applications, this model integrates up to 256 devices and supports up to 100,000 data points. The controller features custom programming capabilities. The functionality gives BSOOB the freedom to develop and define bespoke solutions to meet their specific energy goals. The data can be added to a cloud based storage solution for additional analysis.

- SEL2407 – Satellite Synchronized clock.
  Keeping each component synced and in-step is the time clock. The clock ensures the speed and accuracy of the DERs by synchronizing relays, information processors and computed decision making. Speed and reliability are enhanced by using a satellite driven GPS time source. The synchronized clock provides ±100 ns accuracy for speed and accuracy, second to none.

- SEL2730 – Network switching.
  The switch supports the communications infrastructure for the Microgrid. The network switch interconnects the DERs, the relays and control switches that turn on/off energy components and provides real-time data communications. While it may seem simple on the surface, the network switch meets or exceeds the IEEE 1613 (Class 1), IEC 61850-3, and IEC 60255 industry standards for vibration, electrical surges, fast transients, extreme temperatures, and electrostatic discharge in communications devices.

Smart Relays

Electrical relays were invented in 1835. Since then, there have been enormous improvements in technology and electrical circuitry. Recently, innovations in connectivity allow relays to function as field sensors. The data points provide real-time insight to monitor current conditions. The data gives BSOOB the ability to predict equipment failures and take preventative measures. This ensures the Microgrid stays operational during outages and severe weather events when the community is counting on public transportation the most. The microgrid will utilize the latest in smart electrical relays and controls, specifically SEL700G and SEL751 from Schweitzer. These units provide protection and synchronization solutions for the generator and include several smart technologies.

Breaker Wear Monitoring. Inside each smart breaker are contactors. The contactors act as a switch that opens & closes. Overtime, the contactors wear out and need replacing. The relay records the accumulated breaker contact wear with the breaker monitor function. The internal monitor tracks the total number of close/open operations and records current per phase. The relay features an internal alarm option to alert operators when measured and accumulated quantities approach maintenance thresholds. This information facilitates proactive breaker maintenance and replacement without underutilizing resources.

Current Differential Protection. The relays monitor electrical parameters into and out of the generator and measures the difference, 'Differential'. If a dangerous level is sensed, the relay sends a signal to trip or turn off the breaker. On a complex level, the relay is performing synchronism check with the DERs to ensure the frequencies, volts-per-hertz of the power sources, are all timed correctly.

Islanding Detection. Important smart features can detect utility outages. Upon an outage, utility companies require Microgrids and power sources to automatically disconnect from the utility source. These outages send the Microgrid into 'island mode' where it operates autonomously. When the power goes out, rest assured, the relays will quickly and safely disconnect the Microgrid.

Smart Metering

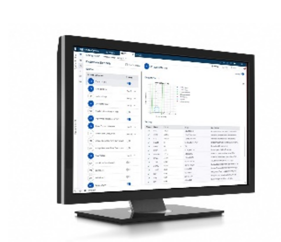
The energy meters communicate directly with the controller and provide valuable data points for analysis and evaluation. This enhances energy production, improves economics, and data analytics. Where possible, components have been selected with integrated metering. Additional energy metering provides real-time usage information and is essential to the success of the microgrid.

The SEL735 high-accuracy metering system provides BSOOB with detailed telemetry and power quality analysis. With data available at their fingertips, operators can easily identify power system anomalies and mitigate their impact as quickly as possible. The metering data provides DER control for automatic start/stop to the power generation assets. Control equations based on logical or mathematical combinations of measured quantities and set points can be used to control a generator or load switch. In particular, the BSOOB Microgrid utilizes this feature to limit unsafe current levels and protect the distribution equipment.

For high-accuracy revenue metering applications, the SEL-735 exceeds ANSI C12.20 0.1 and IEC 62053-22 0.1 S accuracy class requirements. These meters maintain this accuracy throughout its entire service life, minimizing costs associated with field calibration. The smart relays include built-in features for enhanced operational capabilities and long-term analytics.

- Ensure Accurate Revenue Metering
- Compensate for Errors in Instrument Transformers
- Automate Data Reading (Time of Use)
- Measure and Report Reliable Power Quality Indicators
- Log Profile Data
- Capture Waveforms and Trigger Records
- Streamline Commissioning, Testing, and Daily Use

Software



The microgrid controller evaluates data to make the best decision possible. Several software packages are needed to interface, monitor the MGC. Software internal to the MGC monitors real-time conditions and compares against sequence of intent (Auto-Grid | Uplight). Separate external software monitors variables outside of the Microgrid and stores data for additional AI analytics (acSELerator).

The software proactively monitors the microgrid system and component telemetry. Embedded tools detect alarms and can issue and dispatch prompt service when required. Additional smart technology monitors system fluid levels, battery voltage, and other metrics to prevent minor issues from becoming a major problem. In addition, regular testing of microgrids helps keep systems healthy and ready to provide vital backup power when needed. The software provides service technicians with valuable data logs for troubleshooting and resolution, ensuring the microgrid system is always prepared for any event.

An often over-looked feature is ease of use. The software selected for BSOOB provides an interface for user friendly functionality and overall ease of use.

ACSELERATOR **RTAC SEL-5033 SOFTWARE.**
An intuitive, easy-to-use application designed to configure the SEL Real-Time Automation Controller (RTAC) family of products. The software offers a wide range of optional tools, add-ons, and library extensions. This software package establishes set points for system parameters and sequence of intent. It's fully customizable and gives BSOOB the flexibility to expand and easily grow the EV fleet into the future.

ACSELERATOR **DIAGRAM BUILDER SEL-5035 SOFTWARE.**
Diagram Builder is an application that allows users to create and manage visualization projects for the optional web-based HMI designed for SEL Real-Time Automation Controllers (RTACs). The software creates the user feel and experience. It offers a simple easy to use interface to simplify operation and make adjustments on the fly.

Auto-Grid | UPLIGHT
This software package that gives BSOOB the ability to monitor energy performance, energy levels and current conditions and provide pre-emptive protocols to prepare the microgrid for scheduled charging or impending weather conditions. In addition, the software can send notifications to initiative readiness procedures in anticipation of severe weather events. The software hosts a suite of comprehensive tools to assess economic value of battery deployments with a comprehensive, AI-driven platform that enables management across all storage value streams, unlocking the full potential of energy storage assets. Some of the smart analytics include:

- Real-Time Telemetry and Control. High-speed telemetry and control combined with advanced algorithms enable smooth renewable energy integration.
- Frequency Regulation. Monitor grid frequency in real-time for timely responses and efficient grid management.
- Optimization Engine. High-speed telemetry and control combined with advanced algorithms enable planning and dispatch.
- State-of-Charge (SOC) Management. Optimize SOC based on real-time market conditions to maximize battery performance.
- Forecasting. Ensure maximum revenue while maintaining dispatchable capacity for load shifting or system reliability, to minimize risk.

Smart Breakers & Contactors

The BSOOB microgrid features smart switching which allows the MGC to send signals to turn ON or OFF various DER components as needed. This seems elegant and simple on the surface but inside it is cutting edge technology that protects the DER components and simultaneously provides the ultimate in control and customization. The smart breakers feature remote monitoring and connectivity to allow for easy customization via digital modules. The circuit breakers bring future-ready electronics that provide capabilities to build smart, secure, and sustainable power distribution systems. Paired with an integrated control unit, the circuit breakers provide simple and reliable access to data from a smartphone or PC.

The circuit breaker protections feature the latest innovation for high speed response time (milliseconds). The breakers include advanced features for power up-time and protection against cable overloads, short circuits, and insulation faults. The control unit can assist in providing corrective, preventive and predictive maintenance, and energy management to identify potential savings. This new technology allows advanced IoT connectivity and seamless integration with building and energy management systems.

Weather Station

At BSOOB, weather is a dominant factor in readiness and resiliency. The BSOOB site features a local weather station to monitor real time weather conditions. The data acquired will provide ongoing analysis for improved readiness, preparations and preventative maintenance. Combined with the energy usage metering, unique cause & effect correlations can be mined, and discovered to enhance the Microgrids functionality and long term performance.

For example, when temperatures fall below freezing an alert message can be sent to the maintenance department to initiate winter readiness. This could be as simple as checking the fuel levels are topped off, ready for a potential outage. The backup generator is equipped with a cold weather package that keeps the engine block and other components at an optimum temperature for unexpected start up. During periods of extreme cold, the status of the cold weather features can be monitored to ensure they are operating correctly. These are just a few of the real-time analysis that can be applied. As the data set grows, more information can be extracted.

The data collected can be used to evaluate overall system performance. If extreme conditions impede or possibly enhance the overall efficiency and output of the microgrid, this could help with future planning. As more data is collected, more correlations can be discovered and shared with other communities to make their microgrids more efficient.

As far as specifications, the weather station is capable of accurately measuring current weather conditions with a built-in anemometer, rain collector, temperature and humidity sensors. The user interface features a customizable dashboard that can be set to show up to 21 parameters – from temperature to wind to rain – allowing the user to quickly see, understand the information that matters most.

Cybersecurity

Cybersecurity is an essential element of energy management systems and ensures their reliability and protection against potential threats. Several of the DER components have cybersecurity features built in and incorporates industry-standard cybersecurity measures to protect against potential risks. In order to maintain protection, the systems must be properly configured, updated regularly, and adhere to best practices by operators and integrators. For critical infrastructure like energy storage and microgrid systems, a layered cybersecurity approach is essential to ensure reliability and resilience against cyber threats.

The Tesla Megapack contains the following cybersecurity features:

Encryption: Data communication between the Megapack and Tesla's servers is encrypted to prevent interception or tampering.
Authentication: The Megapack requires secure user authentication methods (e.g., two-factor authentication) to access to system controls and monitoring.
Firmware Security: The Megapack receives regular firmware updates to ensure the system is protected against newly discovered vulnerabilities. The signed firmware prevents unauthorized code from being installed.

Network Segmentation: The Megapack employs segmented networks to isolate critical systems and reduce the risk of lateral movement in case of a breach.
Monitoring and Alerts: Tesla continuously monitors its systems for anomalies and issues alerts in case of unusual activity.
Integrated logging supports incident detection and response.
Access Controls: Role-based access control (RBAC) restricts user permissions to necessary functionalities.

The Schweitzer Microgrid Controller (SMC) contains the following cybersecurity features:

Industrial-Grade Protection: The SMC is aligned with designed with standards such as NERC CIP, creating a robust cybersecurity protocol for critical infrastructure.
Secure Communication Protocols: the SMC uses protocols such as IEC 61850 with encryption to secure data exchange between the different DER devices.
Multifactor Authentication: The SMC uses secure login mechanisms for accessing system controls such as multifactor authentication.
Device Hardening: The SMC comes standard with factory-set security features, such as default configurations that minimize vulnerabilities.
Intrusion Detection Systems (IDS): The SMC continuously monitors unauthorized access attempts and generates alerts.
Patch Management: The SMC receives regular updates to address software vulnerabilities.

The Acumen EMS Controls Subscription is a cloud-based energy management platform that integrates with hardware like the Energy Toolbase Monitor to optimize performance. Cybersecurity considerations include:

Cloud Security: The EMS Controls are Hosted on secure cloud platforms with robust perimeter defenses.
Encryption: The data is encrypted in transit (e.g., TLS) and at rest (e.g., AES).
Access Controls: Role-based permissions and user authentication prevent unauthorized access to critical systems.
Data Privacy: The EMS Controls comply with data protection regulations (e.g., GDPR, CCPA) and ensures user and system data are handled securely.
Real-Time Monitoring: the EMS Controls are continuously monitored for anomalies, with automated responses to mitigate potential threats.
Regular Audits: The EMS Controls goes through regular security audits and compliance checks to maintain high standards of cybersecurity.
API Security: The APIs used for system integration are secured with authentication tokens and rate limiting to prevent abuse.

Safety

Safety is a top priority for energy management systems due to the potential hazards associated with high-voltage equipment, energy storage, and grid management. Several components of the microgrid are imbedded with multiple safety features to keep users, technicians, and the over site safe.

The Tesla Megapack comes with numerous built-in safety features:
Thermal Management: Advanced liquid cooling systems ensure consistent temperature regulation across battery modules to prevent a thermal runaway event. The system monitors temperature in real-time and automatically shuts off the battery in case of overheating.
Fire Suppression Systems: Integrated fire detection and suppression systems are designed to contain fires quickly if they occur. The BESS uses non-flammable coolant to mitigate fire risks.
Overcharge Protection: Systems are equipped to detect and prevent overcharging of batteries, reducing the risk of damage or fire.

Robust Enclosure Design: Enclosures are reinforced and weatherproof to be resistant to physical impacts, vandalism, and environmental stress such as , rain, snow, and high temperatures.
Fault Detection: Continuously monitors electrical faults with automated responses to isolate problematic modules or components.
Compliance with Standards: Meets or exceeds international safety standards, such as UL 9540, NFPA 855, and IEC 62619 for battery energy storage systems.

The Schweitzer Microgrid Controller incorporates several safety mechanisms:
Fail-Safe Operation: The controller is designed to ensure the system enters a safe state during communication loss, hardware failure, or abnormal conditions. It includes redundant controls and backups to maintain operational reliability.
Electrical Protection Relays: Integrated relays protect against overcurrent, overvoltage, and frequency abnormalities. Real-time fault detection isolates faults when detected to minimize damage and prevent cascading failures.
Testing and Validation: The controller is subjected to rigorous hardware-in-the-loop (HIL) testing to simulate real-world conditions and ensure safety under various scenarios.
Surge and EMI Protection: Protection against electrical surges and electromagnetic interference to prevent damage to sensitive electronics.
Operator Safety: Interfaces include safeguards to prevent accidental activation of high-power equipment.
Standards Compliance: Adheres to safety standards like IEEE 1547 and IEC 61131-3 for microgrid controllers and automation systems.

The ETB Acumen EMS Controls integrates with monitoring hardware to optimize energy systems, with safety features primarily focused on operational safeguards:
Remote Monitoring and Control: Enables operators to manage systems remotely, reducing the need for physical interaction with high-voltage equipment.
Automated Fault Responses: Detects faults such as energy imbalances, voltage spikes, or power quality issues and responds automatically to maintain system integrity.
User-Friendly Interface: Provides operators with clear alerts and step-by-step guidance during abnormal events, minimizing human error.
Data Integrity and Safety: Cloud-based data storage ensures critical system data is preserved even during local hardware malfunctions.
Safety Compliance: Interfaces are designed to comply with safety standards for energy management systems, ensuring operator and equipment safety.

The EVCS are engineered to provide efficient and safe charging solutions for BSOOB's electric buses. The safety features of these ABB chargers include:
Compliance with International Safety Standards: ABB's chargers adhere to stringent international electrical, safety, and quality standards, ensuring reliable and safe operation.
Robust Enclosure Design: The power cabinets feature protection ratings of IP54 and IK10, equivalent to NEMA 3R, providing resistance against dust, water ingress, and mechanical impacts. Depot charge boxes have an IP65 rating, offering enhanced protection suitable for both indoor and outdoor installations.
Advanced Thermal Management: The chargers are equipped with systems to manage temperature variations, ensuring optimal performance and preventing overheating during operation.
Overcurrent and Overvoltage Protection: Integrated protection mechanisms safeguard both the charger and the connected vehicle from electrical anomalies, such as overcurrent and overvoltage situations, enhancing overall safety.
Emergency Stop Functionality: Emergency stop buttons are incorporated into the design, allowing operators to immediately halt the charging process if necessary, ensuring prompt response to unforeseen issues.

Remote Monitoring and Diagnostics: ABB's chargers come with an extensive suite of connectivity features, including remote services such as monitoring, management, diagnostics, and software upgrades. These advanced services provide equipment owners with powerful insights into their charging operations while enabling high uptime.
User-Friendly Interface with Safety Alerts: The chargers feature interfaces that provide clear indicators and alerts for hazardous conditions, ensuring operators are informed of the system's status and any potential safety concerns.

Maintenance Facility Load and Tie In

Currently the maintenance facility and the existing EVCS are on separate electrical services and separate meters. Based on historical interval data the maintenance facility uses approximately 54,000 kWh per year. In order to provide a more resilient operation, the microgrid will be designed to tie in the existing maintenance facility service into the EV service. This will allow the maintenance facility to be served by the solar PV and BESS every day. This will be done by installing a subpanel on the proposed microgrid switchboard which will feed the existing maintenance facility and disconnect it from its existing utility service.

Sequence of Operations

Normal Operations & Short Outages

The microgrid is designed to be flexible and can operate in a variety of scenarios. The controls and relays allow different energy sources to be connected or disconnected as needed based on varying external conditions (Table 3 – Microgrid Sequences of OperationsTable 3).

Error! Reference source not found. illustrates how the microgrid will operate during normal operations. In this scenario the utility, solar PV, and BESS are working together to provide all the facility power needs, with priority given to the solar and BESS to reduce utility costs. When the solar is not producing and the BESS is depleted the utility is supplying energy to the loads. Under normal conditions, the generator is disconnected and does not operate.

Error! Reference source not found. illustrates how the microgrid operates during short utility power outages (<24 hours). During short utility power outages, the relays sense the utility has lost power. The MGC disconnects the system from the utility power and the connected loads draw power from the Solar PV and BESS systems, operating in "island mode". The solar PV and BESS have been optimized and designed to maintain normal operations for at least 24 hours. During the spring and summer months, operations can be supported for even longer since solar PV generation is maximized and able to fully recharge the BESS daily. During short outages, the generator remains in standby mode and does not supply power to the microgrid. This minimizes operating costs and carbon emissions while operating during a power outage. However, weather conditions are unpredictable. If clouds or rain impede solar production, the generator remains on standby as a backup power source.

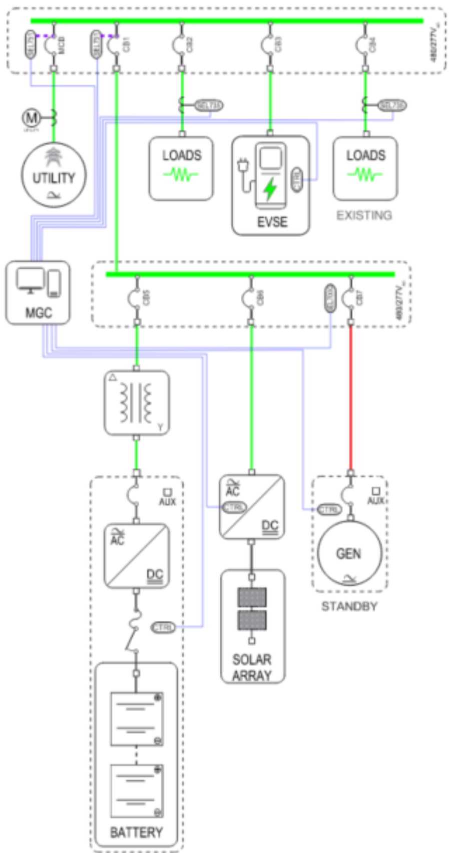


Figure 5. Microgrid Operation During Normal Conditions

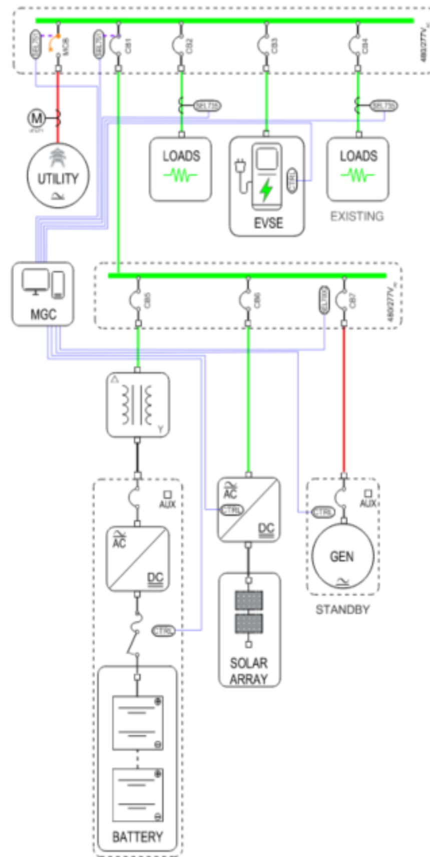


Figure 6. Microgrid Operation During Short Utility Outages

Long Term Outages

Only during extended power outages will the microgrid connect the generator (Figure 8). If the battery State of Charge (SOC) falls below a predetermined set point, the microgrid will activate the standby generator. During this time, solar production is deactivated and the generator recharges the battery. Once the battery is fully charged, the solar is reactivated with the generator back in standby mode. As long as there is a stable natural gas supply, the microgrid can operate indefinitely. The cycle repeats - the solar PV remains connected and supplies power to the facilities; the EV charges and continues to recharge the BESS during daylight hours. Should the generator fail, the BSOOB system is designed to support and quickly connect a mobile generator. Lastly, if the microgrid needs to be taken offline for repairs or maintenance, it can be isolated and disconnected from the electrical distribution. (Figure 7). During this "maintenance mode" the facilities and EV charging would be connected to the utility.

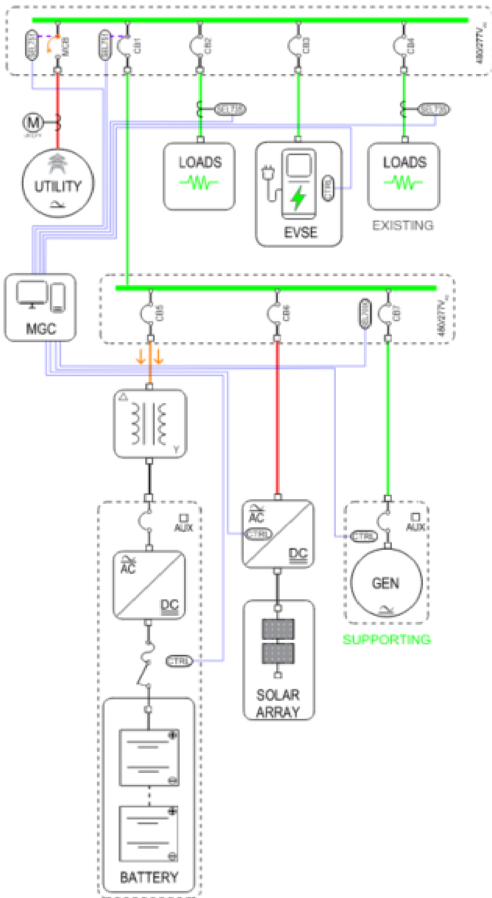


Figure 8. Microgrid Operation During Long Utility Outages

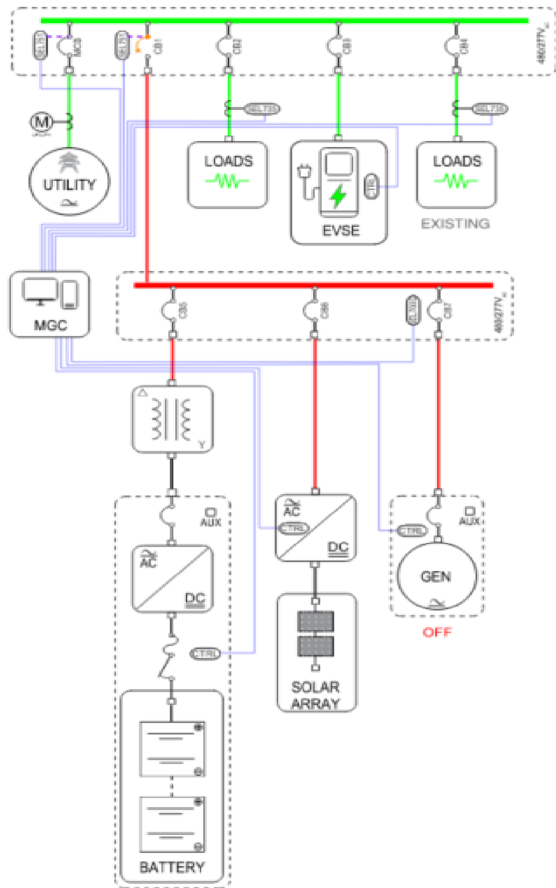


Figure 7. Microgrid Operation During Maintenance Mode

Table 3 – Microgrid Sequences of Operations

Step	MCB	Utility	CB1	Microgrid	CB5	BESS	CB2 | CB4	Loads	CB3	EVCS	Description
1	Closed	Available	Closed	Connected	Closed	Following	Closed	Energized	Closed	Energized	Initial conditions. Utility normal, BESS in following mode, charges and discharges, PV supports loads and fleet EVSE.
2	Closed	Abnormal	Closed	Connected	Closed	Following	Closed	Energized	Closed	Energized	Utility deviation detected. BESS and PV will stay in following until utility parameters exceed allowable range.
3	Open	Unavailable	Closed	Connected	Closed	Forming	Closed	Energized	Closed	Energized	Utility unavailable. MCB opens by protective relay command. BESS goes from following to forming / PV operates with BESS as the forming source.
4	Open	Unavailable	Closed	Connected	Closed	Forming	Closed	Energized	Closed	Energized	Utility unavailable. BESS & PV have been supplying site loads and BESS has reached minimum SOC threshold.
5	Open	Unavailable	Closed	Connected	Closed	Charging	Closed	Energized	Closed	Energized	MGC signal Generator start and loads are now supplied from the Generator. PV output shutdown during Generator operation.
6	Open	Unavailable	Closed	Connected	Closed	Charging	Closed	Energized	Closed	Energized	Generator supplies site load and charges the BESS until SOC Max is restored.
7	Open	Unavailable	Closed	Connected	Closed	Forming	Closed	Energized	Closed	Energized	Once the BESS reaches SOC Max threshold while charging from Generator the MGC will command the Generator to stop.
8	Open	Unavailable	Closed	Connected	Closed	Forming	Closed	Energized	Closed	Energized	System supplies power to site loads with BESS and PV until the utility is restored or BESS minimum SOC threshold is reached again.
9	Closed	Available	Closed	Connected	Closed	Following	Closed	Energized	Closed	Energized	Utility restored. MGC initiates reconnection to resume normal operations. Back to Step 1.
MM	Closed	Available	Open	Unavailable	Open	Unavailable	Closed	Energized	Closed	Energized	Utility connected. Micro-grid is disconnected with all DERs non-operational during repairs & maintenance.

Evaluation Findings

The evaluation of the microgrid and the findings are based on a variety of models on how the microgrid would perform under various conditions. The prototype for this Stage 1 project is the 30% design, which has identified and sized key components that, when built, will provide the expected benefits described in this report. The evaluation of the microgrid and the findings are based on a variety of models on how the microgrid would perform under various conditions. Some of the modelling software used in this project include:

> **Helioscope.** Helioscope is a cutting-edge software platform designed for solar photovoltaic (PV) system design, performance modeling, and analysis. It is widely used by solar developers and accounts for a variety of factors including but not limited to model-specific efficiency and degradation, shading, local solar irradiance, inverter performance, and soiling losses. Helioscope was used to select solar modules, size and place the overall system, and estimate annual energy generation.
> **Energy Toolbase (ETB**). ETB is a robust software platform designed for modeling, analyzing, and optimizing the financial performance of energy storage and renewable energy projects. It is commonly used by energy developers, to evaluate the economics of solar PV, battery storage, and hybrid energy systems. ETB was used to size and estimate pricing for the BESS system for this project.
> **RESTORE.** RESTORE is E3's distributed energy resources (DER) price-taker optimization model. RESTORE maximizes the net benefits of flexible DER technologies such as solar, storage, and firm generation. This tool is used to assess a wide range of technologies and use cases including asset valuation, cost-benefit analyses, market operation simulations, utility retail rate design, and adoption modeling for a diverse set of clients, including utilities, government agencies, developers, and investors. In this analysis, RESTORE was used to evaluate and determine the optimal technology dispatch of the PV, BESS, and a back-up natural gas generator to meet facility and bus charging load needs based on electricity load, vehicle driving profile, vehicle and charger parameters, and retail rates. Key RESTORE outputs for this study include customer electricity bill impacts for each scenario and year modeled.

