WISCONSIN OFFICE OF ENERGY INNOVATION SAUK PRAIRIE EMERGENCY OPERATIONS CENTER MICROGRID FEASIBILITY STUDY

Prepared for the Wisconsin Office of Energy Innovation (WI OEI)

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About SEPA

The Smart Electric Power Alliance (SEPA) is dedicated to helping electric power stakeholders address the most pressing issues they encounter as they pursue the transformation to a carbon-free energy system. We are a trusted partner providing education, research, standards, and collaboration to help utilities, electric customers, and other industry players across three pathways: Regulatory and Business Innovation, Grid Integration, Electrification. Through educational activities, working groups, peer-to-peer engagements and custom projects, SEPA convenes interested parties to facilitate information exchange and knowledge transfer to offer the highest value for our members and partner organizations. For more information, visit www.sepapower.org.

Acknowledgements

SEPA would like to thank the Wisconsin Office of Energy Innovation (WI OEI) for the opportunity to conduct this study. The study was made possible by WI OEI's Critical Infrastructure Microgrid and Community Resilience Centers Pilot Grant Program (CIMCRC), which focuses on innovative pre-disaster mitigation through critical infrastructure microgrids and other resilient building strategies by studying the feasibility of the deployment of distributed energy resources (DERs) and appropriately sized storage, along with a grid-interactive controls schema. This feasibility study was one of sixteen (16) grants awarded across the state.

SEPA would also like to thank its project partners at Sauk Prairie Police Commission, WPPI Energy, and the Village of Prairie Du Sac.

0.0 Executive Summary

Extreme weather events threaten damage to the electrical system and disruption to power supply. These weather events in Wisconsin are increasing in both frequency and economic impact, causing prolonged outages, and disproportionately affecting underserved communities. This project presents an opportunity to collaborate with a Wisconsin police station which will house an emergency operations center (EOC) to assess the feasibility of deploying a microgrid as a pre-disaster mitigation technique. An appropriately sized microgrid could insulate the facility from the impacts of prolonged outages and build resilience for the community. This study identifies a microgrid as a resilience solution, develops microgrid designs that incorporate varying power supply technologies, and utilizes stakeholder input to evaluate the feasibility of each microgrid design. This feasibility study was funded by a grant from WI OEI and donated funds and working time from SEPA, Sauk Prairie Police Commission, WPPI Energy, and the Village of Prairie Du Sac.

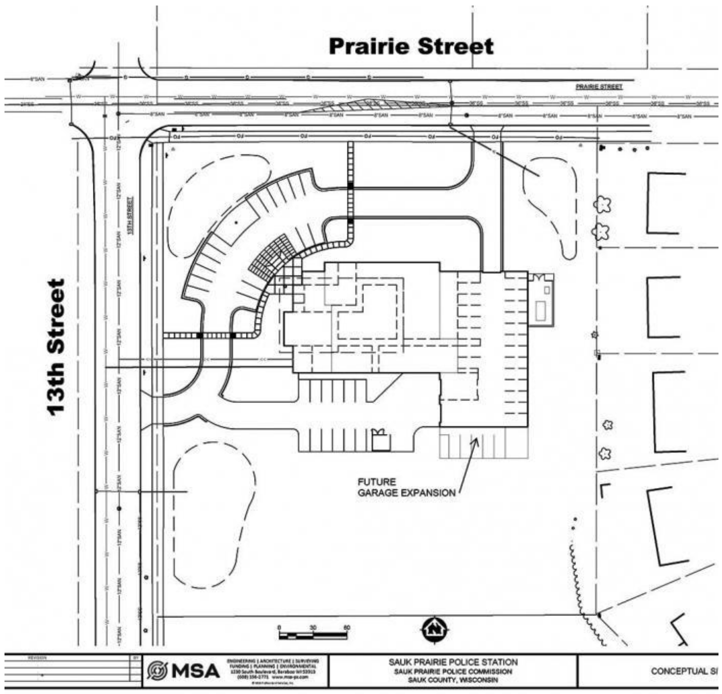
The feasibility study methodology included the following primary tasks:

1. **Stakeholder Engagement** - SEPA convened a core project team of key stakeholders to discuss the feasibility of a microgrid project at Sauk Prairie Emergency Operations Center.
2. **Data Collection** - SEPA collected community, utility, and energy consumption data relevant to the system sizing and financial and environmental impact analysis of a potential microgrid at the emergency shelter.
3. **System Sizing and Analysis** - SEPA evaluated five (5) preliminary microgrid scenarios. Based on stakeholder feedback, the project team conducted a detailed system design of one of the modeled scenarios. The sizing and analysis considered community function as the primary resilience objective and metric.
4. **Financial and Environmental Impact Analysis** - SEPA conducted a benefit-cost analysis of the modeled scenarios to determine economic feasibility.

The project team designed the microgrid scenarios for Sauk Prairie Police Commission's new police station in Prairie du Sac, WI, as seen in Figure 0.1. During emergencies, the police station would be used by the Sauk Prairie Police Department, Prairie du Sac Fire Department, Sauk City Fire Department, Sauk Prairie EMS, the Village of Prairie Du Sac, and the Village of Sauk City. The EOC may also be used by other area emergency government or law enforcement agencies as needed, including Sauk County Sheriff's Department, Sauk County Emergency Government, and Sauk County Public Health Department. The police station was under construction during the time of the study.

This report provides several scenarios for the additional development and seamless integration of a microgrid. The feasibility study partners analyzed the load profiles of a nearby fire station and consumption/load estimates from the site plan as a proxy load profile and developed five potential microgrid designs, as seen in Table 0.1 and Figure 0.2, to serve the load of the police station, while utilizing solar photovoltaic, battery storage, diesel generator, and electric vehicle (EV) charging technologies.

Figure 0.1 – Planned Sauk Prairie Police Station Site Plan



Source: Sauk Prairie Police Station, 2022

To ensure the microgrid designs would serve the needs of the police station and community, the core project team consisted of key project stakeholders. Each month, project team members provided information about