The most important metric to evaluate is the expected reliability and resiliency of the proposed microgrid. This is further described in Part 3. The microgrid is expected to provide resiliency for short term outages with just solar and BESS. If BSOOB experiences multi-day outages the natural gas generator is expected to be able to meet that demand as long as the natural gas supply remains stable. As noted this evaluation is based on models and historical data. If BSOOB makes significant changes to their operations, outage frequency and duration increase significantly from historical outages, or natural weather variations reduce solar irradiance in a given year, then actual performance may vary from modelled results.

Another important metric to evaluate is the financial benefits of the system, also described further in Part 3. The microgrid is expected to eliminate nearly all of BSOOB's energy charges through solar generation, storage, and CMP's current net billing polices. If CMP updates their net billing policies before the microgrid can be constructed, actual cost savings may be reduced.

The Stage 1 project focused on researching different offerings and designing a system that would meet BSOOB's resiliency needs while also addressing DOT's SMART goal areas. The resulting prototype of the Stage 1 project is a 30% design with benefits based on a variety of robust modelling analysis. A summary of how this project furthers DOT's goals is summarized in Table 4, with additional details described further in noted sections.

Table 4 – Project Benefits Towards DOT Goals

DOT Goal Area	Project Benefits
Safety and reliability	BSOOB is obligated to provide as needed transportation support in support of emergency responders during natural disasters including climate caused widespread outages. This project provides the necessary resiliency for BSOOB to reliably operate EV buses during disasters or outages, providing key support to larger public safety operations. Additional information on safety benefits of specific equipment included in this project are described in Section 1.
Resiliency	This core feature and primary benefit of the microgrid is to provide the resiliency necessary for BSOOB to maintain reliable transit operations during climate change induced short duration or long duration outages. In most conditions, the microgrid is expected to provide at least 1 day of backup for typical operations with carbon-free electricity before needing to tap into the generator for multiday backup.
Equity and access	Several of the census tracks in BSOOB's service territory are classified as Historically Disadvantaged Communities per the Climate and Economic Justice Screening Tool. The microgrid will support these Historically Disadvantaged Communities by helping BSOOB provide reliable transit service even when natural disasters create power outages.
Climate	The microgrid will ensure that BSOOB can reliably operate its electric buses to sustain the emission reductions associated by transitioning away from diesel buses. Electric buses do not emit greenhouse gases, though emissions may be associated with the electricity used to charge the buses. The solar PV component of the microgrid will generate over 100% of fleet's annual energy demand on an annual basis, resulting in reducing carbon emissions by 86 metric tons per year. Additional details are described in Section 3.
Partnerships	Developing the microgrid further will require close partnerships with a project developer to complete the design and construct the project. BSOOB will procure the project developer during Stage 2. The project developer will need to work closely with the vendors for each component of the microgrid and then competitively bid out the work to local installers to construct the microgrid once design is complete.
Integration	The microgrid controller is the key component that will integrate different elements of the larger fleet electrification project into one cohesive system. The microgrid controller monitors all of the different components including the solar PV, BESS, generator and EVCS and optimizes the operation of each component. For example, it can control when the BESS discharges to charge the vehicles and support the facility for cost savings or resiliency purposes.
Workforce Development	The transportation sector is increasingly moving away from fossil fuels and as they do, resiliency will continue to be a critical piece of overall operations. By investing in new technology BSOOB will be developing its own workforce so they are prepared for the future. BSOOB's staff will receive training as part of the microgrid construction so they can develop the skills needed to maintain the microgrid in the long run. Additional details on the types of training BSOOB staff will receive under this project is included in Section 5. Lastly, BSOOB is hosting an EV Charging Training Workshop to educate the public and other key local stakeholders on the basics of EV charging and how to properly plan EVCS projects. This workshop will increase broader awareness and illustrate the benefits of converting our decarbonizing our transportation sector.

Performance Metrics

The prototype for this Stage 1 project is the 30% design, which has identified and sized key components that, when built, will provide the expected benefits described in this report based on equipment specifications and the modelling software used during the Stage 1 performance period. As this project is implemented, BSOOB will need to measure several key performance metrics to ensure that the microgrid operates and provides the modelled benefits. Some of these performance metrics include:

- **Microgrid Reliability.** The most important performance metric is how reliably the microgrid performs, which includes measuring multiple variables.
    - **System Uptime/Availability (%):** This is a measures how often the microgrid is operational and available to provide power to the buses. Typical minimum standards for microgrid uptimes is at least 99.9%.
    - **Mean Time Between Failures (MTBF):** Indicates the average time between system failures, which is critical for ensuring consistent bus charging and overall microgrid operation. Each component will have a different MTBF and may vary between 5,000-10,000 hours.
- **Solar Generation.** Actual annual solar generation versus modelled production, in kWh per year. When the solar PV system is installed it will include a production guarantee of at least 90% of the modelled annual production, adjusted for weather. The production guarantee should be in place for at least 3 years, and could be extended to 10 years if BSOOB deems necessary.
- **Battery Performance.** Battery performance will be judged based on multiple metric that all impact its utilization and will be determined by its state of charge, charge, and discharge cycles during typical normal operations and outages. Some of these metric include:
    - **Round-Trip Efficiency (%):** Assesses the efficiency of energy storage systems (batteries), calculated as the ratio of energy output to energy input. The Tesla MegaPack has a round trip efficiency of over 90% which is greater than typical BESS systems that average 80-85% round trip efficiency.
    - **Availability Guarantee (%):** Availability is calculated as the ratio of the time the system is operational, excluding scheduled maintenance, to the total time in the evaluation period. Typically these are a minimum of 95% but can be as high as 99% for critical operations.
- **Cost savings**. Actual electric bills versus modelled bills, and actual reduced fuel expenses, in dollars per year. This will depend on several factors and will need to be adjusted if BSOOB changes its route schedules over time.
    - The microgrid is expected to reduce BSOOB's electric bill by 97% relative to powering buses only on grid power. This will need to be adjusted as actual energy rates change over time.
    - Fuel savings. By reliably powering the electric buses, BSOOB should see approximately $100,000 per year in annual fuel cost savings. Actual performance will need to be adjusted based on the average cost per gallon of fuel as fuel costs change over time.
- **Environmental Impact.** The microgrid will enable BSOOB to reliably operate zero-emission buses and power them with renewable energy. The microgrid should track the solar production and the resulting avoided GHG emissions. The microgrid should avoid at least 144 metric tons of CO_2 per year once the fleet is fully electrified.
- **Island Mode Operation Duration (hours):** This metric measures how long the microgrid can operate independently during a grid outage. The microgrid should be able to operate for over 161 hours over the course of a year in island mode to cover the expected short and long duration outages. Actual performance will be based on actual CMP reported outages and any downtime BSOOB experienced during those outages.

Additional DOT priority metrics of this project are described below.

- **Scalability.** This microgrid is designed to meet 100% of BSOOB's resiliency and energy needs to support its entire fixed route fleet. BSOOB has additional trolley and commuter buses in its fleet that may need to be electrified in 20 years. While excluded from this analysis, all of the elements of the microgrid can be scaled up as needed to support additional vehicles and load.
  - There are additional locations on the site to expand the solar PV, including carports over light duty vehicle parking areas, and distribution equipment areas.
  - Additional BESS can be added to the microgrid to provide additional resiliency.
  - The microgrid controller included in this project would be able to incorporate additional equipment added to the system in the future.
  - Charge management software can limit any new loads to fit within the generator's maximum output. This avoids the need for requiring a new generator.
- **Replicability.** While every transit agency and microgrid would be unique, the components of this microgrid all leverage the most innovative products on the market currently available from established vendors. This allows other small, rural transit agencies to use this design a building block for their own microgrids.

Part 3: Cost-Benefit Analysis

E3 evaluated the costs and benefits of the proposed BSOOB microgrid in order to forecast financial impacts and operational savings of implementing the project at-scale. E3 analyzed three different scenarios, comparing expected impacts for maintaining BSOOB's current, partially electrified bus fleet vs. fully electrifying the bus fleet without adding a microgrid vs. full fleet electrification plus the microgrid implementation. Planned and separately financed expenses associated with the bus fleet electrification will form a baseline for evaluating the microgrid's incremental costs and benefits. Over 20 years, bus electrification alone will provide approximately $2.8 million in benefits, or savings, at a cost of only $2.3 million. The addition of the microgrid provides incremental benefits of $12.5 million, compared to $12 million in costs (before IRA tax credits). Combining these two efforts would then result in benefits of approximately $15 million in benefits versus $14 million in costs. Including anticipated tax credits as a delayed benefit could drive the total benefits up to $17 million.

It is important to recognize that many of the project costs would be incurred up-front, while benefits would appear throughout the project life. When discounting future value streams at a 7% nominal rate, the combined net present value of the microgrid and electrification it supports is $11.19M, with a net present cost of $11.26M, indicating that the ongoing benefits of the project could approximately cover its costs if also expected to provide a 7% return. The microgrid alone provides net present benefits of $9.5M against $9.8M in costs at the same discount rate. At lower discount rates, the benefits fully cover or exceed the costs. The benefits quantified in this report are also expected to slightly underestimate the true societal value that the microgrid will provide. Due to a lack of regional data available, air quality improvements and resulting public health benefits from use of electric buses and the microgrid could not be calculated with a high degree of certainty and so are not factored into this valuation. The microgrid could also be used to support other electric fleets in the region, if needed. Since no data was available on how other fleets may incorporate electric vehicles into their operations, the additional community benefits the microgrid could support are not included in the total calculated benefits.

The most direct, though not necessarily largest, return on investment provided by the microgrid will be the operational cost savings it provides BSOOB – allowing BSOOB to charge buses from its own on-site generation and even export excess generation to minimize its electricity bills. Once BSOOBs fleet is fully electrified, these electricity bills will amount to nearly $1 million in operating expenses over the next 20 years, which may be nearly eliminated through use of the microgrid.

Given the essential role of BSOOB's fleet in connecting local communities, it is crucial that the electrified fleet is able to reliably serve its routes and the communities' needs, even in the face of frequent and often prolonged electric system outages that the region experiences. Resiliency value will therefore play a large part in the evaluation of the microgrid's costs and benefits, despite not being a traditionally monetizable factor. In fact, this analysis determined resiliency to be the greatest single benefit of the proposed microgrid, amounting to over half a million dollars in value every year.

BSOOB's microgrid will be primarily powered by solar and battery storage, providing the societal benefit of reducing emissions from the electricity grid. The proposed microgrid will enable BSOOB's fleet electrification and reliable service, supporting BSOOB to serve its community while piloting innovative technologies to reduce its emissions impact.

Scenario Analysis

E3 compares three scenarios for BSOOB's fleet in the following sections, described in Table 5. Scenario 1 is a reference case in which the status quo of BSOOB's 2025 fleet is maintained. At the moment, BSOOB operates 2 electric buses and 6 diesel buses, but will be obtaining 2 more buses and installing associated charging equipment in 2025. Therefore Scenario 1 reflects the operation of 4 electric buses and charging ports, 4 diesel buses, and no microgrid. This scenario is included to provide a baseline prior to fleet electrification. Scenario 2 represents the full fleet electrification over time, according to the deployment schedule without the microgrid. This scenario, when compared to the baseline, illustrates the benefits of BSOOB's fleet electrification, including reduction in operating costs as well as reduced greenhouse gas emissions. Local air quality improvements are expected to benefit the community, though these are not quantified within this study.

Scenario 3 includes the fleet electrification described by Scenario 2 as well as implementation of the full microgrid. The microgrid includes solar, battery storage, microgrid controller and a natural gas backup generator, as well as cabinets and ports for 4 additional electric bus chargers. While this will incur additional costs without showing clearly monetizable benefits, the addition of these ports will further support the electrification of BSOOB's bus fleet by making an individual charging port available for each of its buses and increase flexibility in the charging schedule. By not having to share ports, buses will be able to optimize use of direct solar generation from the microgrid, thereby minimizing energy losses from cycling the batteries, and will be able to more fully manage charging behavior when drawing from the local electric grid. BSOOB has also experienced challenges in its partial electrification rollout due to charging equipment downtime. These additional ports will be valuable to keep the buses running when one or more chargers is unavailable due to required maintenance.

Table 5 – Cost Benefit Analysis Scenarios

Scenario	Scenario Name	Fleet	Microgrid
1	Reference	2025 Fleet - 4 electric buses, 4 diesel buses	No
2	Full Fleet Electrification, No Microgrid	Fleet fully electrifies over time (8 electric buses, 8 charging ports)	No
3	Full Fleet Electrification, Microgrid	Fleet fully electrifies over time (8 electric buses, 8 charging ports)	Yes

Key Assumptions

Microgrid High Level Power Flows and Solar Export

The microgrid will support the charging of electric buses and onsite maintenance facility load. On a typical day, solar will generate during daytime hours to meet small onsite facility load and charge battery storage while the buses are driving on their routes. Once the fleet has returned to the depot in the evening, battery storage will charge the bus fleet overnight before the fleet departs in the morning. The backup natural gas generator is only intended for use in electricity grid outage conditions.

The microgrid is designed to prioritize solar onsite consumption over grid export to align with the SMART grant and BSOOB's goal of the microgrid supporting fleet charging. Only excess solar not used by storage and onsite load is exported to the grid through Maine's Net Energy Billing (NEB) program, detailed further in the "Net Energy Billing" section of this report.

Retail Rate

Based on forecasted future BSOOB maximum demand of about 450 kW, E3 expects BSOOB to be on the Central Maine Power Intermediate General Service, Secondary Service, Time of Use Rate (CMP IGS-S-TOU). This rate consists of a fixed service charge, $/kWh energy charges (varies by month), and $/kW demand charges (varies by hour and month). The monthly demand charges are calculated as the sum of highest 15-minute periods during the off-peak and peak times multiplied by rates. CMP is currently in a rate proceeding, and IGS-S-TOU is included in the redesign.[7] E3 incorporated the new proposed TOU period and rate charges, published in the rate case. E3 also forecasted future rate values based on escalating current rate by 3% inflation.

The resulting rate costs are made up of Customer + Generation (Energy and Demand) + Transmission + Distribution charges. The Customer[8] and Transmission[9] charges were escalated from today's CMP rate. For Distribution and Generation Demand charges, CMP forecasted rates to August 2025 which were then escalated. Because CMP is a distribution utility only, customers must pay a separate Generation Energy charge. To forecast the Generation Energy component, E3 used the CMP Medium Non-Res Class standard offer rate and escalated to the model year.[10] The resulting energy and demand charges are illustrated in Figure 9.

Energy Charges (2026$/kWh)

January	$0.166
February	$0.163
March	$0.105
April	$0.081
May	$0.074
June	$0.084
July	$0.102
August	$0.090
September	$0.082
October	$0.082
November	$0.108
December	$0.158

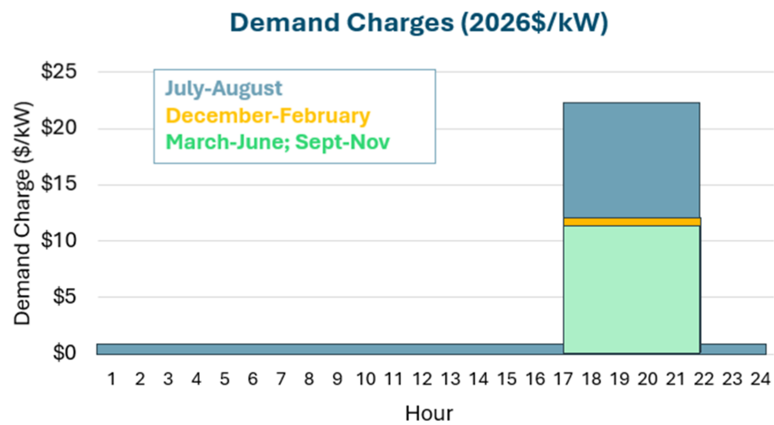


Figure 9. Retail Rate Energy and Demand Charges, Shown for 2026

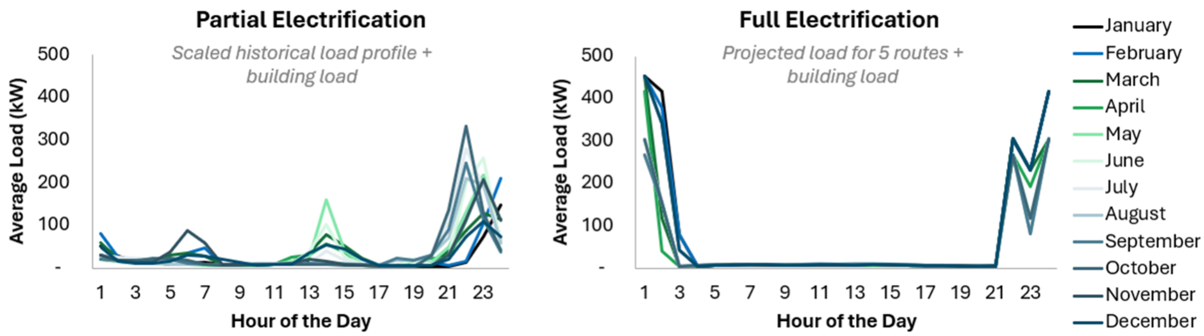
Load Profiles Over Time

Depending on the year and scenario, E3 used two different load profiles. Partial electrification is shown on the lefthand side of Figure 10, which is scaled up from BSOOB's historical bus load to represent four electric buses serving two routes. This load profile is used for 2025 and 2026 in all scenarios, since there will be four electric buses in operation, and for every year in the reference scenario since no more electric buses will be added. The load consists of large demand from bus charging when the buses return to the depot around 9-10pm, with lower morning and midday charging, and small daytime facility demand.

The full electrification load profile on the righthand side of Figure 10 was created by Willdan and described in detail above. This load profile is used for years 2027 onwards for scenarios 2 and 3, which are all eight electric buses. The load consists of large overnight bus charging with small daytime facility demand.

7 Case Filing Item (maine.gov) Central Maine Power Company Request for Approval of Distribution Rate Increase and Rate Design Changes, Pursuant to 35-A M.R.S. § 307, Docket No. 2022-00152, Stipulation (May 31, 2023), Item # 209.
8 Rate IGS-S-TOU Intermediate General Service - Secondary - Time-Of-Use (cmpco.com)
9 Section 44 - Transmission Services (cmpco.com)
10 Central Maine Power Company Medium Non-Residential Class | MPUC

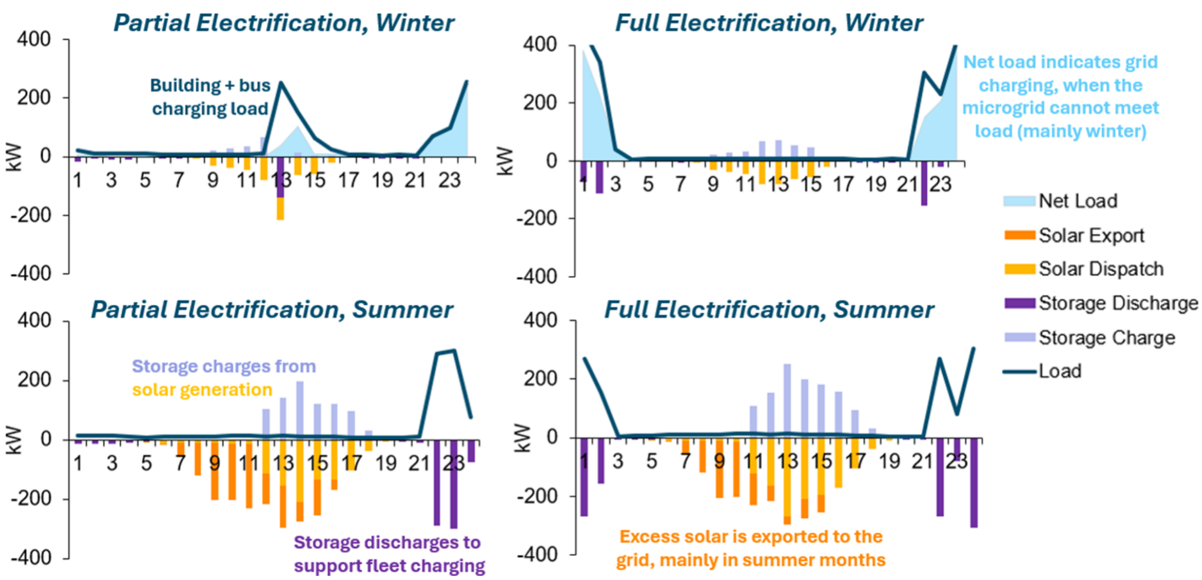
Figure 10. Partial and Full Fleet Electrification Load Profiles



Microgrid Daily Dispatch

E3's distributed energy resources optimization tool, RESTORE, is used to model BSOOB's microgrid operations and electric bills. Two example days of operations are shown in Figure 1111 with the partial fleet electrification case (left) and the full fleet electrification case (right).

Figure 11. Microgrid Dispatch for an Example Winter and Summer Day for Partial and Full Bus Electrification



For all cases, the combined facility and electric bus charging load is represented by the dark blue line above the axis. For the full electrification case, the load is low during the day with facility usage while buses are away on route. Once the transit buses return to the depot in the evening, charging load increases and reaches peak demand overnight. The microgrid technologies are represented by colored bars in the chart. Solar generates midday, represented by the sum of yellow and orange bars below the axis, where orange bars specifically represent solar exported to the grid. Storage charges from solar, represented by light purple bars above the axis, and later discharges to meet load in evening and overnight hours.

Significant seasonal differences are created by much higher bus load in winter driven by bus heating needs, and much lower solar output due to winter weather. In the winter full electrification case, solar generation is so low that the buses will need to charge from the grid to be able to serve their full routes. During the summer, there is excess solar generation than what can be stored in the battery for overnight load use so solar is exported to the grid under the NEB program. Note that the natural gas backup generator is not pictured for a regular day of operations since it is only intended to be used in the event of a power outage.

Microgrid Benefits

BSOOB's proposed microgrid will provide benefits across many of the SMART program goal areas as well as operational cost savings throughout its lifetime. The goal areas of resiliency and climate are quantified in this cost benefit analysis alongside the more explicit financial impacts.

Resiliency Benefits

Resiliency is a crucial consideration for fleet electrification. During power outages, buses cannot charge and therefore risk service disruptions to the community. CMP reports that outages in their service territory are often due to falling trees or limbs, linking outages to storms and severe weather events. These weather events may continue to become more frequent and extreme as the climate changes. Statewide, Maine has declared 8 major disasters in the last two years. Governor Janet Mills has appointed a commission to study disaster response and resilient infrastructure needs.[11] In the following sections, E3 describes their calculation of the resiliency value of BSOOB's proposed microgrid in supporting their electric bus operations.

To quantify the resiliency benefits of microgrid support for transit bus electrification, E3 modeled various length outages throughout the year based on data from EIA[12] and CMP[13], described in Table 6**Error! Reference source not found.**. While it is highly uncertain how many future electric grid outages will occur, historical outages provide a helpful reference point.

Table 6 – Modeled Outages and Sources Used

Month	ISO NE Reported Outages (Hours)	CMP Reported Outages (Hours)	Modeled (Hours)
	EIA, 2023	*CMP News Releases, 2024*	*Using both sources*
January	34	12 to 24	24
February	-	-	-
March	48	48 to 72	48
April	-	48 to 96	48
May	4	-	4
June	-	-	-
July	-	-	-
August	-	-	-
September	30, 14	-	30
October	-	12 to 24	-
November	7	*N/A (future dates)*	7
December	-	*N/A (future dates)*	-
Total	***137***	***120 to 216***	***173***

11 Governing Resilience Article (June 10, 2024)
12 Energy Information Administration Electric Power Monthly, https://www3.eia.gov/electricity/monthly/epm_table_grapher.php?t=table_b_1
13 News Room - CMP (cmpco.com)

The load that would be unserved without the microgrid during an outage is valued at the customer's value of lost load, or "VOLL." VOLL is an economic concept that varies by customer type, location, and willingness to pay and is described in detail in the next section. The final resiliency value is the load during the outages met by the microgrid multiplied by the customer's VOLL.

Resiliency Value ($) = Load Served (kWh) * Value of Lost Load ($/kWh)

Value of Lost Load (VOLL)

Customer resiliency is valued at the "Value of Lost Load (VOLL)." VOLL is used to evaluate the monetary benefits of installing back-up power systems but does not represent any type of payment directly paid to the customer. E3 used a VOLL estimate of $66.49/kWh sourced from LBNL Interruption Cost Estimate (ICE) Calculator[14], which has also been used by CMP in 2015 to study distribution investments in their service territory[15]. E3 reference the Medium and Large Commercial and Industrial (C&I) customer group for BSOOB, which was a conservative estimate compared to the higher VOLL forecasted for the Small C&I group. Inputs to this calculator are the utility's SAIDI (outage minutes per year) and SAIFI (outage times per year), which are IEEE standardized reliability metrics. In 2022, Central Maine Power SAIDI was 856 minutes (5.15 hours) average customer outage duration and SAIFI was 2.7 outages per year.[16]

VOLL estimates have a high range of uncertainty and can vary widely based on assumptions. The resiliency value estimate could be improved with a more BSOOB-specific calculation that considers the essential services provided by the transit agency and associated community impact and activities that would be disrupted. Given these considerations, the current resiliency results provide a conservative estimate of value.

Estimating Load Served During Outages

During forecasted outages, E3 assumed that BSOOB would require full regular bus charging and facility loads. This is a conservative assumption if the BSOOB depot supports additional charging load for providing emergency services or serving additional vehicles. Higher forecasted load during an outage would produce higher forecasted resiliency value.

The timing and duration of power outages significantly impacts the potential resiliency value to BSOOB. E3 conservatively assumed that if the outage is less than 24 hours, it occurs during hours when buses are not charging or could shift charging loads when grid electricity returns before morning vehicle deployment. If the outage is longer than 24 hours, then the buses must charge during the outage to be able to complete their normal service. E3 assumed that load was met by solar and available storage state of charge followed by natural gas backup generation. Usage of the natural gas backup generator would primarily occur during long grid outages in winter months when solar generation is low and bus load is high.

Resiliency Results

The value of resiliency for BSOOB's fleet is a significant benefit. E3's estimation results in an annual resiliency value of $310,000 for the partial electrification case and $620,000 for the full electrification case, shown in Table 7.

Table 7 – Resiliency Value

	Outage Hours	Partial Electrification	Full Electrification
Units	*hours*	*$*	*$*
January	24	$32,000	$60,000

14 LBNL Interruption Cost Estimate Calculator: https://www.icecalculator.com/interruption-cost

15 CMP Usage of ICE Calculator: : https://live-etabiblio.pantheonsite.io/sites/default/files/nexant-ice-calculator-cmp-dist-automation-nov-2015.pdf

16 Energy Information Administration Annual Electric Power Industry Report, https://www.eia.gov/electricity/data/eia861/

	Outage Hours	Partial Electrification	Full Electrification
Units	*hours*	*$*	*$*
February	-	-	-
March	48	$110,000	$226,000
April	48	$100,000	$204,000
May	4	$1,000	$2,000
June	-	-	-
July	-	-	-
August	-	-	-
September	30	$63,000	$125,000
October	-	-	-
November	7	$3,000	$3,000
December	-	-	-
Total	***161***	***$310,000***	***$620,000***

The resiliency value could increase with a higher VOLL, frequency and duration of outages, and load needs. Based on the deployment schedule of the electric buses, the net present value of resiliency is $7.1M over the model horizon, using a 7% discount rate and assuming the outage details and VOLL remain the same over time. The resiliency value estimate provided represents a conservative assumption given that it does not directly quantify the BSOOB-specific value of lost load and transit services or incorporate the potential increase in grid outages in the future with more extreme weather events.

Climate Benefits

The electrification of BSOOB's transit bus fleet will provide baseline climate and air quality benefits by transitioning away from diesel fuel use. Installing a solar-powered microgrid to supply clean electricity for BSOOB's fleet will amplify these benefits and reduce carbon emissions from the local electric grid.

The incremental climate benefits from the microgrid can be measured by the solar energy it produces, or more specifically, the net reduction in electricity consumed from the local grid. Because the microgrid relies primarily on clean electricity and the New England electric grid still relies in part on fossil fuels, every kilowatt hour that the buses can charge from the microgrid instead of the electric grid results in emissions savings.

The National Renewable Energy Laboratory's (NREL) Cambium model provides forecasted marginal carbon dioxide-equivalent emissions factors for Maine's electric grid through the study horizon. In 2025, at the start of the study horizon, the forecasted average marginal emissions rate is 0.00028 metric tonnes of carbon dioxide equivalent (tCO2e) per kilowatt hour.[17] This emissions rate gradually decreases over time as the grid becomes cleaner. By multiplying these factors by the tens of thousands of kilowatt-hours consumed from the grid each year, it is possible to estimate the grid emissions with and without the use of the microgrid. The savings from the microgrid implementation are very slightly reduced by the use of the natural gas back-up generator, which has an emissions factor of around 0.0010 metric tonnes of carbon dioxide equivalent per kilowatt hour.[18] However, the total impact of the generator is very small given its limited expected use during electricity grid outages throughout the year.

Taking these emissions factors into account, the microgrid is able to avoid 86 metric tonnes of carbon emissions by 2027, once the microgrid is in place and the majority of BSOOB's fleet electrified. If converted to a

[17] NREL Cambium 2023 Data Viewer. Average of long run marginal CO2e rate for 2025, ISONE - ME electric grid
[18] Derived from manufacturer throughout rate operating at 25% capacity and EPA GHG Emissions Factors Hub 2024. https://www.epa.gov/climateleadership/ghg-emission-factors-hub

dollar impact using the U.S. Environmental Protection Agency's (EPA) social cost of carbon (SCC), this is equivalent to around $22,000 in emission savings from the use of the microgrid in this year alone.[19] At this point in time, the electrification of the buses themselves would be avoiding an additional 58 tonnes of emissions, for a total reduction of 144 tonnes per year. Table 8**Error! Reference source not found.** displays this comparison. Over the course of the project horizon, the discounted net present value of avoided emissions from the microgrid alone is $150,000. When combined with the impact of bus electrification, BSOOB would avoid over $500,000 in carbon emissions compared to maintaining its 2025 bus fleet without the microgrid.

Table 8 – 2027 Emissions Values with and without Microgrid

	Emissions Factor	Emissions with 2025 fleet	Emissions without Microgrid	Emissions with Microgrid	SCC Impact of Microgrid alone
Fuel Source	*tCO2e / kWh*	*tCO2e*	*tCO2e*	*tCO2e*	*$ (Annual)*
Diesel Buses *(tCO2e/mile)*	0.00151	152.21	38.05	38.05	-
Grid Electricity	0.00021	61.44	117.90	30.81	-$22,566
Solar + Storage	-	-	-	-	-
Backup Generator	0.00096	-	-	1.07	$276
Total Annual Emissions		***214***	***156***	***70***	

Operational Savings

In addition to supporting the community's resiliency and additional SMART grant goals, use of the microgrid will avoid nearly all electricity costs that BSOOB incurs over time from its electrified bus fleet. As BSOOB transitions from a primarily diesel to electric bus fleet, it anticipates fuel cost savings from using electricity instead of purchasing diesel. BSOOB plans to manage its charging patterns to make the transition even more efficient and even without the microgrid would ultimately end up with around $70,000 in annual electric bills instead of over $100,000 in annual diesel costs.

By implementing the microgrid, BSOOB will be able to generate further savings by charging its buses directly from solar anytime the sun is shining and the buses are at the depot. When the buses are en route, BSOOB can opt to either charge idle buses or the onsite storage, so that the active buses can be charged overnight. Similar to the emissions savings from reducing its consumption from the electricity grid, BSOOB will save money directly on its electric bills and avoid incurring the volumetric charges on its bills.

Net Energy Billing (NEB)

Maine's NEB program allows customers to offset their electricity bills with output from renewable generators smaller than 5 MW. This program is under reform, but currently offers $0.1729/exported renewable kWh. This NEB Rate is set annually by Maine Public Utilities Commission (PUC). In order to participate in NEB, BSOOB's site must be technically and electrically compliant, which includes additional controls to demonstrate that storage system specifically is not discharging to the grid.

E3 expects BSOOB to be eligible to participate in Maine's Net Energy Billing program. This would allow the microgrid to export any excess solar energy it generates beyond load or storage charging needs. This makes the microgrid much more cost effective, because the buses will still need to import some electricity from the grid

[19] US EPA Social Cost of CO2 (2.0%) from https://www.epa.gov/system/files/documents/2023-12/epa_scghg_2023_report_final.pdf

during winter months when solar output is low. BSOOB can make up for that by selling excess generation back to the grid during sunny summer days and earn credits on its bill for the energy exported. Under the NEB program, these bill credits can carry over month-to-month and offset all volumetric charges incurred during the winter. Based on the sizing of the microgrid system and anticipated exports, BSOOB would only be responsible for paying the fixed charge portion of its electricity bill.

The combination of avoided grid energy use and exports during periods of excess generation would reduce BSOOB's annual electricity bills from approximately $77,000 to $2,100 in 2026. The incremental microgrid savings would be around $70,000 per year in 2026 dollars in subsequent years. Over 20 years, the cumulative annual savings would total $1.1 million, or a net present value of approximately $700,000.

Non-Quantified Benefits

The air quality benefits associated with both the transition from diesel to electric buses and from reducing reliance on fossil-fuel generated electricity from the grid has not been quantified as part of this analysis. Both the use of electric over diesel buses and of a primarily solar-powered microgrid over the local electric grid will help to avoid negative air quality impacts. Diesel-powered bus engines emit harmful particulate matter, nitrogen oxides, carbon monoxide, and other pollutants which have a range of negative health impacts both for the bus riders and local communities. Switching to the use of electric buses can reduce these types of emissions similar to the reduction in greenhouse gas emissions. Relying on the local electric grid, which still includes some fossil fuel-based generation, will still result in some adverse impacts to air quality, so taking the further step to power the buses from solar on the microgrid will produce even greater benefits. These benefits have not been quantified within this analysis because detailed data is not available on the same selection of air quality pollutants from the local electric grid versus diesel buses and so the avoided emissions cannot be directly compared with a high degree of confidence.

Microgrid Costs

Over the project life, the microgrid will require capital costs for siting and equipment and will incur operational costs tied to both the maintenance of the system and fuel for the back-up generator. These expenses are described in the following section. Because the emissions impacts of the backup generator have already been described and netted out from the climate benefits, they are not included here.

Capital Costs

The bulk of expenses for BSOOB's microgrid will be accrued in the form of capital costs. These costs will cover preparation and grading of the site, as well as the solar array, battery storage, backup generator, additional chargers, and all of the supporting structural and electrical equipment needed to connect and control these systems. Table 9 lists these up-front costs for 2026, the soonest the microgrid can be installed. The solar and storage system costs provided include costs for installation and supporting equipment and will be the primary capital expenses for the microgrid. Storage system costs are described in terms of kWh of battery capacity.

Table 9 – Microgrid Capital Costs (2026$, rounded)

	Unit Cost	Total Up front Cost
Capital Expenditure	*$ / Unit (varying)*	*$*
Site Improvements	-	$1,000,000
Solar System	$5,275 / kW DC	$2,300,000
Storage System	$1,050 / kWh	$2,750,000
Backup Generator	$2,700 / kW DC	$1,700,000

Charging Ports (average per port, including cabinet)	$ 390,000 / port, up-front ($72,000 / port, replacement)	$1,550,000

Solar system costs are estimated based on typical current costs for rooftop and carport systems. Capital costs for the solar PV, BESS, and EV chargers are before potential Investment Tax Credit (ITC), which could provide up to a 30% tax credit or more for these line items, explained further below. Site improvement costs are based on engineering estimates give the area that would need to be graded. This is the most uncertain cost estimate as it could change significantly after a survey is completed. Capital costs for the storage system, backup generator, and charging equipment are based on equipment manufacturer quotes and engineering estimates for installation. Furthermore all costs are turnkey cost estimates and account for design, construction management, and administrative costs to complete the project.

Combined capital costs for the microgrid and additional ports total to just under $9.3 million in 2026.

Useful life and Replacement cost

The solar system and back-up generator are both long lived pieces of equipment expected to last throughout the 20-year study horizon with proper maintenance and care. The storage system, on the other hand, has an expected useful life of 15 years and so would likely need to be replaced again during the horizon. For the purposes of this study, we assume 0% nominal escalation for the storage system capital cost, taking this as an intentionally conservative assumption. This was referenced against NREL estimates of energy storage costs declining at a rate of 2.8% in the near term and 0.21% in the long term.[20] As a result, anticipated storage replacement occurring in 2041 is estimated at a cost of approximately $2.75 million in nominal 2041 dollars. After this replacement, the useful life of both solar and storage would continue beyond the study horizon, though salvage value is not assumed for this analysis.

The charging stations also have a shorter expected useful life of 10 years. However, only the stations themselves would require replacement, the supporting infrastructure would not need to be replaced. These costs are modeled as escalating at 3% nominal over time, so the eventual replacement in 2036 is forecasted to cost $390,000.

Operational Costs

Though the microgrid is expected to provide overall operational savings to BSOOB and its fleet, the operations and maintenance of equipment on site also comes with a share of additional expenses. These O&M expenses, as well as the cost of fuel expected for the natural gas backup generator, are described in Table 10, using 2026 as an example year.

Table 10 – Microgrid Unit and Annual Operating Expenses (2026$, rounded)

	Unit Cost	Total Cost
Expense Type	*$ / Unit (varying)*	*$ / year*
Solar O&M	$33 / kW DC	$14,500
Storage O&M	$3.66 / kWh	$2,400
Backup Generator O&M	$43 / kW DC	$27,000
Backup Generator Fuel (Natural Gas)	$17.33 / MMBtu	$3.32*
Charging Port O&M	$3,200 / Port	$25,000

**Once all electric buses are operating in 2027, the backup generator annual fuel expense is modeled to increase to $360*

[20] Calculated from NREL Annual Technology Baseline, found at https://atb.nrel.gov/electricity/2024/index

Solar O&M cost is estimated from current market rates for typical solar PV O&M services. Storage O&M is determined based on quoted cost figures for the selected Tesla BESS storage system, and the backup generator O&M is based on an NREL study comparing natural gas and diesel generators.[21] Generator fuel costs come from the weighted average annual unit cost from BSOOB's recent natural gas bill with Unitil, its local utility provider.[22] Charging port O&M is based on quotes obtained from selected manufacturers and adjusted for labor. All O&M and fuel unit costs are modeled to escalate at a nominal 3% per year.

In total, annual operating expenses tied to the microgrid and additional ports are estimated to be $69,000.

Inflation Reduction Act Tax Credit Direct Payments

The Inflation Reduction Act (IRA) includes several tax credit provisions for entities that purchase electric vehicles or install new solar PV, BESS, microgrid, and EVCS assets. While BSOOB is a tax-exempt entity, the IRA included provision for public agencies to claim these credits as a direct payment following completion of a project. At the time of this report no changes have been made to the IRA since its initial passing, and it is unknown how the Trump Administration may change the tax credits in future years.

For Solar PV & BESS, the tax credit percentage has been estimated at 25.5%, and applying this to the estimated eligible PV & BESS costs of $5,050,000, the dollar value would be estimated at $1,287,750. The assumptions used to make this estimation are as follows:

- Prevailing Wage and apprenticeship requirements met
- Project Construction Commencement in 2025
- Equipment is not considered Domestic Content eligible (final IRS guidance is pending on this matter, and eligible equipment availability is still not a given at the time of writing this report, so a conservative approach was taken to assume equipment used is not eligible)

For projects over 1 MWac in size that utilize the Direct Payment, if Domestic Content is not used, the bonus is not granted, and in addition a reduction is applied. For projects commencing construction in 2025, it is a 15% reduction, and projects commencing construction in 2026 or later, there is a 100% reduction in the ITC Direct Payment.

EVCS are eligible for tax credits as long as the EVCS are installed in a qualifying low-income or non-urban census tract. BSOOB's main bus depot is in a qualifying census tract, and thus is eligible for EVCS tax credit. The value

[21] https://www.nrel.gov/docs/fy19osti/72509.pdf

[22] Natural gas price is converted from $ / Therm, and includes distribution, supply, EERA, and ERC charges. The resulting value also aligns with the Energy Information Administration commercial price estimated for Maine at $17/MMBtu.

Federal ITC Estimate	
Customer:	**BSOOB**
Project:	**Microgrid - Solar & Storage**
Percentage Basis Estimate	
30.0%	Base Credit
0.0%	Domestic Content Bonus
0.0%	Energy Community Bonus
30.0%	**Initial ITC Percentage Basis**
Reductions	
15.0%	Lack of Domestic Content (if >1MWac)
0.0%	Tax-Exempt Financing
25.5%	**Final Estimated ITC Percentage**
Dollar Value Estimate	
$ 5,050,000	Total ITC Eligible Project Costs
$ 1,287,750	**Final Estimated ITC Value**

of this credit is either 6% or 30% of the cost of property subject to depreciation, with a maximum credit of $100,000 for each single item of property. The 30% credit can be claimed if the project meets labor requirements including laborers being paid prevailing wages and at least 15% of the labor hours are completed by apprentices. It is assumed that BSOOB will be able to meet this labor requirement to claim the full 30% tax credit. The microgrid cost estimates assume prevailing wage labor is used.

The IRS has indicated that a single item of property is each charging port. The costs of components and parts that are essential to the operation of the charging port or fuel dispenser, including labor costs for constructing and installing the property, are also eligible for the credit. Based on IRS's guidance, BSOOB should be able to claim tax credits for the two dispensers added to the existing power cabinets as well as the new power cabinets and dispenser. The estimated tax credit for the two new dispensers on the existing power cabinets is $86,604 and the tax credit for the new power cabinets and dispensers is estimated to be $400,000.

Electric vehicle purchases are eligible for tax credits under the IRA. Electric vehicles with a gross vehicle weight rating greater than 14,000 pounds are eligible for a tax credit of 30% of the incremental cost of the electric vehicle compared to an internal combustion engine vehicle up to $40,000 per vehicle.

In all cases, the tax credit is assumed to be claimed the year following the purchase of the vehicles or installation of the equipment. Final tax credits will depend on the final design and cost. BSOOB will need to work with a financial or tax advisor to register and file for the tax credits. Tax credits and grant funding combined cannot exceed the total project costs. If this project is fully funded with a grant, BSOOB may not be able to capture the tax credits. Since grant funding has not been secured at the time of this report, the financial analysis assumes that BSOOB is able to capture these tax credits.

Comparison of Benefits and Costs

The intent of the microgrid is to support BSOOB's transition to a fully electrified bus fleet while ensuring that it can maintain reliable service to meet community needs. To provide the impact of the microgrid in that context, E3 has assessed the benefits and costs of fleet electrification with and without the microgrid in relation to a baseline scenario maintaining BSOOB's existing fleet.

Benefits and costs are presented for Scenarios 1, 2, and 3 in Figure 12 and Table 11. The reference case representing BSOOB's 2025 fleet, Scenario 1, is shown for context on the full range of benefits this project can achieve when paired with fleet electrification. Scenario 2 depicts the fully electric fleet without the microgrid and Scenario 3 depicts the fully electric fleet with the microgrid. Comparing these two scenarios illustrates the incremental costs and benefits of the microgrid itself. Note that the results presented in this chart and table reflect a net present value, discounted at a 7% nominal rate. This ultimately leads to valuing some of the up-front capital costs as more significant compared to the operational savings and resiliency value, both of which accumulate later on in the time horizon.

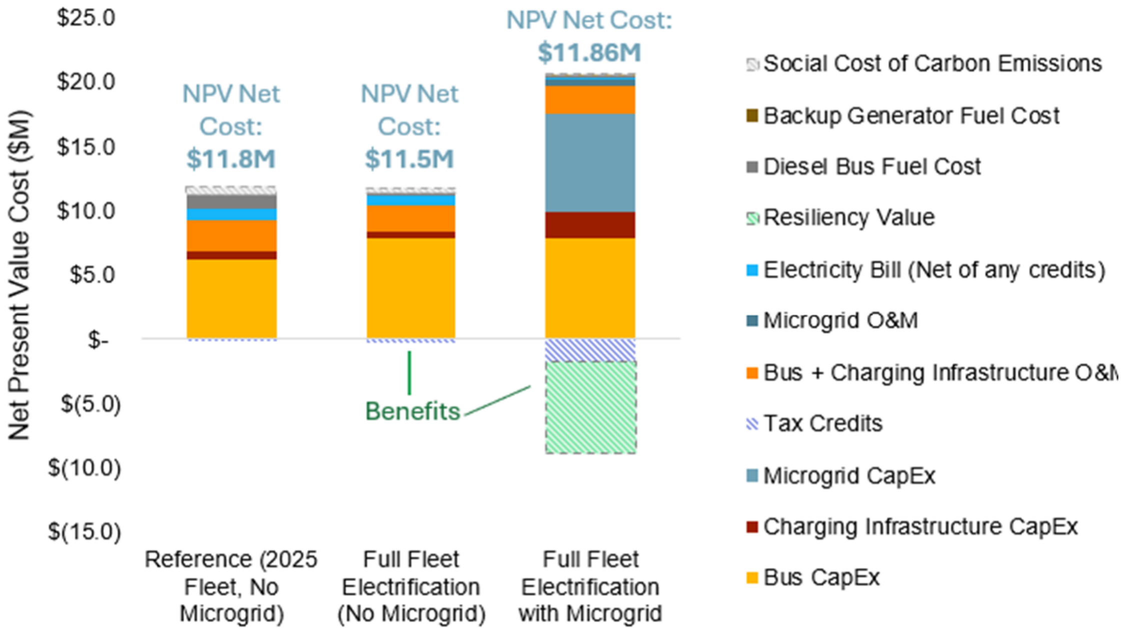


Figure 12. Net Present Value Cost Comparison (2024$ Values from 2025-2044)

Table 11 – Net Present Value Cost Comparison (2024$, rounded)

	NPV Net Cost, 2025 2044
Scenario	*2024$*
Scenario 1 – 2025 Fleet, No Microgrid	$11.8 Million
Scenario 2 – Electrified Fleet, No Microgrid	$11.5 Million
Scenario 3 – Electrified Fleet, with Microgrid	$11.86 Million

Even with discounting and the conservative cost assumptions modeled, Scenario 2 results in a lower NPV net cost than the reference scenario, and Scenario 3, including both the microgrid and additional charging infrastructure, has nearly identical costs to the reference scenario. Table 12 breaks out capital and operational expenses for each scenario relative to one another to determine an incremental benefit-cost ratio for fleet electrification and the addition of the microgrid.

Table 12 – Comparison of Scenario Benefits and Costs (2024$ NPV with 7% nominal discount rate, rounded)

	Fleet Electrification Relative to Scenario 1 (2025 Fleet)		Microgrid + Fleet Electrification Relative to Scenario 1 (2025 Fleet)	
	Benefits	*Costs*	*Benefits*	*Costs*
Incremental Capital Expense	-	$1.57M	-	$10.7M
Incremental Tax Credits	$0.1M	-	$1.6M	-
Incremental Operating Expense/Savings	$1.4M	-	$2.0M	$0.5M
Incremental Emissions + Resilience Value	$0.4M	-	$7.6M	-
Total	$1.88M	$1.57M	$11.19M	$11.26M
Benefit / Cost Ratio	**1.19**		**0.99**	

The benefit-cost ratios from each comparison nearing or exceeding 1 indicates again that BSOOB's fleet electrification and microgrid projects approximately breakeven, even when including a 7% discount rate. This discount rate reflects the cost of capital and risk premium, such that breaking even would reflect earning a 7% annualized rate of return.

For comparison, Figure 13 and Table 13 highlight the results in real 2024 dollars without discounting. Under this sensitivity, looking purely at the cash flows, investments for both fleet electrification and microgrid would achieve a benefit cost ratio of 1.2.

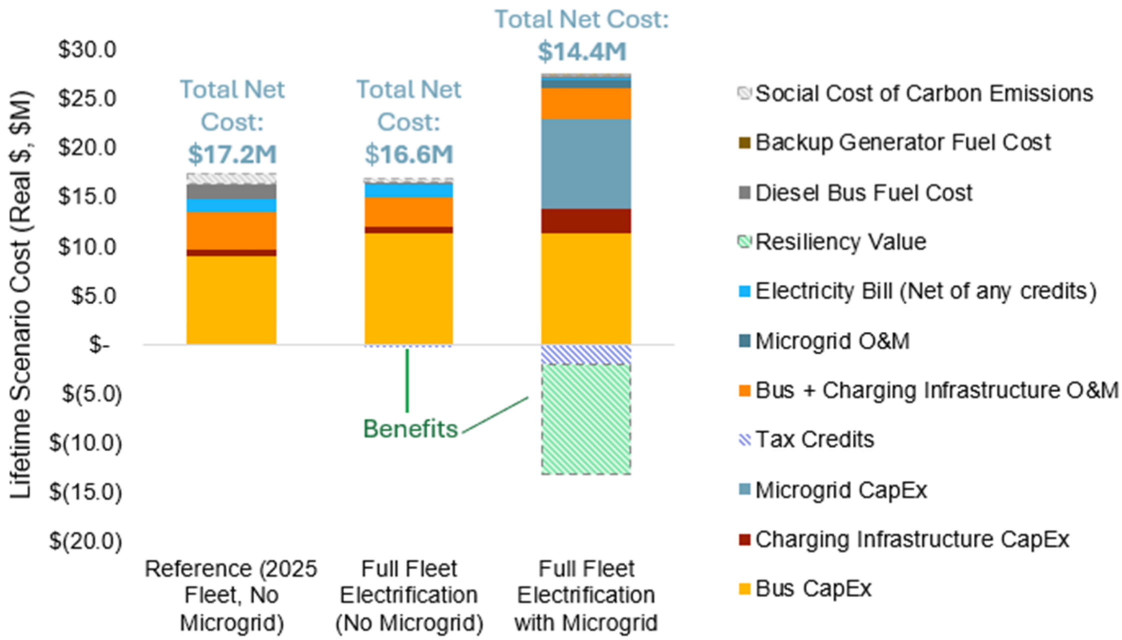


Figure 13. Non-Discounted Lifetime Net Cost Comparison (2024$ Values from 2025-2044)

Table 13 – Comparison of Scenario Benefits and Costs (2024$ without discounting, rounded)

	Fleet Electrification Relative to Scenario 1 (2025 Fleet)		Microgrid + Fleet Electrification Relative to Scenario 1 (2025 Fleet)	
	Benefits	*Costs*	*Benefits*	*Costs*
Incremental Capital Expense	-	$2.3M	-	$13.3M
Incremental Tax Credits	$0.15M	-	$1.9M	-
Incremental Operating Expense/Savings	$2.2M	-	$3.1M	$0.8M
Incremental Emissions + Resilience Value	$0.6M	-	$12.0M	-
Total	$2.95M	$2.3M	$17.0M	$14.1M
Benefit / Cost Ratio	1.26		1.20	

It is important to note that the social cost of carbon and resilience value are not monetizable but do provide value and make up a significant portion of the benefits. Additional benefits not quantified in this comparison include the air quality improvements and increased uptime that the microgrid's additional charging infrastructure can provide for other fleets. Both of these categories of impact serve to make the proposed fleet electrification and microgrid even more valuable investments.

Benefits and Costs Over Time

In addition to the relative cost impacts of each scenario, the concentration of these costs over the project horizon will help determine the viability of the microgrid project after initial funding. In a sense, this is a reverse of the NPV valuation structure for comparing different scenarios, because financing that occurs early on will be able to ensure that projects with relatively low operational costs can remain viable throughout their life and successfully continue to provide benefits for the local community. This provides an especially positive outlook for BSOOB's microgrid, because those capital costs are nearly all up-front and the microgrid will provide significant operational savings over time. Figure 14**Error! Reference source not found.** helps illustrate this (excluding the additional positive impact of tax credits that may be received).

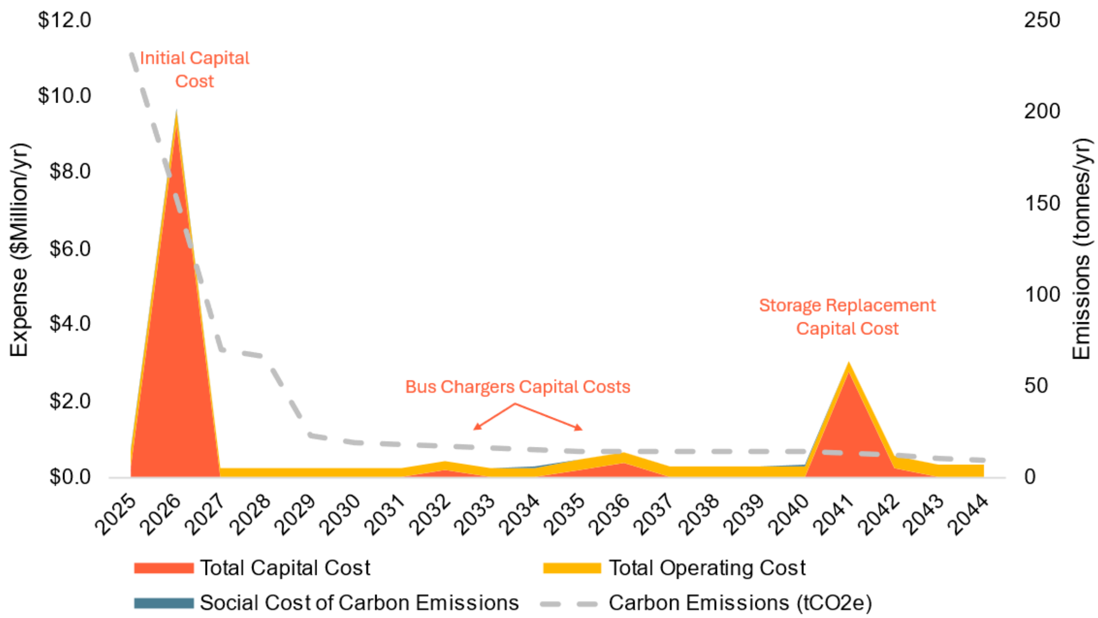


Figure 14. Microgrid Costs and Emissions Over Time (Nominal $)

Figure 15 displays the cumulative costs and benefits of the microgrid over time, with the cumulative carbon savings plotted against the right-hand axis rather than included as a dollar value. As shown, the capital costs jump with the primary outlays in 2026, rise slightly in 2036 for charger replacement, and one last time in 2041 for storage system replacement. Net operational savings are relatively small, indicated by the yellow bar, but still are in fact savings rather than costs relative to the other scenarios. The resilience value increases linearly over time, eventually overtaking the cumulative capital costs. This contrasts with the NPV comparison in Table 12, because while values are converted to real dollars, they are not discounted. Finally, the cumulative carbon savings are curved and slightly concave down. This reflects the fact that the grid is expected to gradually decarbonize, so the additional savings shown by the slope of the curve will gradually decline.

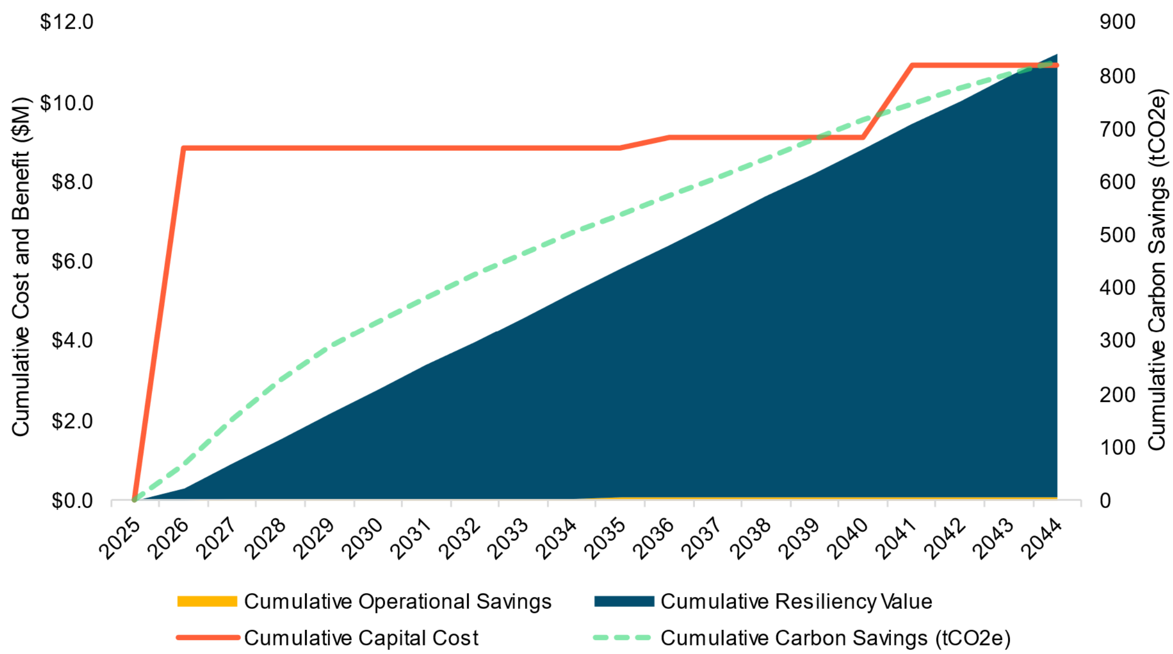


Figure 15. Cumulative Microgrid Costs and Benefits Over Time (2024$)

Conclusion and Measurement of Costs and Benefits

Ultimately, the benefits provided by the microgrid are roughly able to pay back the up-front investment, even under these conservative (high-end) cost assumptions and when factoring in a discount rate to reflect an effective rate of return. The high capital costs of the assets are offset by the combination of operational savings, reduced carbon emissions, and resiliency benefits that the microgrid provides to BSOOB and its fleet. The most significant of these benefits are shared, by extension, with the local community relying on BSOOB.

BSOOB will be able to observe and measure these microgrid impacts almost immediately upon deployment of the system. Operational savings can be measured via the net kWh and dollar cost reduction on its utility bills, while emissions impact can be estimated based on those same reductions in grid energy use. BSOOB will also be able to observe the reduced downtime without electricity for its facilities and buses as soon as the first utility grid outage occurs.

The microgrid and associated chargers will provide further benefits not quantified here, including increased operational reliability for charging equipment, local air quality impacts, and progression toward the additional SMART goals described earlier on in this analysis. The core benefit of the microgrid is that it will enable BSOOB's fleet electrification, allowing BSOOB to continue serving the community while piloting innovative technologies to reduce its emissions impact and improve resiliency.

Part 4: Challenges and Lessons Learned

Through this planning and design process BSOOB worked through several challenges and lessons learned. There will be some risks implementing the project.

Unknown Future Rate Tariffs

The microgrid and charging schedules were designed based on CMP's forecasted changes to rate tariffs. CMP is forecasted to adjust its time of use (TOU) rates tariffs by shifting weekday on-peak periods from 7 A.M. - 12 P.M. and 4 P.M. - 8 P.M. to 5 P.M. - 9 P.M. CMP is planning to implement this change by January 1, 2025, before the microgrid is expected to be built. The EV charging strategy and resulting loads have been modelled assuming this change in on-peak times happens and does not change throughout the lifecycle of the project. If CMP delays implementing these changes or adjusts its on-peak periods during the 20-year financial forecast that could alter the financial benefits of the microgrid. The risk of significant changes to financial benefits is expected to be minimal as the microgrid controllers can adjust when the BESS should be charged and discharged, and when the buses should be charged to avoid on-peak times.

Lessons Learned

While this modeling accounts for immediately anticipated rate updates and equipment charging behavior should be able to react to future changes, the uncertainty around electric rates underlines the importance of remaining flexible and attentive to these key price signals. As the industry evolves, electric rate structures throughout the country are changing and becoming more nuanced. This development will provide opportunities for dispatchable and flexible resources like the BESS and buses to achieve greater benefits but does pose an inherent risk of increased costs if equipment operators don't make the most of this flexibility.

Utility Coordination

The existing EVCS service cannot support additional EVCS, though a larger transformer pad was previously installed to support a larger service in the future when the time came. It is BSOOB's understanding that CMP installed the largest transformer it could at the time without requiring significant utility-side upgrades.

During the project Willdan reached out to CMP to review our preliminary microgrid design to understand utility impacts from the additional charging load and the supporting microgrid. At the time of this report. Willdan has not received feedback from CMP on the proposed design or feedback on potential grid impacts or benefits to the proposed microgrid. The increased EVCS load may stress local grid infrastructure, potentially requiring CMP to upgrade transformers, distribution lines, or substations. Doubly so, if the EVCS load increase occurs during peak demand periods, it could contribute to congestion and higher overall grid costs. The microgrid may be able to mitigate some of these impacts by shaving the EVCS's peak demand, particularly when the grid demand is high.

Generally utilities do not review potential grid impacts until after an interconnection application is submitted, so it is possible that this will remain an unknown until BSOOB moves into implementation. If significant utility upgrades are needed to support the increased bus load it is unknown if CMP will pass on some or all of those costs to BSOOB. Typical improvements for this type of project generally include medium voltage wiring and trenching from the Utility Pole to the transformer, low voltage wiring and trenching from the transformer to the new meter, and a new transformer. These are expected to cost approximately $400,000. However, it is unknown if further upstream utility side improvements will be needed.

Lessons Learned

Engaging the utility early and often is key to implementing microgrid projects. The review process can be lengthy and utilities may not conduct detailed studies until new service applications or requests from additional load are submitted. Having backup plans to work within existing utility constraints can mitigate potential delays or unexpected costs. For this project, load management could still allow all the buses to fully charge before their morning deployment using the existing EVCS transformer. While load management could potentially reduce operational flexibility, given the available slack in the charging schedule the buses would still be able to perform normal operations. The microgrid would still able to support the bus fleet during outages as designed.

Design Constraints

Throughout the project the design needed to account for multiple constraints and considerations. BSOOB's main bus depot has a designated wetland and streams onsite which will limit where the microgrid, EVCS, and supporting infrastructure can be located. Microgrid components and site improvements should abide by 75ft setbacks from wetlands to reduce permitting complexity. This limits the available area that can be dedicated to the solar array and limits where supporting infrastructure and equipment can be located. It also introduces additional stormwater mitigation measures. Buffer strips will need to be added between the solar canopy and the wetlands to manage stormwater runoff in compliance with low impact development requirements. While not all transit agencies will have wetlands on site, smaller rural transit agencies are more likely to have undeveloped land on or near their properties that they can develop into solar canopies for their buses. That will require navigating local environmental regulations to develop the land.

The solar canopy will act as a shaded structure for bus parking, not passenger vehicles. This introduces additional design conditions for the solar structure. The solar canopy will be a single long span array which involves several constraints and potential downsides compared to solar canopies for passenger vehicles. One primary challenge is the structural integrity required to support both the weight of the solar panels and the span length necessary to cover multiple buses. This typically demands advanced engineering solutions and high-quality materials, which can significantly increase costs. Columns must be taller and spaced wider than usual to account for the clearance and turning radii of the buses while leaving adequate room for drivers to maneuver when other buses are already parked under the array. In Maine the solar canopy will need to account for potentially adverse weather conditions, such as high winds or heavy snow. Microgrid cost estimates assumed generally conservative pricing for the solar PV canopy to account for this, but depending on the results of a structural analysis final costs could be higher.

Lessons Learned

When starting a design project, its important to first understand the existing conditions, end goal of the project, and the design constraints. This helps inform the initial design and prevents the design team from moving in the wrong direction. Identifying potential roadblocks or permitting considerations can prompt targeted research early in the design process. For this project, the onsite wetland consideration was a new design constraint for the Willdan team. As a result, the design team reviewed permitting and stormwater requirements so the microgrid could abide by the 75 foot setback to avoid a more complicated permitting process.

Federal Policy Changes

At the time of this report, the Inflation Reduction Act (IRA) provides tax credits for up to 30% of the cost for eligible solar, BESS, and EVCS projects. Tax-exempt public agencies are able to take advantage of this tax credit as a direct payment following completion of the project. With the new federal administration following the 2024 election, it is possible that Congress and the Executive branch change elements of the IRA that reduce, eliminate, or make it more difficult to obtain these tax credits. The microgrid is very capital intensive, so being able to leverage a variety of funding sources, beyond the SMART grant program will increase its chances of success.

Lessons Learned

While changes to federal policy and potential incentives are outside of BSOOB's control, BSOOB should be tracking potential external impacts to the project and conduct a sensitivity analysis to understand project impacts if certain policies or funding options change. If a project is still viable without certain incentives that reduces the chance of a project falling through due to external changes. In this project, microgrid costs are provided before and after potential IRA tax credits, where even if tax credits are not available in the future the microgrid still provides net benefits relative to its costs. The ability to capture tax credits may not be a deciding factor for implementing this project, though if they can be captured it can reduce the amount of funding needed from other sources, such as the SMART grant.

Part 5: Deployment Readiness

This project focused on understanding BSOOB's long term needs to support electrifying all of its fixed local route service and identifying the appropriate technologies to provide resilient operations. Throughout the project, Willdan considered and engaged with different technology vendors to understand market offerings as we prepared the 30% design. Some additional steps would be needed to deploy the microgrid at scale including finishing the design, bidding the work to local contractors, acquiring the necessary permits, and completing construction. After the microgrid is built BSOOB will need to train its staff and/or hiring third parties to maintain the microgrid components in good working fashion to realize the benefits.

Design Completion

The key components of the design have already been completed. Equipment has been selected, sized and proposed locations have been agreed upon, which constitutes the "prototype" completed for the Stage 1 grant. While there may be some minor changes when a construction set is completed, the microgrid is not expected to change significantly. The design assumes that CMP will be able to supply a transformer to meet the forecasted peak loads. The biggest risk to potential changes may come from the utility if CMP cannot easily supply the requested power. The existing EVCS have a peak output of 300 kW and with the additional EVCS and the facility on a single service the peak load would increase to 625kW. Utilities generally are obligated to provide the power their customer's request; however, depending on local grid constraints the major impacts are usually time and money. If the utility needs to make major upstream upgrades to provide the requested power, it can take years for the utility to upgrade their systems and could pass on those costs to BSOOB. The microgrid should be able to mitigate some of these risks as the EVCS load management software and microgrid controller will be able to limit the max output of all the EVCS to the power CMP can provide; however it could impact the overall charging schedules and flexibility of the operations. There may need to be additional discussions with CMP so they are comfortable with nameplate loads potentially being oversized based on the capacity available.

Permitting and Regulatory Compliance

Several permits will need to be acquired to deploy the microgrid, and multiple Authorities Having Jurisdiction (AHJs) are expected to be involved. Many of the components for the microgrid will require a building permit from the Biddeford Planning and Development Department. An electrical permit will be needed for the microgrid and will be applied for once the design is completed[23]. Additional stormwater permits may be needed given the wetland on site, and an air quality permit will be needed for the natural gas generator. Beyond permitting, no other regulatory issues are expected for the construction and operation of the microgrid.

Stormwater Permit

A wetland, watercourse, and potential vernal pool survey was completed at the BSOOB site on Pomerleau Street in Biddeford, ME. The survey was completed on Nov. 2, 2022. Results determined there are two wetlands identified within the survey area and shown in Figure 16.**Error! Reference source not found.** One is on the northeast side of the access road ('W-KMN-1'), while the second wetland occurs to the south of the access road ('W-KMN-2').

The Maine Department of Environmental Protection (DEP) is responsible for protecting and restoring Maine's natural resources and enforcing the state's environmental laws. The Natural Resources Protection Act (NRPA) Chapter 305 "Permit by Rule" process is not applicable for this project because there are identified wetlands on the property. A Permit by Rule applies when a project will not significantly affect the environment and

[23] Application for Biddeford Commercial Electrical Permit, https://www.biddefordmaine.org/DocumentCenter/View/8175/Electrical-Permit---Commercial-2020-PDF

generally has less of an impact on the environment than an activity requiring an individual permit. Projects that qualify for Permit by Rule satisfy the Natural Resources Protection Act permit requirement and Water Quality Certification requirement. Since the BSOOB property contains a wetland, the streamlined Permit by Rule does not applicable.

Since BSOOB's bus depot contains a wetland and a stream onsite a full Natural Resources Protection Act (NRPA) NRPA permit application will need to be submitted. A DEP NRPA permit is required when an "activity" will be: Located in, on or over any protected natural resource, or located adjacent to (A) a coastal wetland, great pond, river, stream or brook or significant wildlife habitat contained within a freshwater wetland, or (B) certain freshwater wetlands. An "activity" is (A) dredging, bulldozing, removing or displacing soil, sand, vegetation or other materials; (B) draining or otherwise dewatering; (C) filling, including adding sand or other material to a sand dune; or (D) any construction, repair or alteration of any permanent structure. In addition, a DEP NPRA permit is required for jobs that are "in, on, over or within 75 feet of a protected Natural Resource." **The design accounts for this and the microgrid infrastructure and site improvements observe this 75 foot setback (Figure 17) from the stream to minimize permitting requirements and complexity.**

Figure 16. Wetland Survey

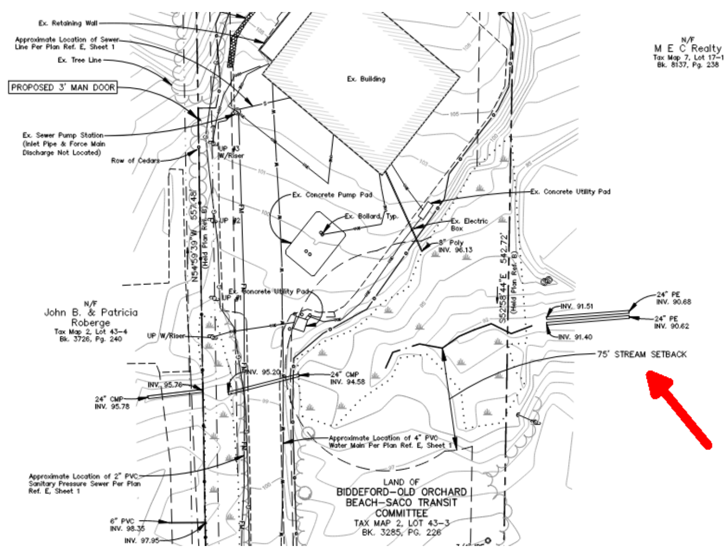


Figure 17. Wetland and setback requirements

Air Quality Permit

The natural gas generator will require a license from the Maine Department of Environmental Protection (DEP) to operate, in addition to an electrical permit from the City of Biddeford. **Based on the proposed size, the generator is considered a "Minor Source" of emissions**. As part of the permitting process a Public Notice of Intent to File for a license application must be completed[24],[25]. Then the Chapter 115 License Application must be filed with DEP, and a fee must be paid initially for the license, along with an annual renewal fee[26],[27].

After the generator is approved, licensed, installed, and running, annual runtime and emissions reporting must be submitted to DEP through CAERS[28]. BSOOB will need to designate a responsible officer as the Certifier to submit the yearly emission information, and the signup form to register the Certifier is on the DEP website[29]. Online CAERS system training is available[30].

For background information related to backup emergency generators, DEP has a series of written rules that govern various environmental topics. Chapter 169 is the applicable rule on the DEP website that contains the regulations related to emissions standards and stack requirements for stationary electric generators[31].

Charger Maintenance

EV chargers require regular maintenance. Generally, a preventative maintenance check should be performed once every 6-12 months for all Level 2 and DCFCs. DCFC's typically need to replace air filters every two years. Other maintenance checks typically occur every 5 years, and BSOOB should refer to product owner manuals for specifics. Aside from hardware maintenance, software is a large component of the networked charger operation. Software doesn't require maintenance and most charger vendors will conduct over-the-air updates as needed.

Most EV charger vendors have extended warranty packages that last up to 5 years; and most EV chargers have a design life of 10 years. A good rule of thumb is to budget 5-10% of the charger's product cost for annual maintenance and repairs. Until staff are trained in the maintenance and repair of chargers and have the staffing available, it is recommended BSOOB purchase full extended manufacturer's warranty to cover maintenance issues.

Periodic maintenance of charging stations and infrastructure for electric transit buses is essential for maximizing operational efficiency and minimizing downtime. By scheduling regular inspections and servicing, potential issues can be detected and resolved before they lead to equipment failure, ensuring that buses remain on schedule and reducing costly disruptions. This proactive approach ensure that chargers are functional throughout their 10 year design life, optimizes their performance, leading to faster and more reliable charging. Regular maintenance enhances safety by ensuring all components function correctly, reducing the risk of electrical faults and potential accidents. Furthermore, it helps maintain energy efficiency, resulting in lower operating costs. Overall, periodic maintenance is an investment that supports the reliability, safety, and cost-effectiveness of electric transit bus operations. Table 14 summarizes typical periodic maintenance activities and frequency for EV charging stations and associated infrastructure.

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[24] Maine DEP Minor Source License Applications, https://www.maine.gov/dep/air/permits/minor.html

[25] DEP Public Notice of Intent to File for a Minor Source License, https://www.maine.gov/dep/air/licensing/notices/intenttofile.docx

[26] DEP Chapter 115 License application, https://www.maine.gov/dep/air/permits/docs/Form11520160201.docx

[27] DEP Fee Schedule for Minor Source Licensing, https://www.maine.gov/dep/feeschedule.pdf

[28] DEP CAERS, https://www.maine.gov/dep/air/emissions/reporting.html

[29] DEP CAERS User Registration agreement, https://www.maine.gov/dep/air/emissions/docs/CAERS%20Fillable%20Form.pdf

[30] DEP CAERS training, https://www.epa.gov/combined-air-emissions-reporting/combined-air-emissions-reporting-system-caers

[31] DEP Rule 169 Document for emissions standards and stack requirements for stationary electric generators, https://www.maine.gov/sos/cec/rules/06/096/096c169.docx

Table 14 – Typical EVCS Maintenance Schedule

Maintenance Item	Frequency	Description
Visual Inspection	Daily	Conduct a visual inspection of EVCS and infrastructure to check for any obvious signs of damage, wear, or vandalism. Ensure all ports, cables, and connectors are intact and undamaged.
Check Charging Status	Daily	Verify the status of each EVCS to ensure that they are operational and available for use. Address any issues promptly to minimize downtime.
Clean Connections	Daily	Inspect and clean ports, nozzles, and connectors to remove dirt, debris, or corrosion. Ensure proper electrical connections to prevent charging interruptions.
Functional Testing	Weekly	Perform a functional test of each EVCS to ensure they are charging correctly and delivering the expected voltage and current levels.
Check Equipment Temperature	Weekly	Monitor the temperature of charging equipment to ensure that they operate within specified limits. Address any overheating issues promptly.
Inspect Grounding System	Weekly	Check the grounding systems of EVCSs to ensure proper grounding and electrical safety. Repair or replace any damaged grounding components.
Inspect Electrical Components	Monthly	Conduct a thorough inspection of electrical components, including cables, transformers, and circuit breakers, for signs of wear, damage, or overheating. Repair or replace any damaged components as needed.
Load Testing	Quarterly	Conduct load testing on EVCSs to verify their performance under maximum load conditions. Identify and address any issues related to voltage fluctuations or power delivery.
Inspect Cooling Systems:	Quarterly	Check the cooling systems of charging equipment, such as fans or heat sinks, to ensure proper operation and cooling efficiency. Clean or replace any clogged filters or damaged components.
Inspect Physical Infrastructure	Quarterly	Inspect the infrastructure surrounding EVCSs, including mounting brackets, support structures, and signage, for signs of wear or damage. Repair or replace any damaged components.
Comprehensive Inspection	Annually	Conduct a thorough inspection of all EVCSs and associated infrastructure. Check for structural integrity, corrosion, and other signs of deterioration. Perform any necessary repairs or upgrades.
Calibration Check	Annually	Calibrate charging equipment, including voltage and current sensors, to ensure accurate measurement and charging performance.
Review Emergency Procedures	Annually	Review and update emergency procedures for responding to EVCS issues, such as accidents, power outages, or equipment failures. Ensure that all relevant personnel are familiar with these procedures.
High-Voltage System Inspection:	Bi-Annually	Conduct a detailed inspection of high-voltage systems, including transformers, inverters, and circuit breakers, to ensure proper operation and safety compliance. Test insulation resistance and perform any necessary repairs or upgrades.
Ground Resistance Test	Bi-Annually	Perform a ground resistance test on the grounding systems of EVCSs to verify compliance with safety standards. Address any issues related to grounding resistance.
Review Maintenance Records	Bi-Annually	Review and update EVCSs and infrastructure maintenance records. Document all maintenance activities, repairs, and inspections for future reference and compliance purposes.

Microgrid Maintenance

The microgrid will consist of many different pieces of equipment, each of which will have their own maintenance requirements. As BSOOB deploys the microgrid they will need to train their staff on how to maintenance the equipment, or work with vendors to provide ongoing maintenance on the equipment.

Solar PV Maintenance

The solar PV system will require ongoing operations and maintenance (O&M) support to maximize energy generation needed to support the microgrid. As a more established technology, solar PV developers and installers regularly include a suite of annual preventative maintenance services as part of production guarantees. It is recommended BSOOB request ongoing O&M support from the developer and/or installer These services typical include but may not be limited to:

- System testing (voltage/amperage)
- System visual inspection and necessary corrections:
  - Inspect for stolen, broken or damaged PV modules, record damage and location.
  - Inspect PV wiring for loose connections and wire condition.
  - Inspect for wires in contact with the structure or hanging loose from racking
  - Check mechanical attachment of the PV modules to the racking
  - Check attachment of racking components to each other and the structure
  - Verify proper system grounding is in place from panels to the inverter
  - Check conduits and raceways for proper anchorage to structures
  - Inspect all metallic parts for corrosion
  - Check combiner boxes for proper fuse sizes and continuity
  - Inspect all wiring connections for signs of poor contact at terminals (burning, discoloration, etc.)
  - Inspect disconnects for proper operation
  - Survey entire jobsite for debris or obstructions
  - Inspect fasteners for proper torque and corrosion
  - Inspect inverter pad for cracking or settling
  - Inspect electrical hardware for proper warning and rating labeling
  - Inspect alignment of arrays and racking to identify settling foundations or loose attachments
  - Inspect operation of tracking hinges, pivots, motors and actuators if present
  - Check for proper operation and reporting of monitoring hardware
  - Inspect sealed electrical components for condensation buildup
  - Inspect wiring and hardware for signs of damage from vandalism or animal damage
- Routine system maintenance to include correction of loose electrical connections, ground connections, replacement of defective modules found during testing, other minor maintenance repair work.
- Module cleaning.
- Routine DAS maintenance, not less than once per year, to include sensor calibration and data integrity check.
- Report and schedule any necessary outage required to administer maintenance, cleaning or corrective repairs.

BESS and Microgrid Controller Maintenance

In comparison to the EVCS and solar PV system, both the BESS and microgrid controller would relatively less ongoing operations and maintenance (O&M) support as there are no moving parts. However, there is still a gap in the industry for vendors or other service providers regularly providing ongoing maintenance for these systems due to their complexity. Some subsystems may not be monitored by storage providers due to their complexity. Installers and storage providers must have keen knowledge and address issues across all subsystems that include electrical, chemical, electro-mechanical, and thermal systems. Additionally, they must plan for any future-related failure events by developing performance metrics for public safety power shortages (PSPS) or any battery degradation events. If BSOOB decides to procure a maintenance agreement from a third party it should be evaluated on the value it provides by limiting battery degradation so that the BESS can continue to operate at its rated capacity throughout its lifetime.

Commercial O&M costs have reduced due to cost efficiencies achieved in system maintenance and monitoring over its lifetime[32]. If BSOOB procures ongoing O&M services on their BESS and Microgrid Controller systems it should include the following types of services:

- General Maintenance over the system's lifetime
- Scheduled and/or Unscheduled Maintenance over the system's lifetime
- Hardware equipment upgrades such as Switchgear and/or Transformer
- Upgrades on Power Control Systems (PCS) that meet UL, IEEE, and/or IEC standards[33]
- Hardware/Software technology updates and/or upgrades
- Communications, Monitoring and Metering improvements
- HVAC-Maintenance for Microgrid system
- Asset Management and Security
- General system inspections
- Battery augmentation

Generator Maintenance

Generator maintenance and upkeep will be driven, in part, by air quality permit requirements which will require a minimum amount of preventative maintenance, operational testing, and emission limit verification. The air quality permit may also limit operation to required testing and use during outages. When the generator is being tested it is recommended to include some testing under load to verify generator performance and that it can meet required loads in the event of an extended outage. Control systems, sensors, and alarms should be tested and calibrated as part of regular testing. BSOOB will want to regularly check that there is a consistent and adequate supply of natural gas. This may include monitoring gas pressure and flow rates to maintain optimal performance.

The generator will require regular replacement of engine oil, engine filters, coolant, and air filters based on manufacturer's requirements. Several key components of the generator should be inspected regularly leaks, corrosion, or any signs of wear or damage. These components may include but may not limited to:

- associated systems (fuel, electrical, cooling, exhaust),
- oil levels and oil quality
- hoses, belts, and the radiator,
- starting batteries,
- Exhaust system and muffler

Given that generators are a mature technology some of this maintenance may be handled by BSOOB's internal staff or could be outsourced to the vendor or local service technicians. Since BSOOB already operates diesel

[32] Distributed Generation Costs and Characteristics in Building and Industrial Sector - Distributed Generation, Battery Storage, and Combined Heat and Power System Characteristics and Costs in the Buildings and Industrial Sectors (eia.gov)

[33] Resilience and Economics of microgrids with PV, battery storage and networked diesel generators - https://www.osti.gov/biblio/1810535

fuel pumps on-site some of the skills used to maintain the existing pumps may carry over to maintaining the generator.

Workforce Training

BSOOB will need to upskill its workforce to successfully implement, maintain, and operate the microgrid over the course of its useful like. This upskilling will provide the local workforce with the knowledge and skills to be successful in a world that increasingly adopts electric vehicles and distributed energy resources.

Skills Gap Survey

In September 2024, four staff members from Biddeford Saco Old Orchard Beach (BSOOB) Transit participated in an online survey to assess their knowledge, skills, and training needs related to the agency's Electric Bus, Charging, and Microgrid Maintenance Project. The survey aimed to capture each team member's familiarity with electric bus components, EV charging infrastructure, microgrid systems, and related diagnostic and maintenance tools, as well as to identify any gaps in training that could enhance operational efficiency and support the transition to advanced, sustainable transportation technologies. The following key takeaways are:

Current Knowledge and Training Gaps

Electric Bus Components: All team members possess basic knowledge, with only one achieving mastery. Most have received formal training from sources like Proterra and Cengage Hybrid.
EV Charging Stations: Team members have general familiarity with EV charger maintenance and installation but lack mastery. Training sources include ABC Prevost and hands-on sessions.
Microgrid Systems: While three team members are familiar with microgrid components, none have formal training, highlighting an essential need for dedicated microgrid training.
High-Voltage Systems: Although all team members have some training in high-voltage systems, only one has achieved mastery, suggesting further training is beneficial for most.
Diesel Engine Maintenance: Team members display high proficiency in diesel maintenance, with two reaching mastery, covering areas like project management, electrical diagnosis, and fuel systems.

Experience with Diagnostic and Maintenance Tools

Diagnostic Tools and Troubleshooting: Most team members are comfortable with diagnostic tools and have some training in vehicle system troubleshooting, with experience ranging from shadowing technicians to advanced diagnostics and module reflashing.
Fleet Management Software: Proficiency is mixed, with most rating a 3 out of 5 and one achieving mastery. Training has included Dosier, Proterra, ChargePoint, and Cummins, with an expressed need for standardized software training across the team.

Training Preferences and Development Needs

Training Needs: Key areas identified for further training include EV charging, hybrid buses, the shop fleet management system, and layout. Notably, one respondent expressed a need for training across all areas mentioned in the survey.
Preferred Training Style: All team members favor hands-on training with equipment or systems, aligning with practical job requirements.
Ongoing Training Requests: There is a preference for continuous, incremental training in accountability areas, including Automotive Service Excellence-style programs, as opposed to intensive, one-time sessions.

Team Dynamics and Adaptability

Adaptability to New Technologies: Three out of four respondents rated their adaptability as high (4 out of 5), with one reaching the top score, indicating strong readiness for evolving technologies.
Team Collaboration: Teamwork is rated positively, with 50% scoring a 5 out of 5 and the other half at 4 out of 5, though there is an opportunity to enhance team-building skills.
Leadership in Maintenance Roles: All respondents have prior leadership experience in maintenance, involving tasks like overhauling production lines, electrical diagnostics, and guiding maintenance projects.

Recommendations:
The survey results underscore a strong baseline knowledge among team members but reveal key areas where targeted training would enhance their technical proficiency and operational consistency. The following recommendations will address these needs:

Standardized Training Programs: Implement standardized training for electric bus maintenance, EV chargers, and microgrid systems to unify skill levels across the team.
Hands-On, Progressive Training Approach: Develop a hands-on training regimen that introduces concepts gradually to facilitate retention and application, aligned with team member preferences.
Focused Team-Building and Leadership Development: Incorporate team-building exercises and expand leadership development programs to leverage and enhance the existing collaborative skills and leadership experience within the team.

A copy of the full results is contained in Appendix F. Additional training that BSOOB's staff will need to implement is described in this section.

Vehicle and Charger Training Needs

BSOOB intends to work with battery electric vehicle and EVCS manufacturers to include training as part of the initial vehicle and charger purchases. BSOOB will work to with new vehicle OEMs to include test vehicles in advance of the vehicles arriving to start the training program. BSOOB will test new EVs and EVCS for at least 30 days before putting the vehicles in revenue service. Once an OEM is engaged, a preliminary training schedule will be drafted. The training schedule will identify the training name, description, audience (by personnel designation), provider, course length, and any other salient information. Additional refresher training will be completed on an as-needed basis. Table 15 includes a sample of the training options the BSOOB may implement as it electrifies its fleet.

Table 15 – Sample Training Program

Training	Description	Trainees	Provider	Hours
General HV Safety Awareness	General EV electrical safety	Vehicle operator trainers, maintenance technicians, staff	OEM / 3rd Party	16
Operator Training	Orientation and driver training	Vehicle operator trainers	OEM	16-24
First Responder Training	Training on emergency response for BEVs	Vehicle operators, local first responder representatives, Maintenance	OEM / 3rd Party	1-4
EVSE Training	Maintenance and operation of EVSE	City electricians, helpers/ maintainers	OEM / 3rd party	4-20
HV Electrical Systems	Lockout/Tagout, HV PPE, Contact Release, Fall Protection, Energy Storage System (ESS), Battery Electric Propulsion System	Maintenance HV technicians	OEM	16

Training	Description	Trainees	Provider	Hours
Vehicle Systems Training	Maintenance training	Maintenance technicians	OEM	32-48
First Aid	Basic first aid training	Maintenance HV technicians	3rd Party	1-4
OEM Maintenance	OEM Maintenance	Maintenance specialties	OEM	32-48
HVAC System	System training	Maintenance specialties	HVAC / OEM	Varies
Telematics / Diagnostic Tools	Vehicle diagnostics	Maintenance specialties Information Technology	OEM	Varies
Structural Composites	Body repair training	Maintenance specialties	OEM	Varies

Certain types of training, such as high-voltage training will be completed independently and ahead of vehicle-specific training. As BSOOB works with OEMs on the appropriate training program, BSOOB will update its standard operating procedures and regular training programs to reflect the needs of an EV fleet. Specific workforce training programs may cover topics such as vehicle maintenance, charger operation, vehicle operation, and high voltage safety. Their workforce development should include retraining existing staff as well as building local partnerships to train the future EV workforce at community colleges, universities, and other public agencies where possible.

As BSOOB upskills its workforce, it may either add responsibilities or certifications to existing staff or recategorize trained staff to focus solely on managing different elements of the electric fleet. The largest skill gap when integrating EVs into a maintenance program is typically High Voltage (HV) electrical system service. High voltage systems on EVs generally range from 50 volts alternating current (VAC) up to 1000 VAC which is a critical distinction from conventional fuel vehicles. Not only must staff understand HV systems and how to service them, but they must also understand electrical safety. There are both automatic safety features and manual safety procedures to ensure that HV systems are deactivated when a fault is present or when system service is required. Maintenance personnel responsible for de-energizing HV systems must be trained in HV, PPE, and zero voltage verification procedures.

Personnel designations can help clarify what level of training is required based on staff exposure to high voltage systems. BSOOB may follow Los Angeles County Metropolitan Transit Authority (LACMTA) example and develop 2 designations for staff that have exposure to HV systems: HV Level I and HV Level II. Level I include personnel with low to no exposure to HV, they include service, maintenance, supervision and management staff, bus operators, and first responders. Level II includes personnel with moderate to high exposure to HV, they include maintenance instruction staff, select mechanic classifications such as master, warranty, and HVAC technicians, maintenance management and supervision, and OEM technicians. For LACMTA, training requirements differ based on the personnel level and are listed below in Table 16 for reference.

Table 16 – Training Requirements by Designation (LACTMA)

Training Concepts	HV Level I	HV Level II
General HV Safety Awareness	✓	✓
OEM HV Safety Training	✓	✓
OEM Maintenance Bus Orientation	✓	✓
OEM Operator Bus Training	✓	✓
Bus Systems Training	✓	✓
HV Electrical Systems		✓
Battery Electric Propulsion System		✓
Energy Storage Systems (ESS)		✓
Lockout/Tagout (LOTO)		✓
HV PPE		✓
Contact Release		✓
First Aid		✓

As BSOOB develops a training implementation plan, BSOOB will employ a "train the trainer" approach. The goal of this practice is to select key individuals within the operations or maintenance department to take part in OEM training with the intent of bringing future training in-house. This may be a lead technician or supervisor who has the technical expertise necessary and can effectively administer training for staff. This can be an effective technique if OEM training occurs off site far from the agency, if BSOOB must train many personnel regularly, if there is high employee turnover, and if the agency plans on recurrent training.

Microgrid Training Needs

Microgrid training courses offer invaluable knowledge and skills for transit agencies seeking to electrify their fleets while integrating a microgrid system. These courses provide BSOOB staff with comprehensive training on microgrids' design, installation, operation, and maintenance, including renewable energy integration, energy storage, and grid management strategies.

By equipping transit personnel with the expertise needed to implement and manage microgrid systems, these courses would enable BSOOB to maximize the efficiency, reliability, and resilience of their electric bus operations. By leveraging the insights and best practices gained from these courses, transit agencies can effectively navigate the complexities of transitioning to electric buses while harnessing the benefits of microgrid technology to optimize energy use and reduce environmental impacts. Some training resources include:

- **U.S. Department of Energy (DOE)**
    - **Better Buildings Initiative**: Offers resources and training programs related to energy management and microgrids[34]
    - **National Renewable Energy Laboratory (NREL)**: Provides various workshops and training sessions on renewable energy technologies and microgrid systems[35]
- **GridWise Alliance:** Focuses on promoting and advancing the modernization of the U.S. electric system. They offer training and resources on smart grid and microgrid technologies.[36]
- **Electric Power Research Institute (EPRI):** Provides research, development, and training programs on energy and grid management, including microgrids.[37]

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[34] DOE Better Buildings Initiative, https://betterbuildingssolutioncenter.energy.gov/
[35] NREL, https://www.nrel.gov/
[36] Gridwise Alliance, https://gridwise.org/
[37] EPRI Training, https://www.epri.com/training

- **International Association of Electrical Inspectors (IAEI):** Offers training and certification programs for electrical inspectors, including aspects related to microgrids and renewable energy systems.[38]
- **IREC (Interstate Renewable Energy Council):** Provides credentialing and training programs for clean energy workforce development, including microgrid systems
- **American Public Power Association (APPA):** Offers webinars, workshops, and certification programs related to microgrids and distributed energy resources.[39]
- **Clean Energy States Alliance (CESA):** Provides training and resources on clean energy technologies, including microgrids.[40]
- **Microgrid Knowledge:** Hosts conferences and training sessions on microgrid technology, development, and policy.[41]
- **Smart Electric Power Alliance (SEPA):** Offers educational programs and resources on integrating distributed energy resources, including microgrids, into the electric grid.[42]

Community Engagement

As a transit agency BSOOB regularly engages the community as it develops new technologies and adjusts its services. The goal of the engagement is to gather feedback, and inform stakeholders about plans, services, or changes to transit operations. Deploying the microgrid is unlikely to directly require community engagement as its impact is only on BSOOB's depot and not the general public. However, as BSOOB continues to electrify its fleet, additional community engagement may be warranted, as the change in vehicles, and their operational capabilities will impact riders. Beyond traditional engagement efforts, BSOOB will host a public EVCS training workshop to educate residents and key stakeholders on how the benefits of electrification and how to plan EVCS projects. The workshop will also provide a summary of the benefits of the microgrid BSOOB has developed under this Stage 1 grant.

Community Training Workshop

BSOOB acts as a local resource for several fleets in the region and is one of the first regional fleets to start its electrification journey. As a pillar in the community and a leader for other local fleets, BSOOB will host a 4-hour EV training workshop geared towards the public and key community stakeholder groups on the important elements of a vehicle electrification project. The goal of the training workshop is to raise awareness on the benefits of electrification and explain what it takes to develop a successful EVCS project. Following the training BSOOB will use its site and pilot EVCS deployment project as a real world example of how the concepts discussed in the training get applied in the field.

The training will be held on February 19, 2025 and will cover the following topics:

- Background of GHG emissions and climate change and why decarbonization is important
- Explanation of grid mix and how different energy sources impact the GHG footprint of electricity
- Overview of basic electricity principles including power, voltage, available capacity, kWh, kW
- Explanation of how load varies throughout the day and how peak demand impacts electricity prices, including time of use rates
- Explanation of Level 1, Level 2, and DCFC and how to calculate the cost to charge vehicles at each level
- Comparing the efficiency, GHG emissions, pollution of an EV versus an ICE vehicle

[38] IAEI Training, https://www.iaei.org/page/online-training
[39] American Public Power Association Training, https://www.publicpower.org/education-and-events/virtual-education-and-training
[40] CESA, https://www.cesa.org/resource-library/
[41] Microgrid Knowledge, https://www.microgridknowledge.com/
[42] SEPA, Online Training, https://sepapower.org/events/online-learning/

GHG emissions associated with an EV versus an ICE vehicle and how the grid mix impacts the emission footprint of EVs.
How incorporating solar PV and battery storage can shift EV charging loads to lower cost times of the day
Site feasibility on how to develop cost effective EVCS projects
How to calculate EV energy needs and how to select the right charging strategy

Part 6: Wrap-Up

The Stage 1 grant has successfully funded 30% schematic design of the BSOOB microgrid, serving as the prototype categorized within the smart grid technology domain. The feasibility study consisted of both technical and financial components that have validated the positive economic, societal and environmental impact to the riders and wider community.

Table 17 summarizes the financial results of this study, presenting present value net costs and incremental benefits and costs of three different scenarios in which BSOOB maintains its current bus fleet or electrifies the remainder of its fleet and powers it with a solar-powered microgrid.

Table 17 – Summary of Benefits and Costs by Scenario (2024$ NPV, rounded)

	NPV Net Cost, 2025 2044	Incremental Benefit	Incremental Cost	Benefit / Cost Ratio
Scenario	*2024$*	*2024$*	*2024$*	*#*
Scenario 1 – 2025 Fleet, No Microgrid	$11.8 Million			
Scenario 2 – Electrified Fleet, No Microgrid	$11.5 Million	$1.88M	$1.57M	**1.19**
Scenario 3 – Electrified Fleet, with Microgrid	$11.86 Million	$11.19M	$11.26M	**0.99**

From a financial perspective, BSOOB's investment in a fully electrified fleet will more than pay itself back over the next twenty years. Investing in a microgrid to support this fleet further increases the operational savings for BSOOB and will provide greater resilience and environmental benefits to the local community. Though the up-front capital costs of the microgrid are high, the ongoing stream of benefits will allow the project to effectively break even and also include non-quantified advantages for fleet operation and air quality.

The proposed microgrid is expected to sufficiently meet the needs of BSOOBs future electrified fixed route fleet when it is built out. Throughout the planning and design process Willdan engaged with various technology vendors to understand which options would best meet BSOOBs needs.

It is anticipated that transit-oriented microgrids will be a prevailing solution to make advancements in e-mobility in compliance with tighter regulations on air quality standards. This feasibility study should be made available to other communities to aid in mitigating the uncertainty associated with fuel switching from diesel to electric fleets, regardless of whether it's for public or private enterprise.

If awarded Stage 2 funding for full-scale implementation, the design development process will allow BSOOB to make changes as the owner's basis of design evolves, including greater clarity of project constraints. This design stage includes selection and location of major components, but this is subject to change. One area that could change at full scale deployment is the fuel source for the backup generator. While natural gas is a cleaner fuel source than diesel, other fuel sources could be considered.

Appendices

Appendix A – Duty Cycle Analysis

		January	February	March	April	May	June	July	August	September	October	November	December
Proterra 440kWh 35' ZX5+Duopower Drivetrain	Daily Miles (mil)	195	195	195	195	195	195	195	195	195	195	195	195
	Daily kWh Recharge (kWh)	547	542	460	425	360	352	371	345	348	371	495	525
	Route SOC (%)	-24%	-23%	-5%	3%	18%	20%	16%	22%	21%	16%	-13%	-19%
	Minimum Layover Available (hr)	0:40	0:40	0:40	0:40	0:40	0:40	0:40	0:40	0:40	0:40	0:40	0:40
	Window 1 Energy Recharge (kWh)	240	240	240	240	0	0	0	0	0	0	240	240
	Window 2 Energy Recharge (kWh)	307	302	220	185	360	352	371	345	348	371	255	285
	Window 2 - Charge Time (hr)	2:02	2:00	1:28	1:13	2:24	2:20	2:28	2:18	2:19	2:28	1:42	1:53
	Total Charge Time (hr)	2:42	2:40	2:08	1:53	2:24	2:20	2:28	2:18	2:19	2:28	2:22	2:33
	Window 1 Energy Delivered (kWh)	284	284	284	284	0	0	0	0	0	0	284	284
	Window 2 Energy Delivered (kWh)	363	357	261	219	426	416	439	409	411	439	302	337
Proterra 440kWh 35' ZX5+Duopower Drivetrain	Daily Miles (mil)	222	222	222	222	222	222	222	222	222	222	222	222
	Daily kWh Recharge (kWh)	620	614	522	482	409	399	421	391	394	421	562	595
	Route SOC (%)	-41%	-40%	-19%	-10%	7%	9%	4%	11%	10%	4%	-28%	-35%
	Minimum Layover Available (hr)	0:49	0:49	0:49	0:49	0:49	0:49	0:49	0:49	0:49	0:49	0:49	0:49
	Window 1 Energy Recharge (kWh)	294	294	294	294	294	294	294	294	294	294	294	294
	Window 2 Energy Recharge (kWh)	326	320	228	188	115	105	127	97	100	127	268	301
	Window 2 - Charge Time (hr)	2:10	2:08	1:31	1:15	0:45	0:42	0:50	0:38	0:40	0:50	1:47	2:00
	Total Charge Time (hr)	2:59	2:57	2:20	2:04	1:34	1:31	1:39	1:27	1:29	1:39	2:36	2:49
	Window 1 Energy Delivered (kWh)	348	348	348	348	348	348	348	348	348	348	348	348
	Window 2 Energy Delivered (kWh)	386	379	270	222	136	124	150	115	119	150	317	356
Proterra 450kWh ZX5+ with Prodrive Drivetrain	Daily Miles (mil)	211	211	211	211	211	211	211	211	211	211	211	211
	Daily kWh Recharge (kWh)	612	606	515	476	403	394	415	386	389	416	554	587
	Route SOC (%)	-36%	-35%	-15%	-6%	10%	12%	8%	14%	14%	8%	-23%	-31%
	Minimum Layover Available (hr)	0:40	0:40	0:40	0:40	0:40	0:40	0:40	0:40	0:40	0:40	0:40	0:40
	Window 1 Energy Recharge (kWh)	240	240	240	240	240	240	240	240	240	240	240	240
	Window 2 Energy Recharge (kWh)	372	366	275	236	163	154	175	146	149	176	314	347
	Window 2 - Charge Time (hr)	2:28	2:26	1:50	1:34	1:05	1:01	1:10	0:58	0:59	1:10	2:05	2:18
	Total Charge Time (hr)	3:08	3:06	2:30	2:14	1:45	1:41	1:50	1:38	1:39	1:50	2:45	2:58
	Window 1 Energy Delivered (kWh)	284	284	284	284	284	284	284	284	284	284	284	284
	Window 2 Energy Delivered (kWh)	440	434	326	279	193	182	207	173	177	208	372	411
Proterra 450kWh ZX5+ with Prodrive Drivetrain	Daily Miles (mil)	337	337	337	337	337	337	337	337	337	337	337	337
	Daily kWh Recharge (kWh)	976	967	822	758	643	628	662	616	620	662	884	936
	Route SOC (%)	-117%	-115%	-83%	-68%	-43%	-40%	-47%	-37%	-38%	-47%	-96%	-108%
	Minimum Layover Available (hr)	1:36	1:36	1:36	1:36	1:36	1:36	1:36	1:36	1:36	1:36	1:36	1:36
	Window 1 Energy Recharge (kWh)	576.0	576.0	576.0	576.0	576.0	576.0	576.0	576.0	576.0	576.0	576.0	576.0
	Window 2 Energy Recharge (kWh)	399.7	390.7	245.6	182.1	66.7	51.9	86.0	39.8	44.3	86.4	307.7	360.4
	Window 2 - Charge Time (hr)	2:39	2:36	1:38	1:12	0:26	0:20	0:34	0:15	0:17	0:34	2:03	2:24
	Total Charge Time (hr)	4:15	4:12	3:14	2:48	2:02	1:56	2:10	1:51	1:53	2:10	3:39	4:00
	Window 1 Energy Delivered (kWh)	682	682	682	682	682	682	682	682	682	682	682	682
	Window 2 Energy Delivered (kWh)	473	462	291	215	79	61	102	47	52	102	364	427
New Flyer 435kWh XE 35'	Daily Miles (mil)	52	52	52	52	52	52	52	52	52	52	52	52
	Daily kWh Recharge (kWh)	143	142	120	111	94	92	97	90	91	97	129	137
	Route SOC (%)	67%	67%	72%	74%	78%	79%	78%	79%	79%	78%	70%	68%
	Window 2 - Charge Time (hr)	0:57	0:56	0:48	0:44	0:37	0:36	0:38	0:36	0:36	0:38	0:51	0:54
	Window 1 Energy Delivered (kWh)	169	168	142	131	111	109	115	107	108	115	153	162

Appendix B – Compiled Load Profiles

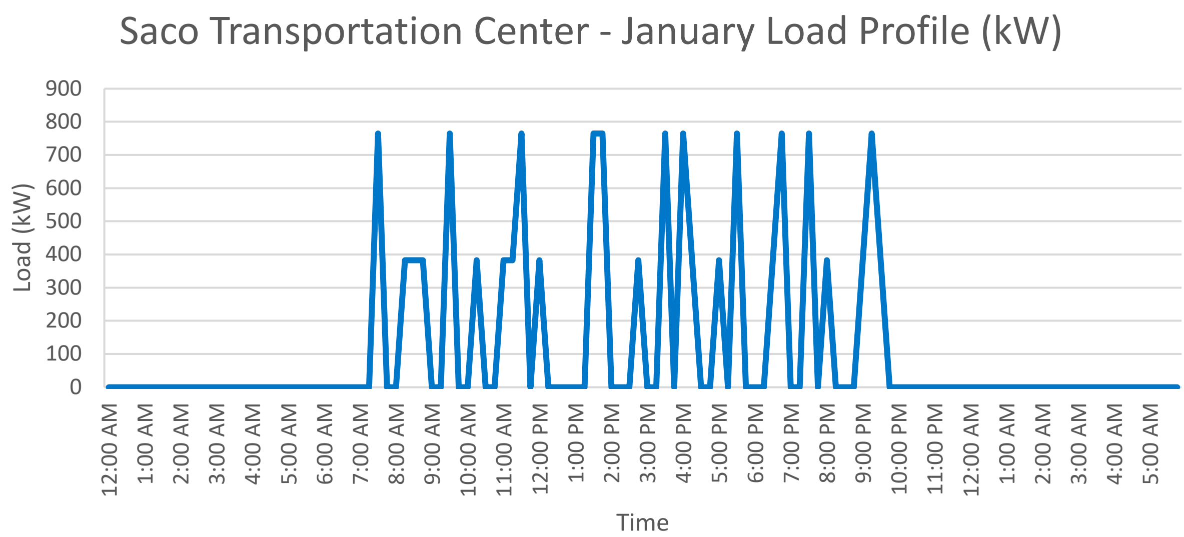

Figure B.1. January Saco Transportation Center Load Profile

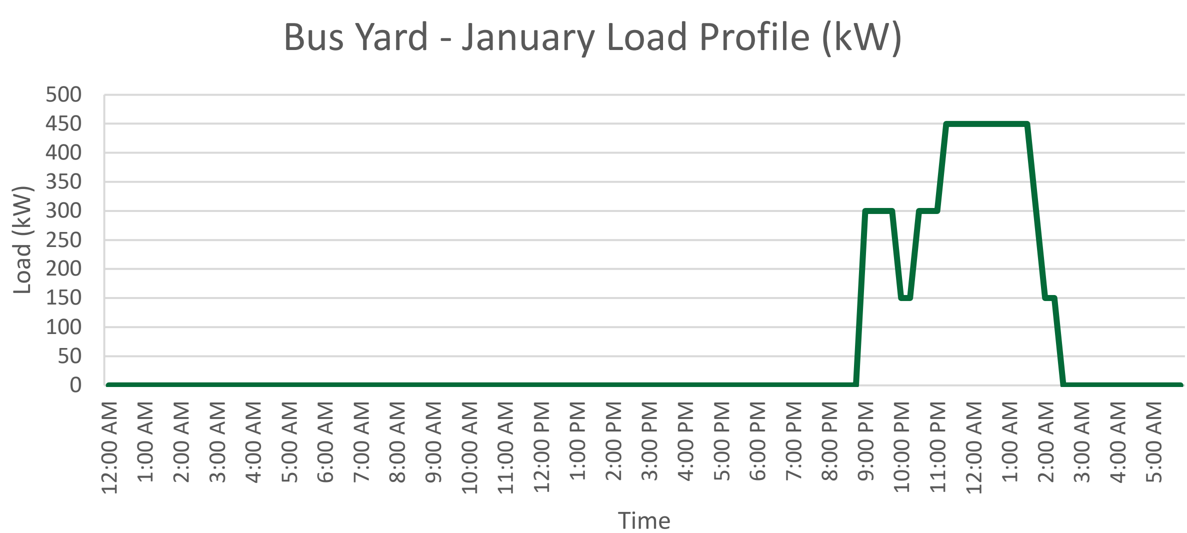

Figure B.2. January Bus Depot Load Profile for Microgrid

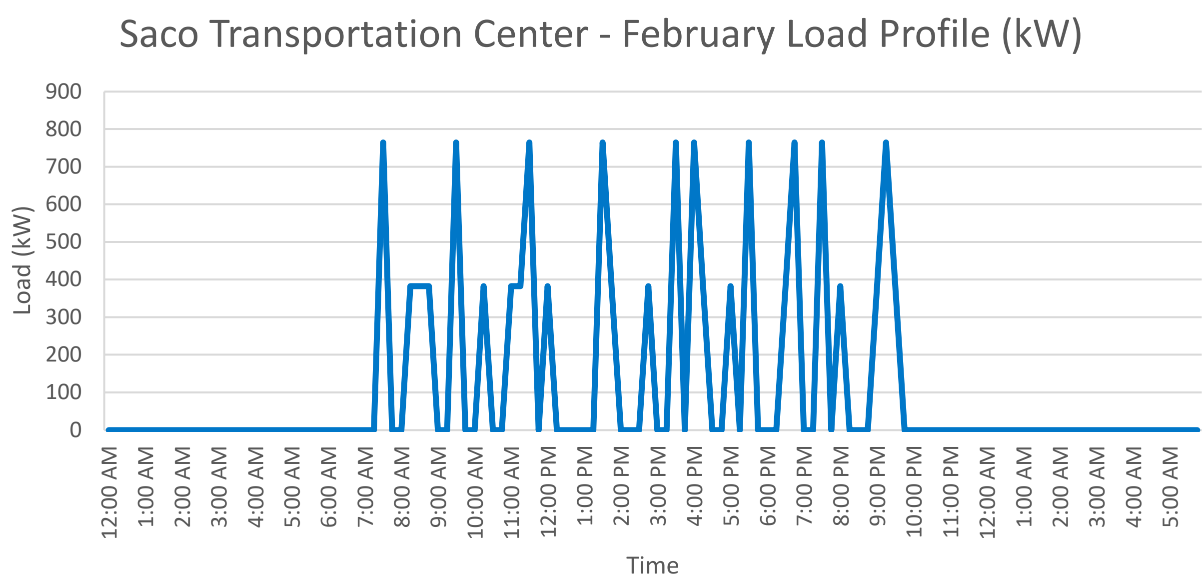

Figure B.3. February Saco Transportation Center Load Profile

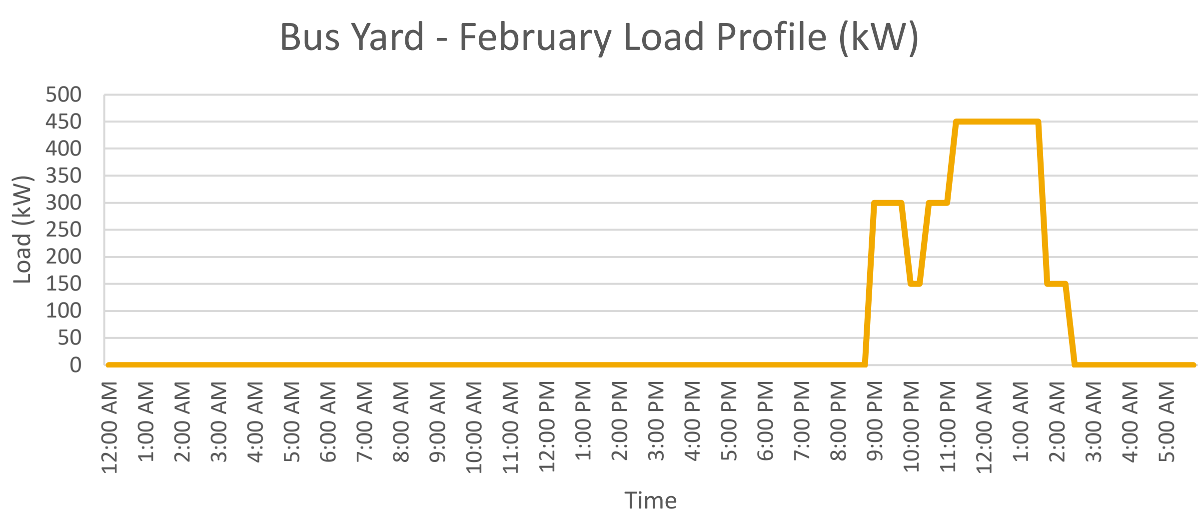

Figure B.4. February Bus Depot Load Profile for Microgrid

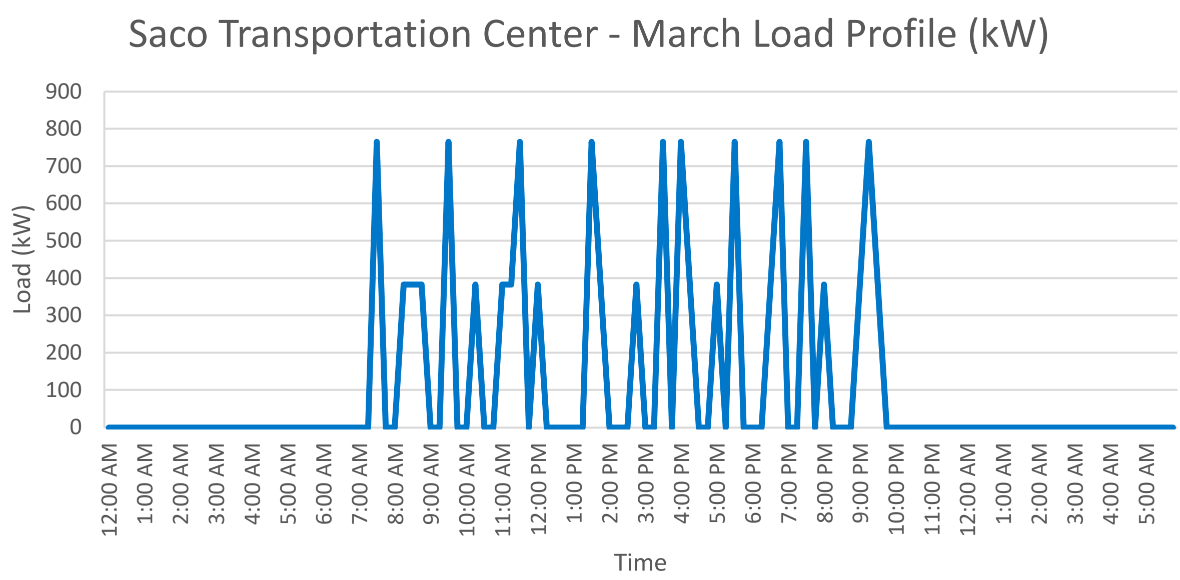

Figure B.5. March Saco Transportation Center Load Profile

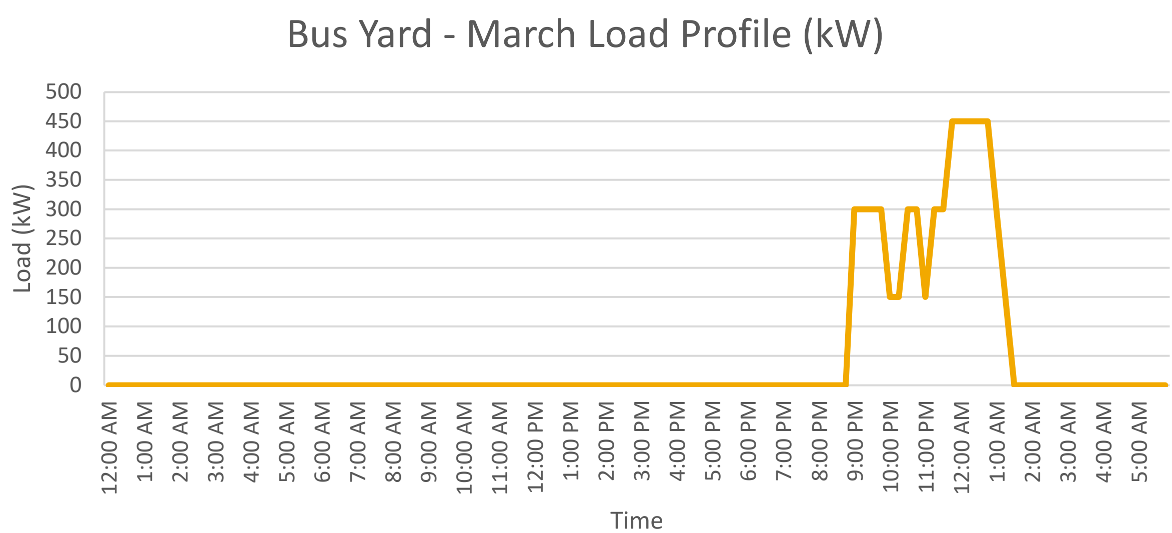

Figure B.6. March Bus Depot Load Profile for Microgrid

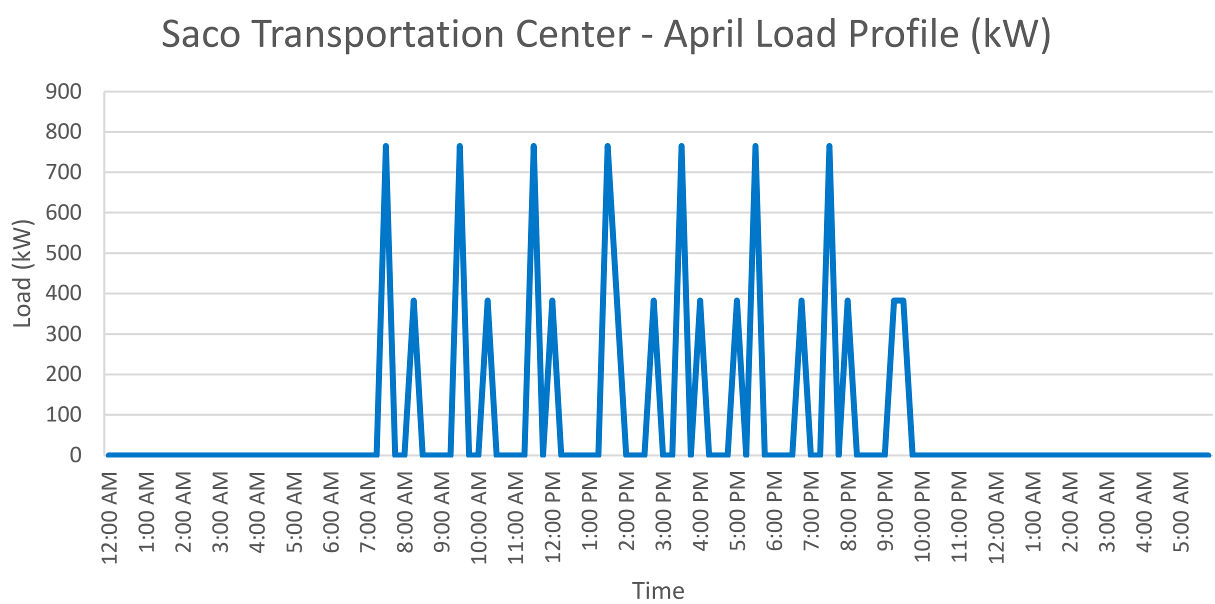

Figure B.7. April Saco Transportation Center Load Profile

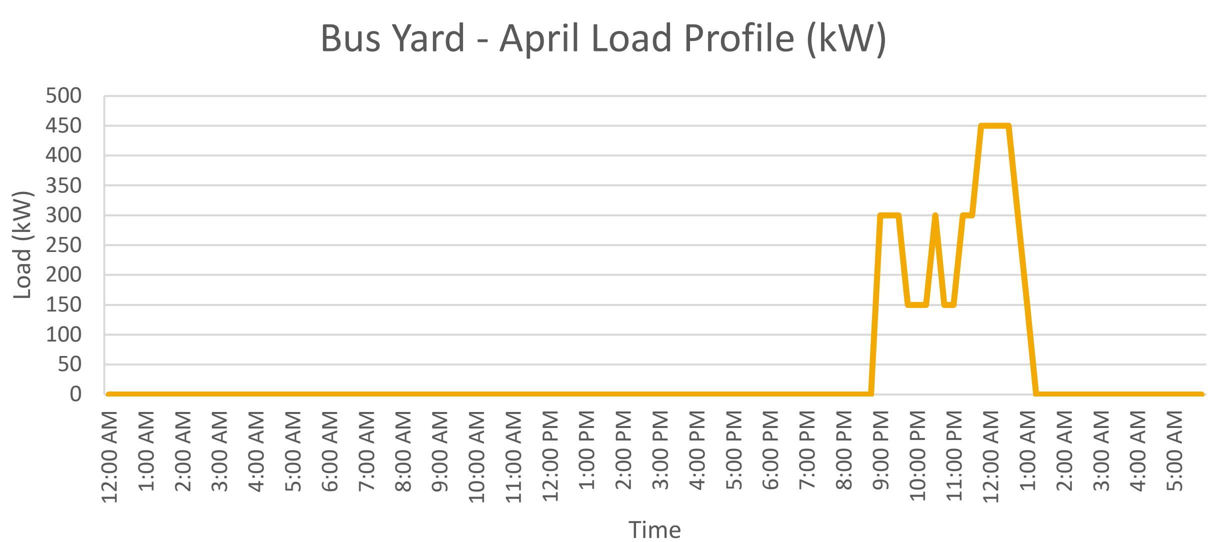

Figure B.8. April Bus Depot Load Profile for Microgrid

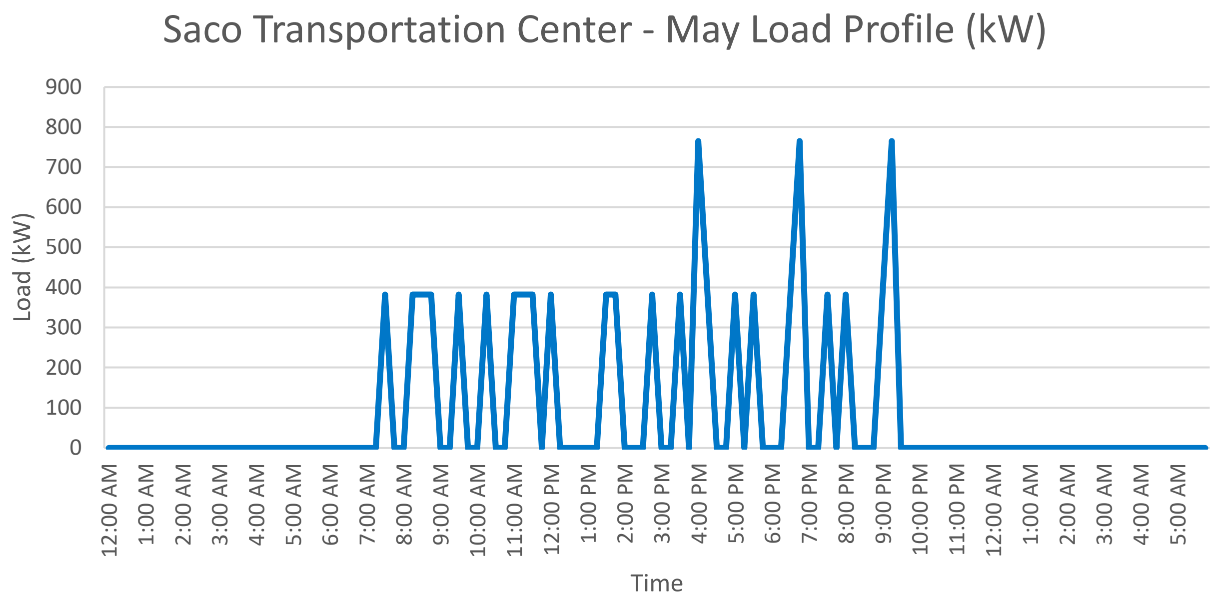

Figure B.9. May Saco Transportation Center Load Profile

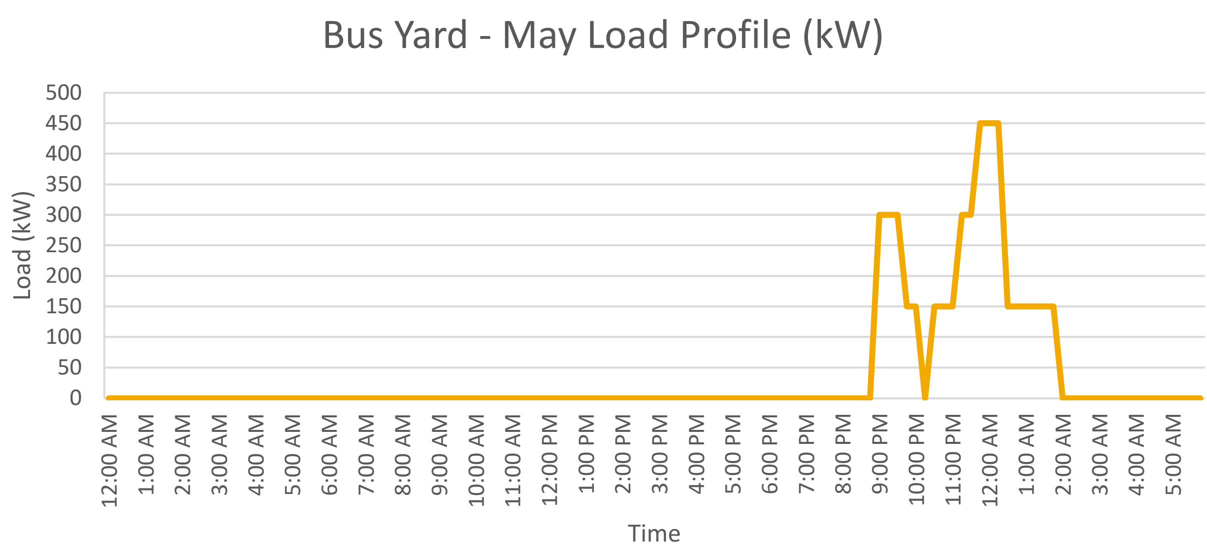

Figure B.10. May Bus Depot Load Profile for Microgrid

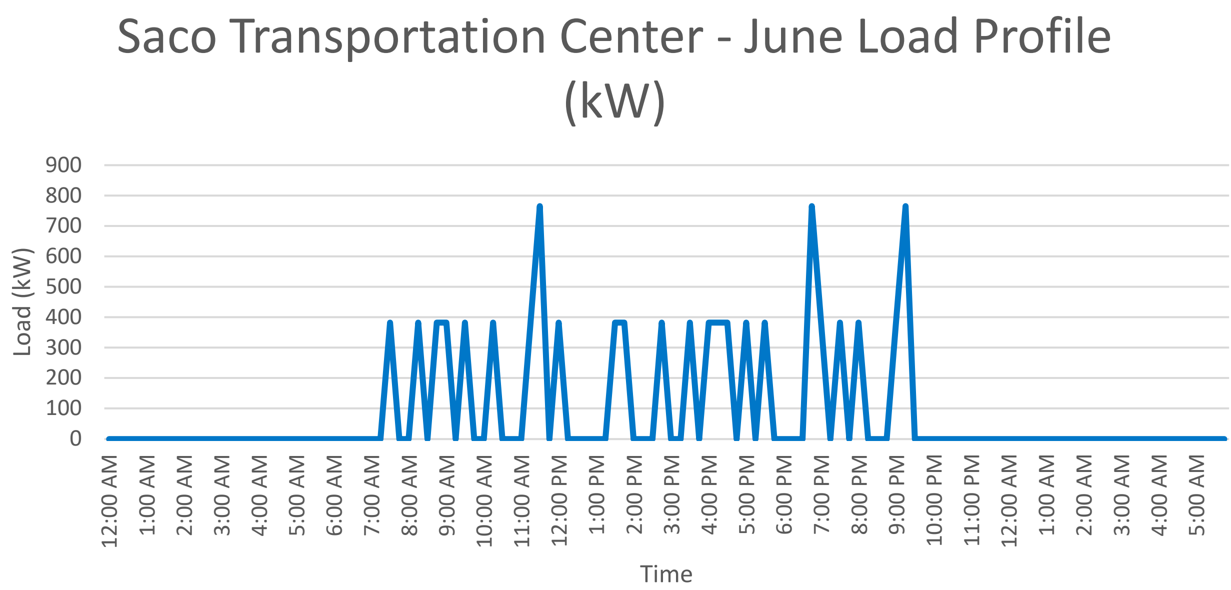

Figure B.11. June Saco Transportation Center Load Profile

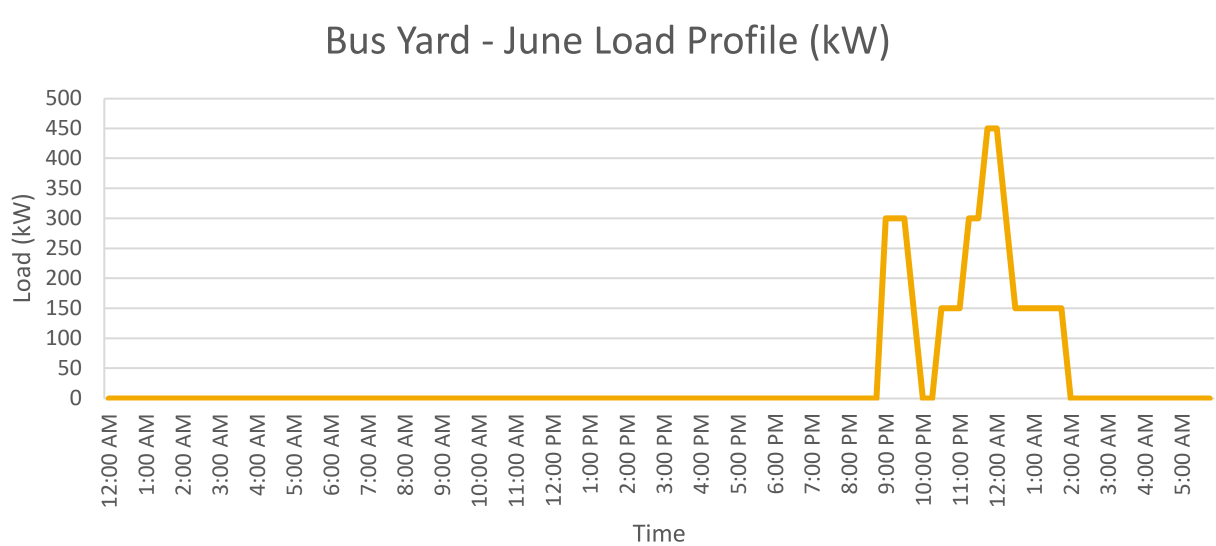

Figure B.12. June Bus Depot Load Profile for Microgrid

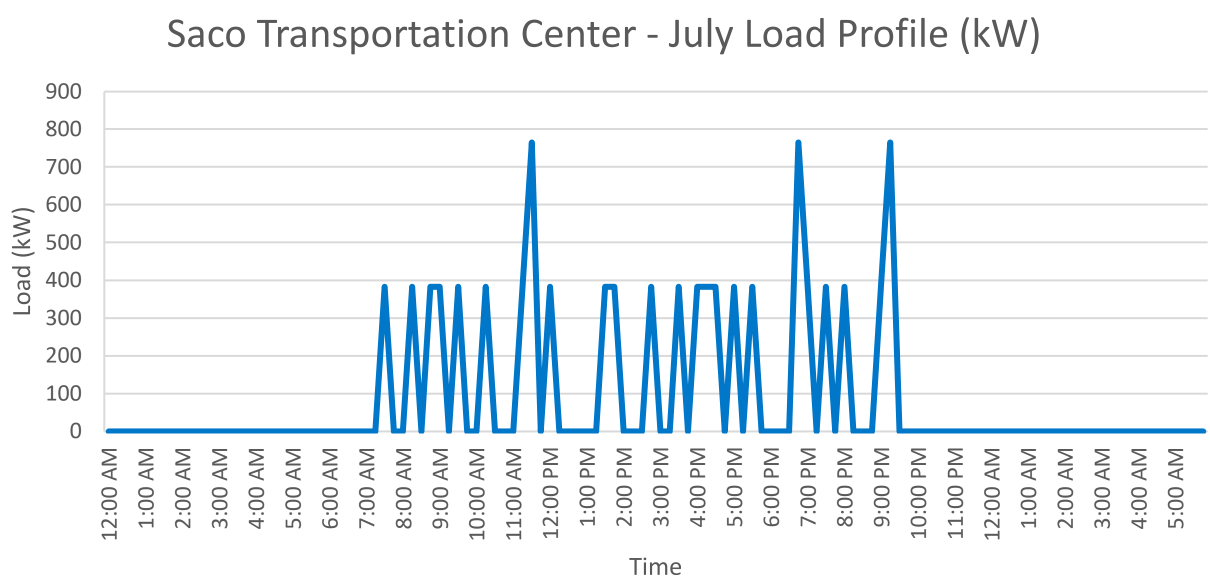

Figure B.13. July Saco Transportation Center Load Profile

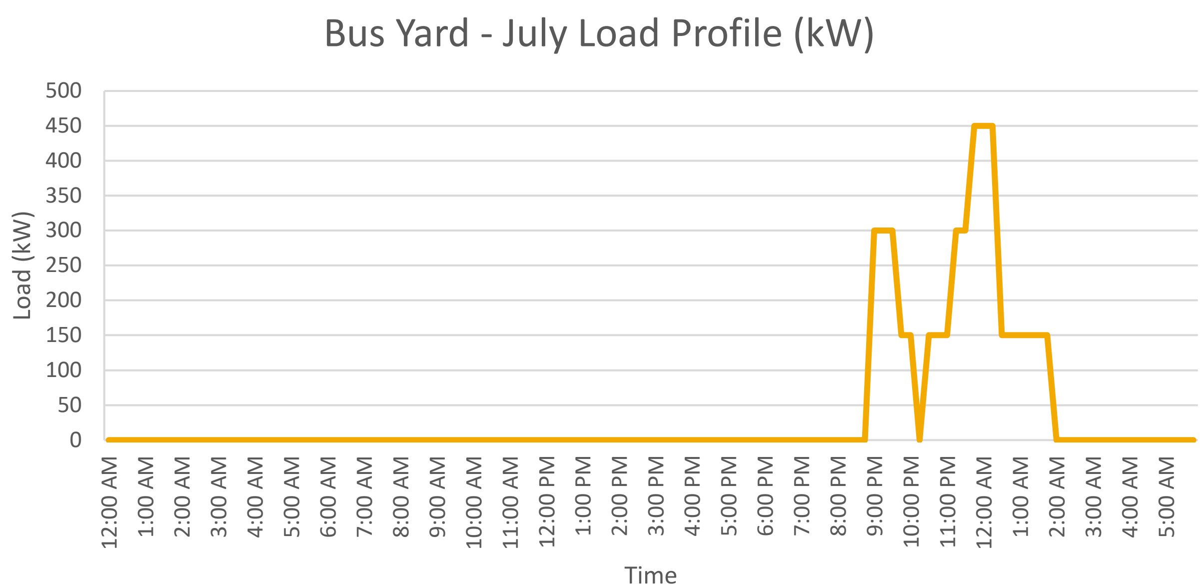

Figure B.14. July Bus Depot Load Profile for Microgrid

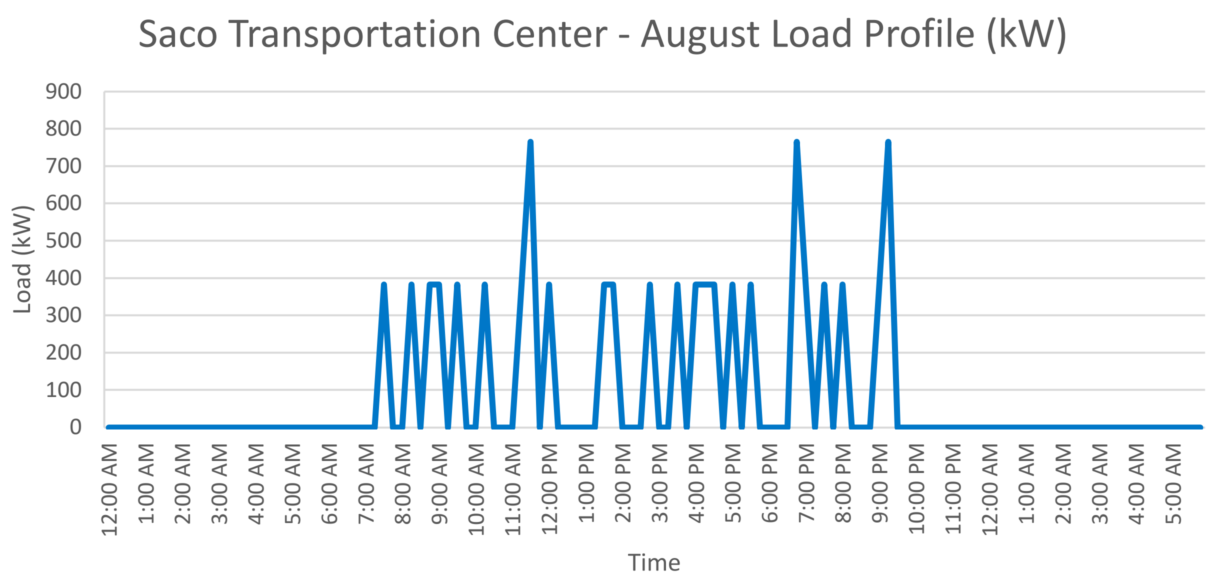

Figure B.15. August Saco Transportation Center Load Profile

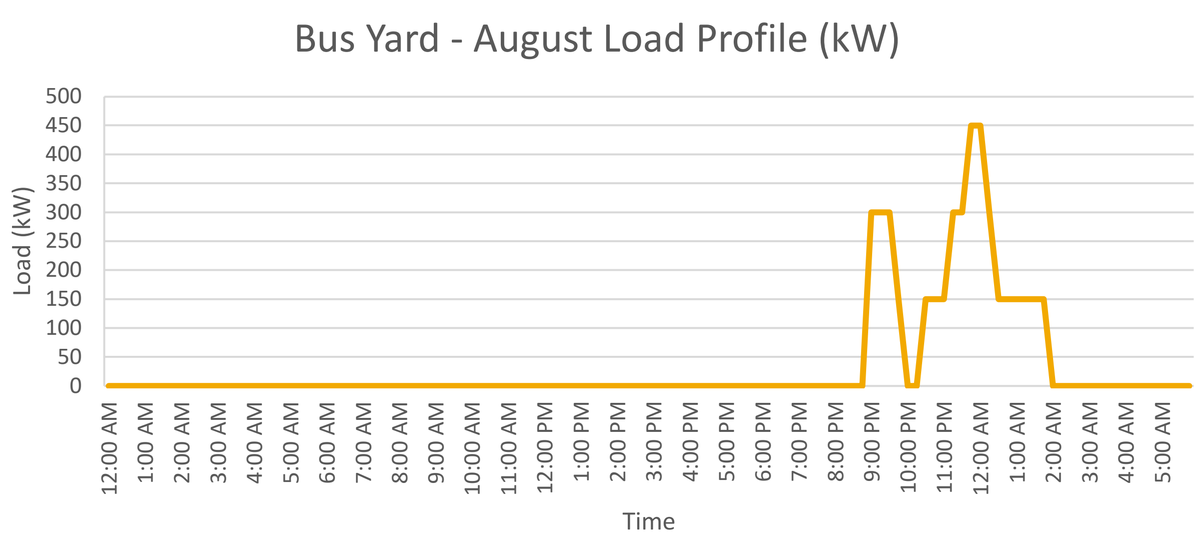

Figure B.16. August Bus Depot Load Profile for Microgrid

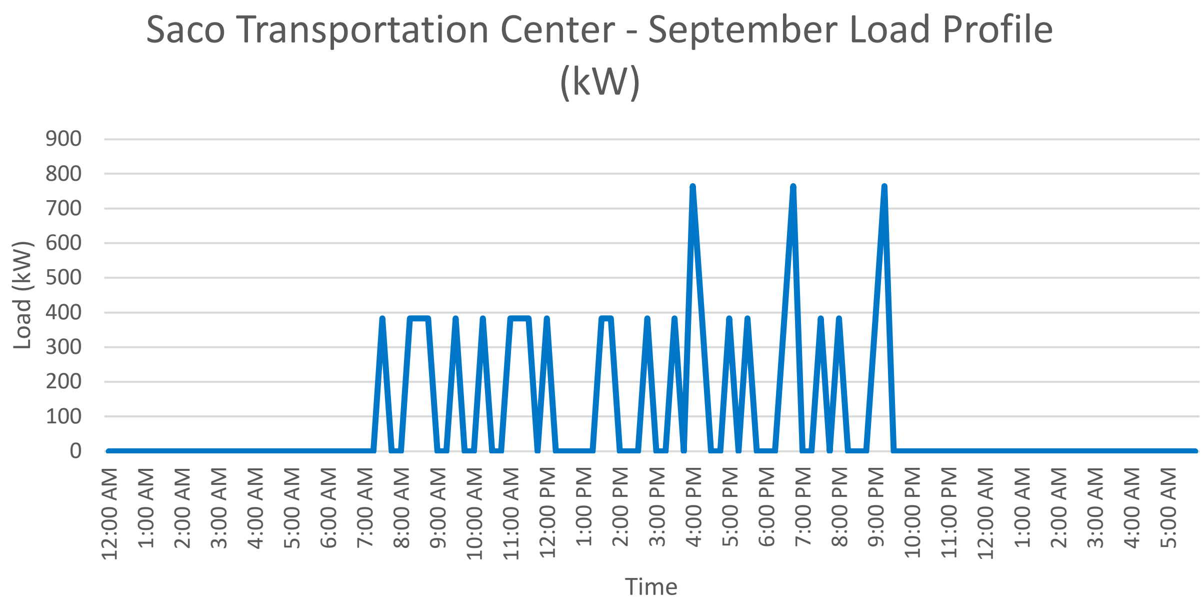

Figure B.17. September Saco Transportation Center Load Profile

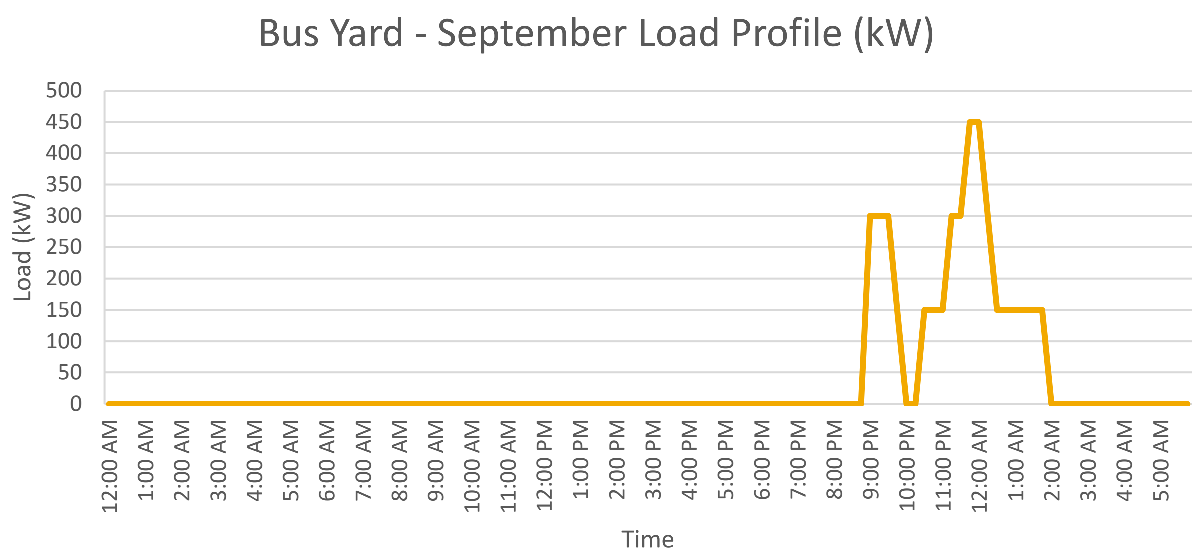

Figure B.18. September Bus Depot Load Profile for Microgrid

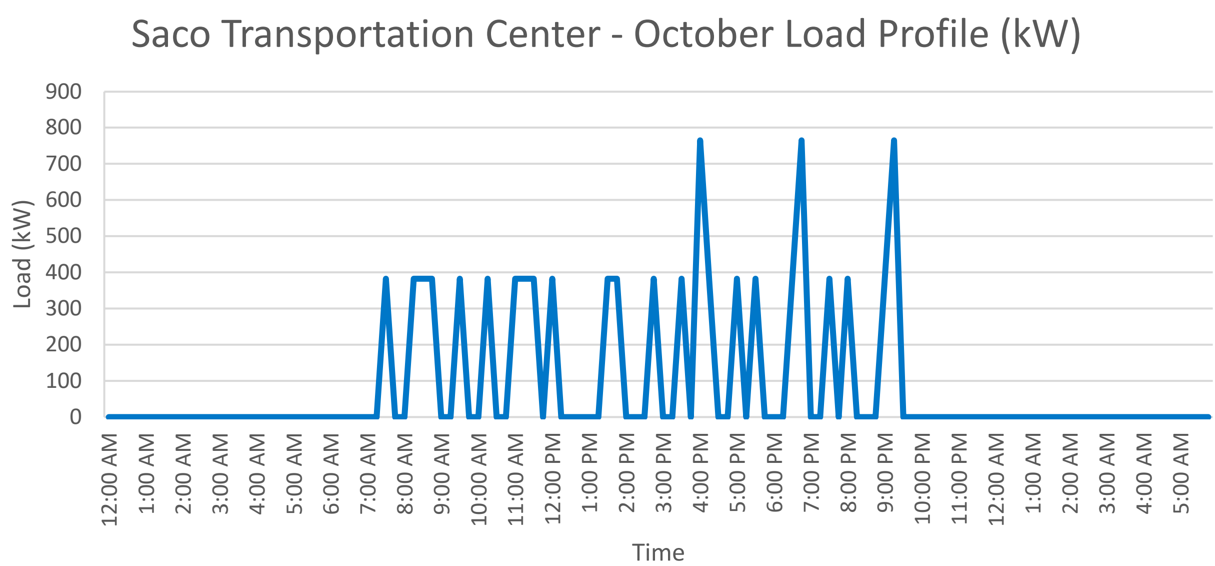

Figure B.19. October Saco Transportation Center Load Profile

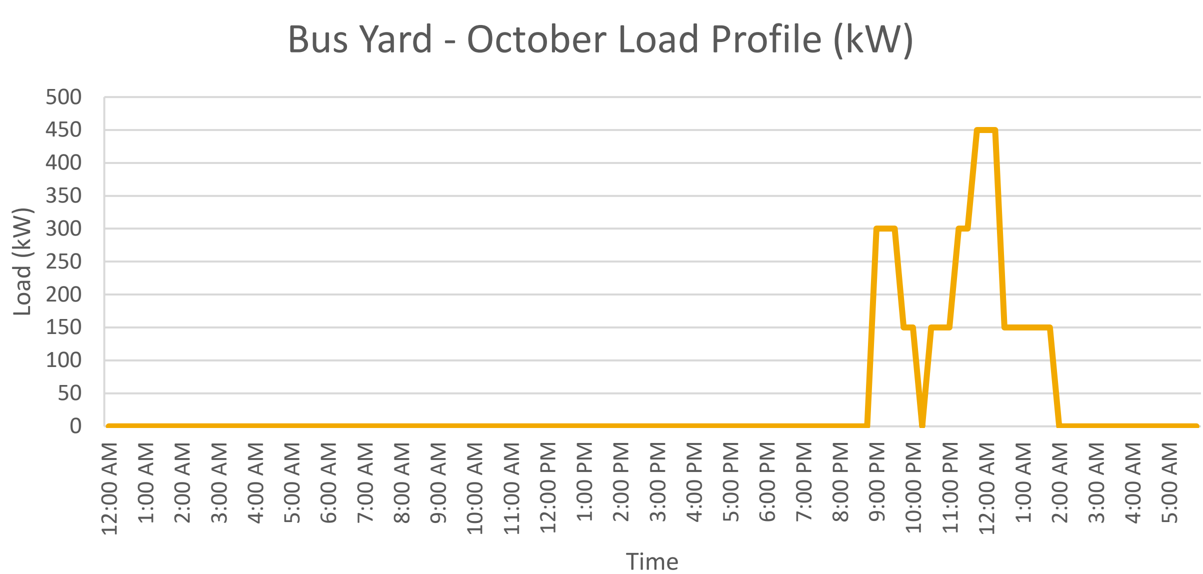

Figure B.20. October Bus Depot Load Profile for Microgrid

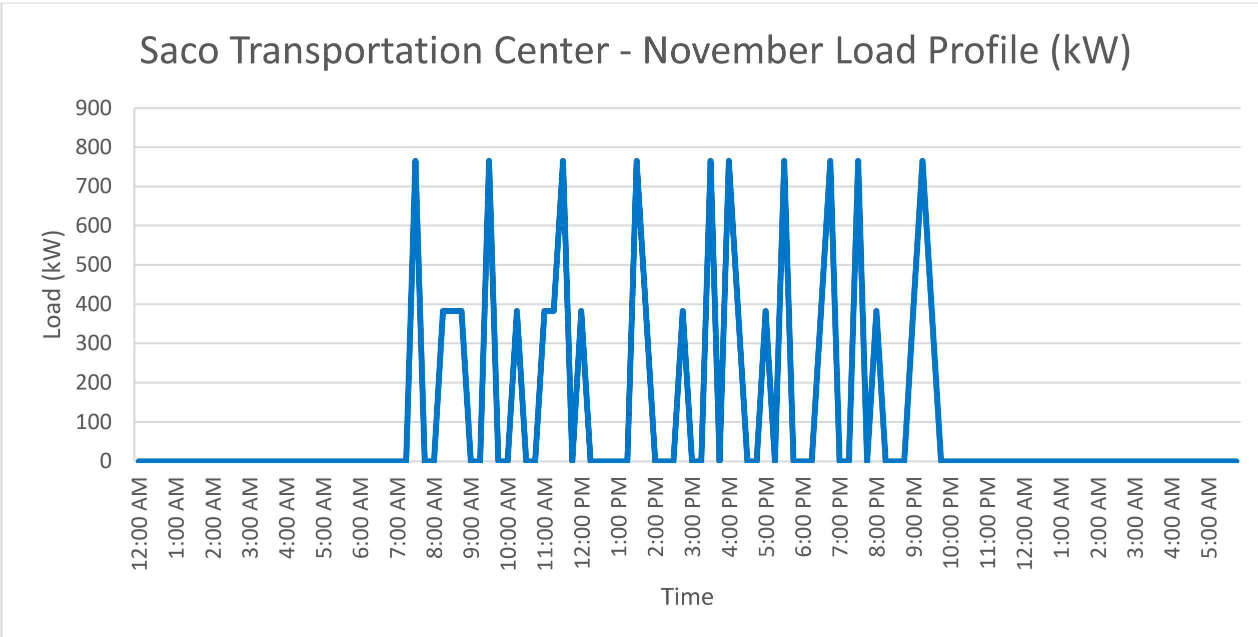

Figure B.21. November Saco Transportation Center Load Profile

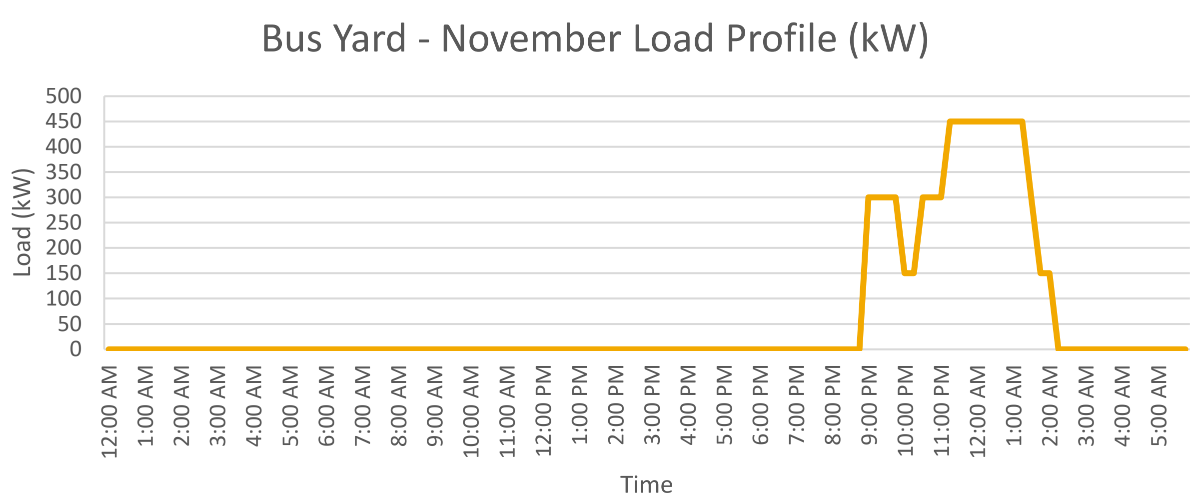

Figure B.22. November Bus Depot Load Profile for Microgrid

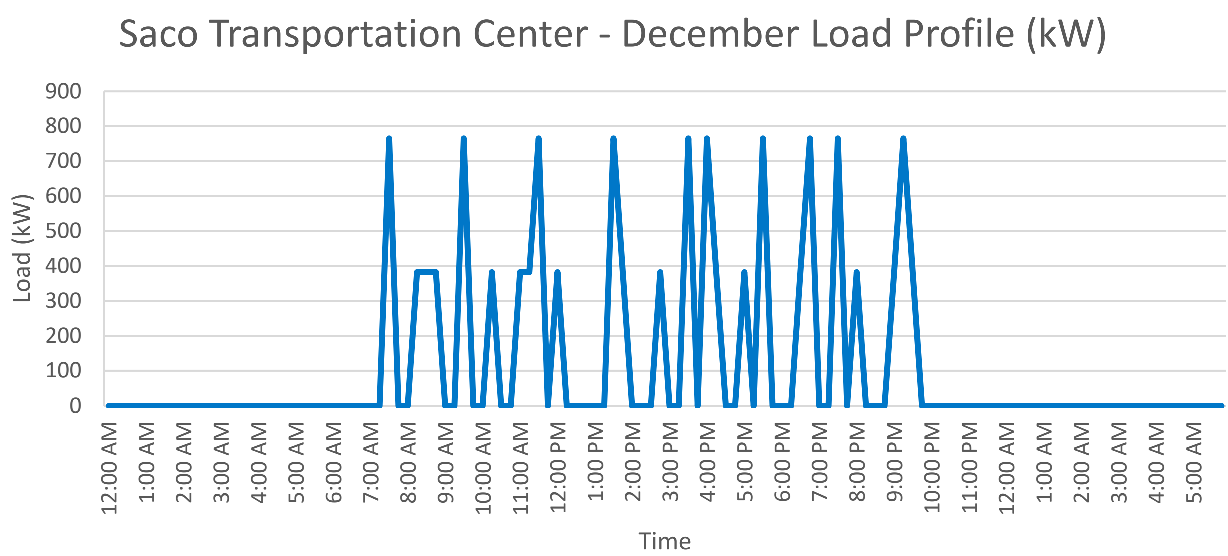

Figure B.23. December Saco Transportation Center Load Profile

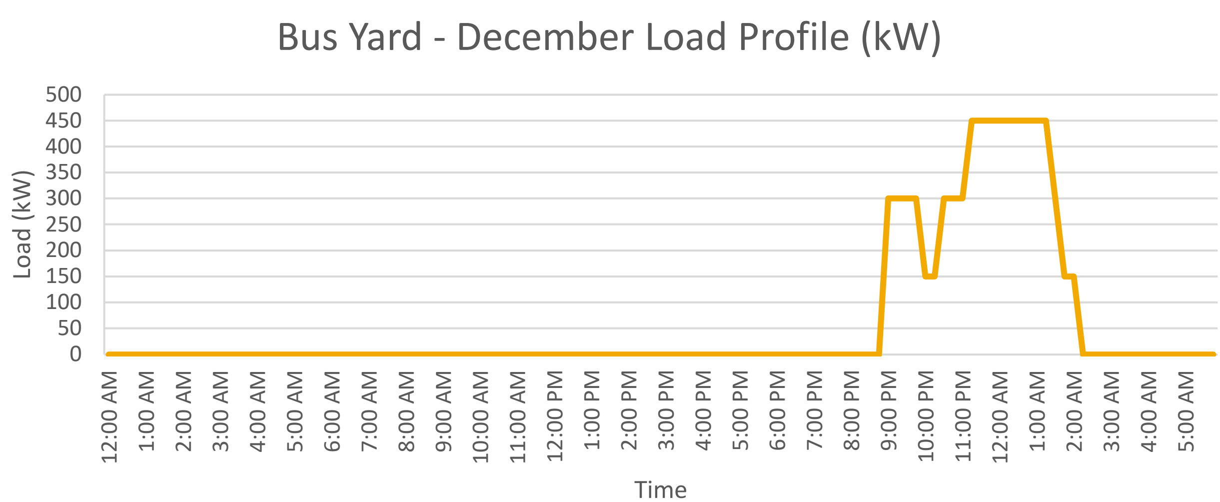

Figure B.24. December Bus Depot Load Profile for Microgrid

Appendix C – 30% Design

DISTRIBUTED ENERGY EVCS SYSTEM
BIDDEFORD SACO OLD ORCHARD BEACH TRANSIT

13 POMERLEAU STREET, BIDDEFORD ME, 04005

PROJECT TEAM

DESIGNER:
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80112
TEL: (303) 346-8975
TKELLEY@WILLDAN.COM

ELECTRICAL ENGINEER:
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DRIVE, SUITE 100
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EXT. 2176
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CIVIL ENGINEER:
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PKWY N, SUITE 405
CITY OF INDUSTRY, CA
91746
TEL: (562) 368-4903
KEVIN.SMITH@WILLDAN.COM

WILLDAN

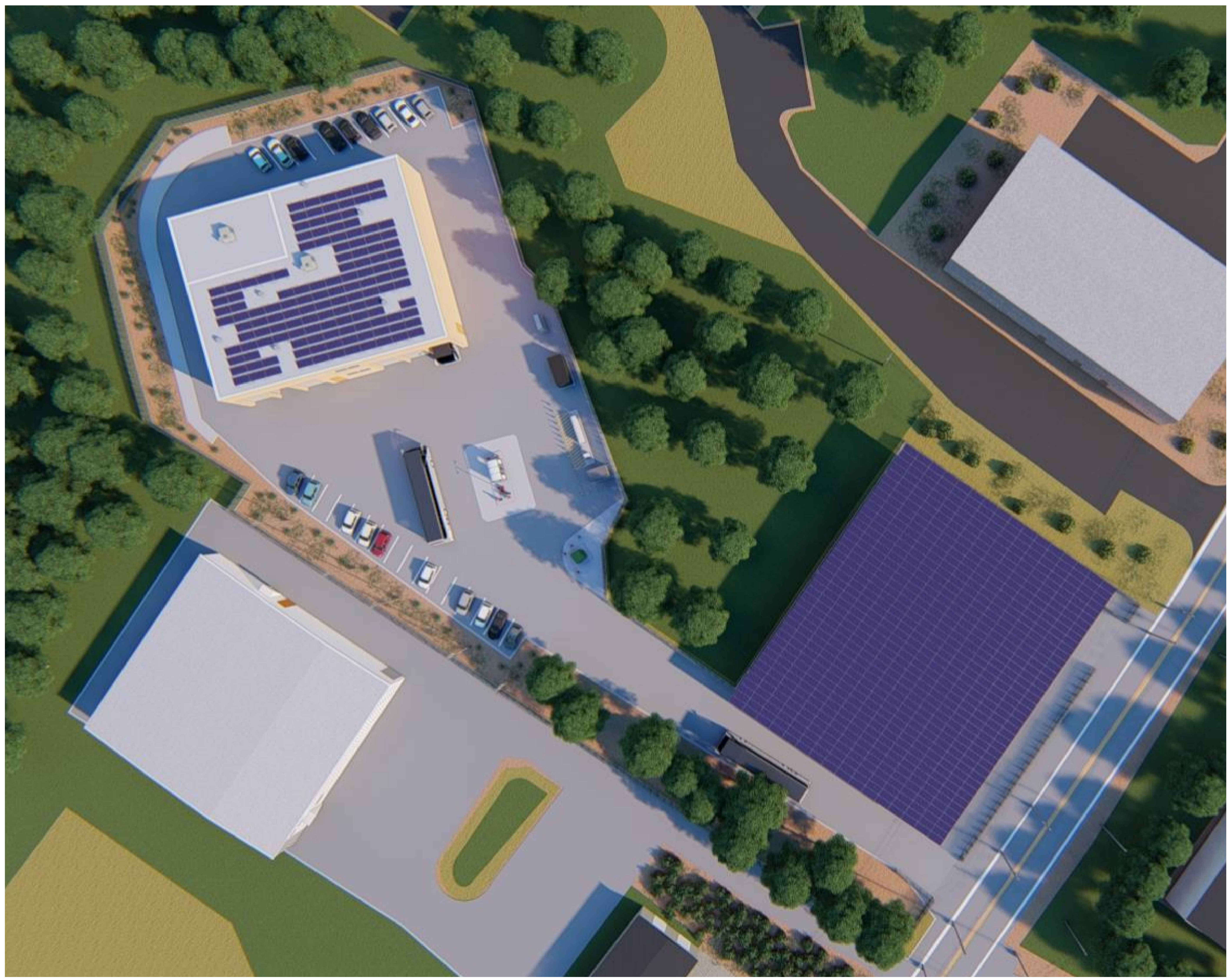
PROFESSIONAL SEALS

PRELIMINARY NOT FOR CONSTRUCTION

PROJECT TITLE

PROJECT SCOPE

SCOPE OF WORK INCLUDES THE INSTALLATION OF A MICRO-GRID AND BATTERY ENERGY STORAGE SYSTEM, PAIRED WITH A PV ELECTRICAL SYSTEM AND EV CHARGING SYSTEM. THE SYSTEM SHALL CONSIST OF ALL ASSOCIATED ELECTRICAL EQUIPMENT, CONCRETE PADS, RACKING AND ALL OTHER EQUIPMENT REQUIRED TO CONNECT TO THE ELECTRICAL DISTRIBUTION SYSTEM PER THE REQUIREMENTS OF THE NATIONAL ELECTRIC CODE AND UTILITY.



PLAN VIEW RENDERING

AUTHORITY HAVING JURISDICTION (AHJ)
CITY OF BIDDEFORDE

ELECTRIC UTILITY

CENTRAL MAINE POWER

CODE SUMMARY & REGULATIONS

THIS PROJECT IS SUBJECT TO DRAWING REVIEW AND JOB SITE INSPECTIONS BY THE AUTHORITY HAVING JURISDICTION (AHJ)

1. THIS PROJECT SHALL CONFORM TO THE LATEST ADOPTED CODE VERSIONS.

2. 110.2 APPROVAL: ALL ELECTRICAL EQUIPMENT SHALL BE LABELED, LISTED, OR CERTIFIED BY A NATIONALLY RECOGNIZED TESTING LABORATORY ACCREDITED BY THE UNITED STATES OCCUPATIONAL SAFETY HEALTH ADMINISTRATION.

GENERAL NOTES

1. ALL WORK SHALL BE COORDINATED WITH PROJECT MANAGER TO MINIMIZE DISRUPTION TO OWNER'S OPERATIONS
2. ALL CHANGES TO THE APPROVED DRAWINGS SHALL BE MADE BY ADDENDUM OR CHANGE DOCUMENTS APPROVED BY ENGINEERS OF RECORD AND THE AHJ.
3. CONTRACTOR SHALL RETURN ALL RED-LINED DRAWINGS TO WILLDAN FOR INCORPORATION INTO RECORD DRAWINGS.

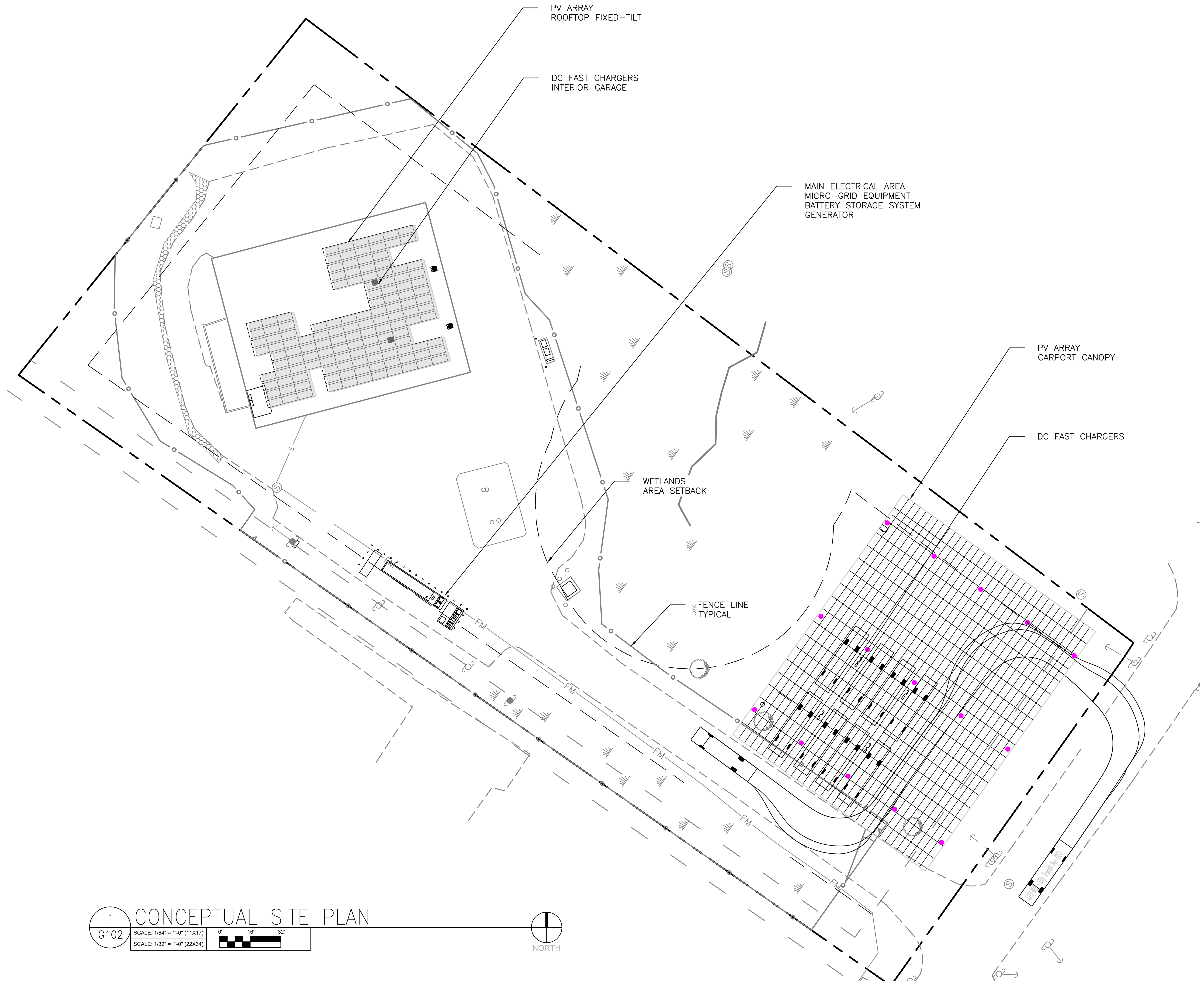
REV.	MARK	DATE	DESCRIPTION

PROJECT NO: ----
DATE: 7/24/2024
CHK'D BY: TSK
DRAWN BY: TSK

SHEET TITLE
TITLE - SHEET

T100

7/24/2024 7:29 PM



1 G102 CONCEPTUAL SITE PLAN

SCALE: 1/64" = 1'-0" (11X17)
SCALE: 1/32" = 1'-0" (22X34)

LINE TYPE LEGEND

EXISTING
NEW
DEMO

LINEWEIGHT & STYLE INDICATES SCOPE OF WORK

*Dashed may also indicate below grade.

WILLDAN

PROFESSIONAL SEALS

PRELIMINARY
NOT FOR
CONSTRUCTION

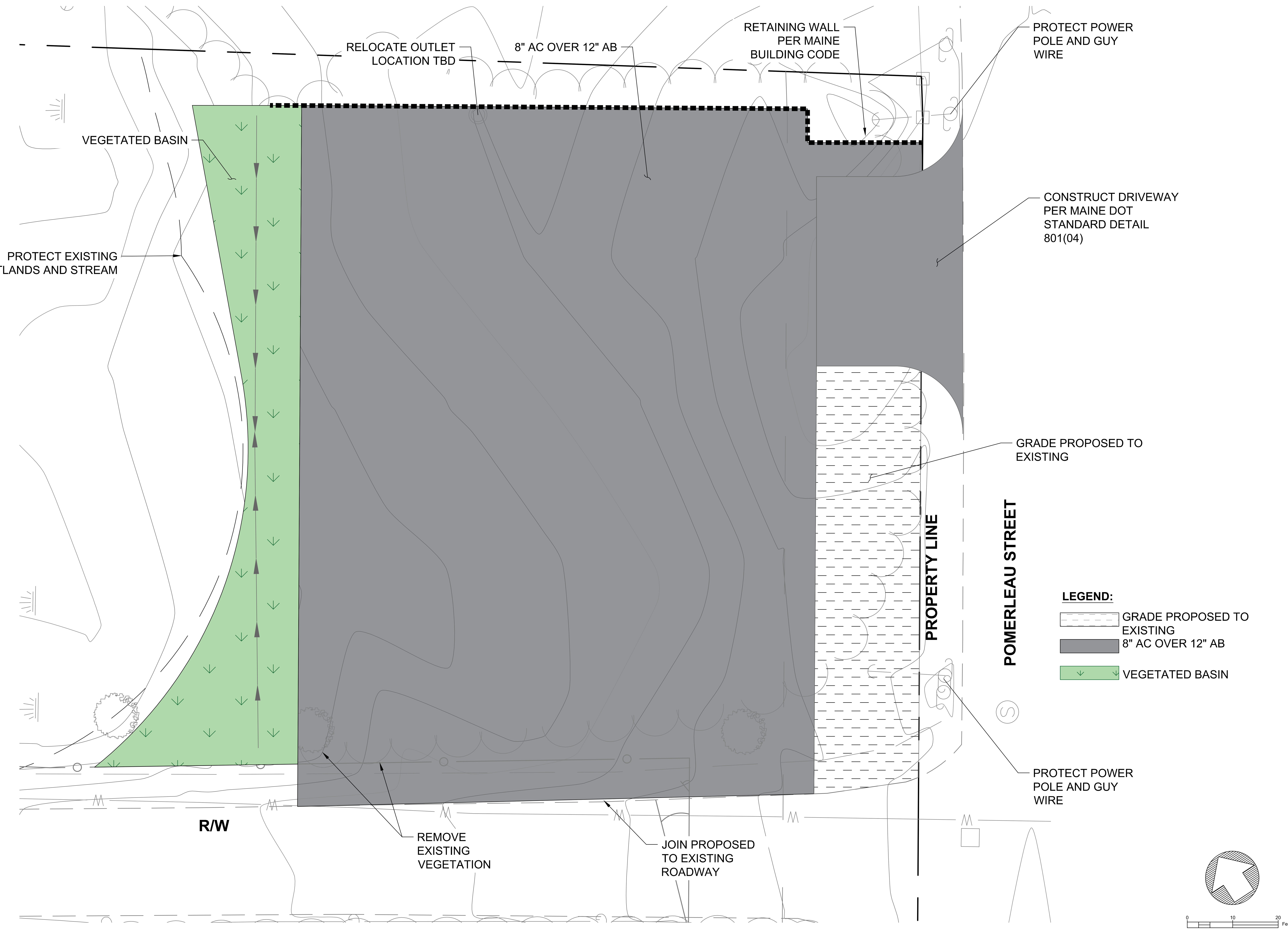
PROJECT TITLE

REV.	MARK	DATE	DESCRIPTION

PROJECT NO: ----
DATE: 7/24/2024
CHK'D BY: TSK
DRAWN BY: TSK

SHEET TITLE
SITE PLAN - 30P

G-102



\\irv-vdi1-fs1\shares\redirection\RMichel\Documents\BSOOB, Main Bus Parking Stalls\BSOOB_24.06.21.dwg6/25/2024 3:20 PM

WILLDAN

13191 CROSSROADS PKWY NORTH, SUITE 405
CITY OF INDUSTRY, CA 91456

PROFESSIONAL SEALS

NOT FOR CONSTRUCTION

PROJECT TITLE

BIDDEFORD SACO OLD ORCHARD BEACH TRANSIT

13 POMERLEAU ST

BIDDEFORD, ME 04005

ALTERNATE 2

REV.	MARK	DATE	DESCRIPTION

PROJECT NO: 113038
DATE: 06/21/24
CHK'D BY: MC
DRAWN BY: RM

SHEET TITLE

CONCEPTUAL CIVIL LAYOUT

ALTERNATE 2

LINE TYPE LEGEND

EXISTING		LINEWEIGHT & STYLE INDICATES SCOPE OF WORK
NEW		
DEMO		

*Dashed may also indicate below grade.

1
E101

ELECTRICAL SITE PLAN

SCALE: 1/64" = 1'-0" (11X17)
SCALE: 1/32" = 1'-0" (22X34)
0' 16' 32'

NORTH

WILLDAN

PROFESSIONAL SEALS

PRELIMINARY
NOT FOR
CONSTRUCTION

PROJECT TITLE

REV.	MARK	DATE	DESCRIPTION

PROJECT NO: -----
DATE: 7/24/2024
CHK'D BY: TSK
DRAWN BY: TSK

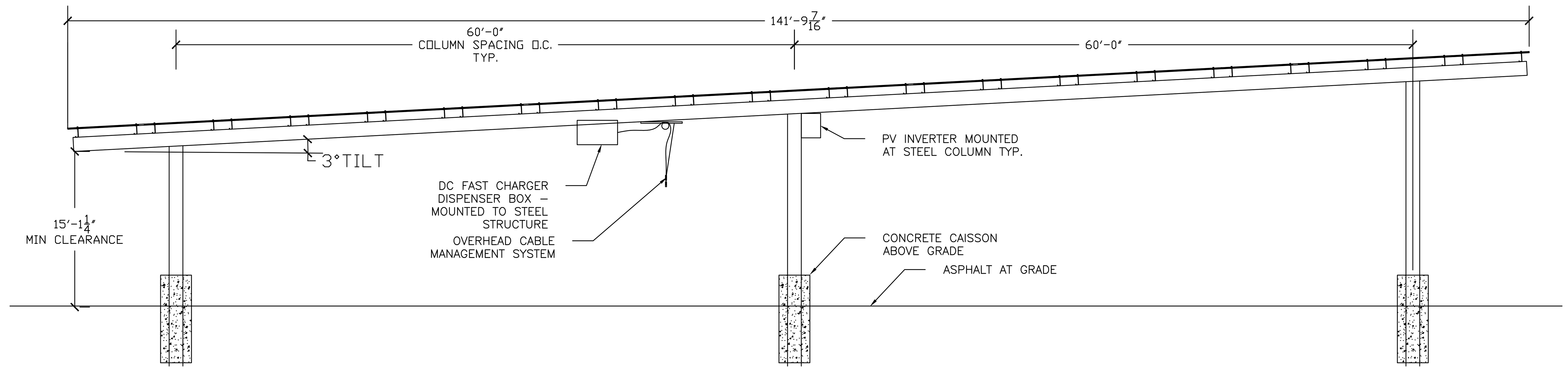
SHEET TITLE
ELECTRICAL SITE PLAN

E101

LINE TYPE LEGEND

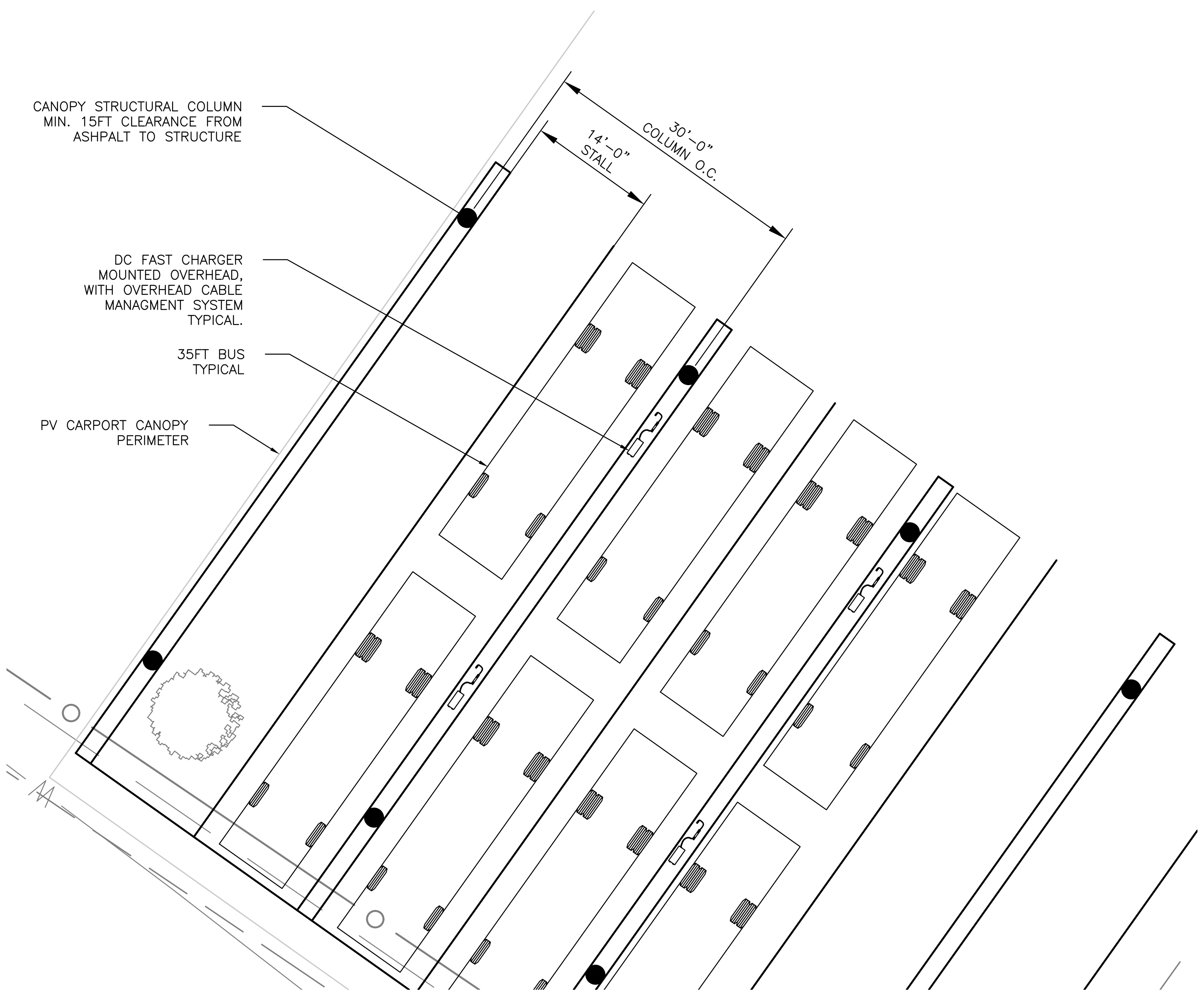
EXISTING — NEW — DEMO: LINEWEIGHT & STYLE INDICATES SCOPE OF WORK

*Dashed may also indicate below grade.



1
E401
ELEVATION VIEW – PV CANOPY PROFILE

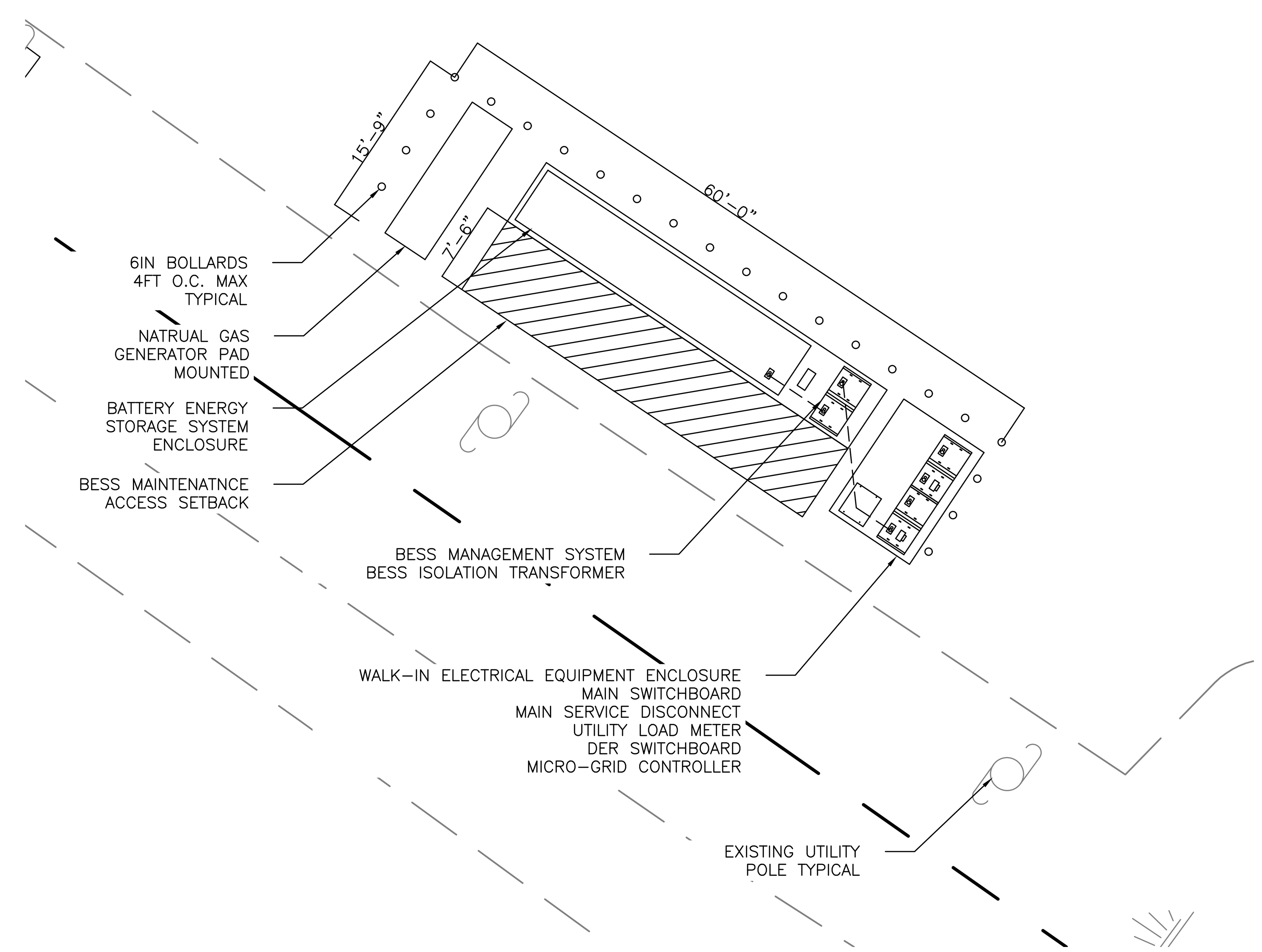
SCALE: 1/16" = 1'-0" (11X17)
SCALE: 1/8" = 1'-0" (22X34)



2
E401
ENLARGED VIEW – CANOPY CHARGING AREA

SCALE: 3/64" = 1'-0" (11X17)
SCALE: 3/32" = 1'-0" (22X34)

NORTH



3
E401
ENLARGED VIEW – MAIN ELECTRICAL AREA

SCALE: 3/64" = 1'-0" (11X17)
SCALE: 3/32" = 1'-0" (22X34)

NORTH

WILLDAN

PROFESSIONAL SEALS

PRELIMINARY NOT FOR CONSTRUCTION

PROJECT TITLE

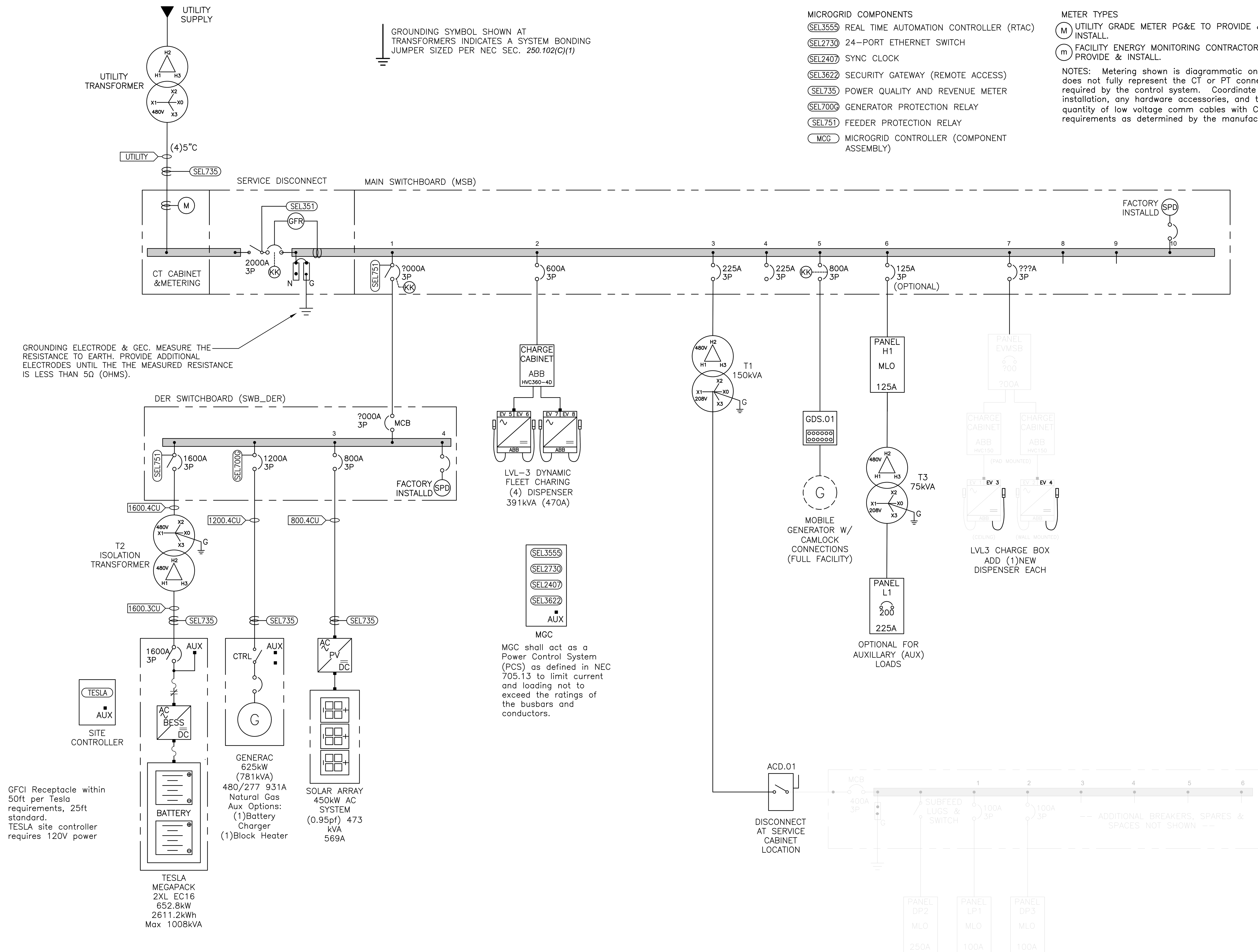
REV.	MARK	DATE	DESCRIPTION

PROJECT NO: ----
DATE: 7/24/2024
CHK'D BY: TSK
DRAWN BY: TSK

SHEET TITLE
ELECTRICAL ENLARGED PLANS

E401

7/24/2024 7:29 PM



MICROGRID COMPONENTS

- SEL3555 REAL TIME AUTOMATION CONTROLLER (RTAC)
- SEL2730 24-PORT ETHERNET SWITCH
- SEL2407 SYNC CLOCK
- SEL3622 SECURITY GATEWAY (REMOTE ACCESS)
- SEL735 POWER QUALITY AND REVENUE METER
- SEL700G GENERATOR PROTECTION RELAY
- SEL751 FEEDER PROTECTION RELAY
- MCG MICROGRID CONTROLLER (COMPONENT ASSEMBLY)

METER TYPES

- M UTILITY GRADE METER PG&E TO PROVIDE & INSTALL.
- m FACILITY ENERGY MONITORING CONTRACTOR TO PROVIDE & INSTALL.

NOTES: Metering shown is diagrammatic only and does not fully represent the CT or PT connections required by the control system. Coordinate installation, any hardware accessories, and the quantity of low voltage comm cables with CT/PT requirements as determined by the manufacturer.

LINE TYPE LEGEND

- EXISTING
- DEMO*
- NEW

LINEWEIGHT & STYLE INDICATES SCOPE OF WORK

*Dashed may also indicate below grade.

GENERAL NOTES:

1. REFERENCE DRAWING E001 AND E002 FOR LEGEND, ABBREVIATIONS, AND NOTES.
2. THE EXISTING INFORMATION SHOWN IS BASED ON SITE OBSERVATIONS AND THE ORIGINAL AS-BUILT DRAWINGS WITH ACCURACY BASED ON LIMITED FIELD VERIFICATION. PRIOR TO STARTING WORK, CONFIRM ALL FEEDERS AND CONDUIT ROUTES WITHIN THE SCOPE OF WORK. ANY FIELD DISCREPANCIES FOUND THAT AFFECT THE DESIGN INTENT SHALL BE REPORTED TO THE INSTALLING CONTRACTOR. WHERE DESIGN CHANGES ARE REQUIRED THE ENGINEER SHALL BE NOTIFIED AND SHALL BE REQUIRED TO APPROVE ANY DESIGN CHANGES.
3. CONDUCTOR SIZES ARE TYPICALLY LIMITED TO WIRE SIZE #350AWG AND SMALLER TO MAKE WIRE PULLING AND TERMINAL CONNECTIONS EASIER. EC MAY ELECT TO USE LARGER FEEDERS AT THEIR DISCRETION.
4. WHERE SETS, OR PARALLEL RUNS ARE REQUIRED EACH PHASE A-B-C, NEUTRAL, EQUIPMENT GROUNDING CONDUCTOR, OR EQUIPMENT BONDING JUMPER SHALL BE GROUPED PER CONDUIT AND IS COUNTED AS A SET (RE: "ELECTRICAL NOTES" NOTE #34 ON SHEET E001.
5. CONTRACTOR TO PERFORM COORDINATION STUDY FOR THE NEW SERVICE AND NEW ELECTRICAL DISTRIBUTION ONCE FINAL BREAKER SELECTIONS HAVE BEEN DETERMINED, SUBMITTED, AND APPROVED.
6. CONTRACTOR TO PERFORM ARC FLASH STUDIES AT ALL REQUIRED EQUIPMENT. AS PART OF THE CALCULATION, A SEPARATE FAULT CURRENT ANALYSIS WILL ACCOMPANY THEIR STUDY ONCE THE EQUIPMENT SIZES, FEEDERS AND CONDUCT RUNS HAVE BEEN DETERMINED.
7. CONTRACTOR SHALL PROVIDE AND INSTALL ALL REQUIRED ARC FLASH LABELS ONCE THE ELECTRICAL CONTRACTOR'S ARC FLASH STUDY IS COMPLETED. TYPICAL LABEL SHOWN BELOW WITH A SAMPLE OF THE REQUIRED INFORMATION PRINTED ON THE LABEL.

KEYED NOTES:

1. UTILITY LOAD METER WILL BE NET METERING
2. PV AC DISCONNECT LOCATED WITHIN 10FT OF UTILITY SERVICE DISCONNECT, VISIBLE AND LOCKABLE
3. THE EXISTING LEVEL-3 EV CHARGER CABINET WILL BE CONNECTED AND SUPPLIED WITH NEW FEEDERS FROM THE NEW "MSB".
4. EXISTING FACILITY BUILDING SERVICE AND FEEDERS AND CT CABINET WILL BE DEMOLISHED, REPLACED WITH NEW FEEDERS FROM "MSB" AND VOLTAGE TRANSFORMER.
5. COORDINATE METER BASE AND CT CABINET TO ACCEPT ONE OF THE APPROVED UTILITY METER SOCKET PIN CONFIGURATIONS.
6. PROVIDE AND INSTALL A NEW ENGRAVED PLASTIC LABELS ON ALL NEW EQUIPMENT INCLUDES ALL: SWITCHBOARDS, PANELBAORDS DISCONNECTS, TRANSFORMERS, ETC. ENGRAVED LABELS SHALL BE PHENOLIC TYPE ADHESIVE BACKED, WITH A BLACK BACKGROUND AND WHITE LETTERING. LETTERING SHALL BE ALL UPPERCASE WITH A MINIMUM HEIGHT OF 5/8".
7. MAIN BREAKER SHALL BE SPECIFIED TO INCLUDE ENERGY REDUCTION MAINTENANCE SWITCH (ERMS) PER NEC 240.87. AN ERMS WITH A LOCAL STATUS INDICATOR SHALL BE INCLUDED WITH MAIN BREAKER. ERMS SHALL REDUCE THE INSTANTANEOUS PICKUP SETTING TO NO MORE THAT TWO TIMES THE SENSOR CURRENT. WHEN PROCURING SWITCHBOARD ENSURE THE ERMS AND ITS ASSOCIATED COMPONENTS ARE NOT INSTALLED IN PG&E SECTIONS.
8. FOR TESTING PURPOSES, MEANS ARE ALSO REQUIRED TO DISCONNECT THE SWITCHBOARD NEUTRAL BUS FROM THE GROUNDED SERVICE NEUTRAL CONDUCTOR (SINGLE-PHASE, THREE-WIRE; AND THREE-PHASE, FOUR WIRE SYSTEMS). TO COMPLY WITH THIS REQUIREMENT, A REMOVABLE LINK (SOLID BAR) IS PROVIDED IN THE SWITCHBOARD NEUTRAL BUS. THIS LINK IS GENERALLY LOCATED NEAR THE POINT WHERE THE MAIN FEEDERS ENTER THE SWITCHBOARD OR IN THE AREA OF THE MAIN DISCONNECT DEVICE WHERE ONE IS PROVIDED.
10. TO FULLY COMPLY WITH NEC AND UL REQUIREMENTS, A SEPARATE BONDING STRAP IS REQUIRED CONNECTING THE NEUTRAL BUS TO THE SWITCHBOARD FRAME. THIS BONDING CONNECTION IS LOCATED ON THE LINE SIDE OF THE REMOVABLE NEUTRAL LINK, MAINTAINING A SERVICE GROUND TO THE SWITCHBOARD FRAME WHEN THE TEST LINK IS REMOVED.
11. PROVIDE ENERGY METER INSTALLED ON NEW ELECTRICAL DISTRIBUTION EQUIPMENT TO MONITOR ENERGY USAGE AND STORE DATA FOR 12MONTH MINIMUM. METER SHALL BE DENT POWER SCOUT, OR APPROVED EQUIVALENT, WITH INTERNAL STORAGE AND NETWORK CARD FOR INTERCONNECTION TO LOCAL ENERGY MANAGEMENT SYSTEM (EMS). EC TO PROVIDE CTs AND ALL NECESSARY HARDWARE TO INSTALL.
12. GENERATOR DOCKING STATION TRYSTAR 1200A 480Y/277 3PH CAMLOCKS (WALL MOUNT). SIZED FOR FULL FACILITY BACKUP POWER CONNECTION.

1 / E701 ELECTRICAL ONE-LINE DIAGRAM
NOT TO SCALE

WILLDAN
2401 E. KATELLA AVE. SUITE 300
ANAHEIM, CA 92806

PROFESSIONAL SEALS

PRELIMINARY NOT FOR CONSTRUCTION

PROJECT TITLE

DISTRIBUTED ENERGY EVCS SYSTEM

BSOOB - DER

13 POMERLEAU STREET, BIDDEFORD ME, 04005

30%

REV. MARK	DATE	DESCRIPTION

PROJECT NO: ---- | DATE: 7/24/2024
CHK'D BY: TSK | DRAWN BY: TSK

SHEET TITLE
ELECTRICAL ONE LINE DRAWING

E701

Appendix D – Compiled Spec Sheets for Microgrid Components

Appendix E – Microgrid Renderings

Appendix F – Skills Gap Survey Results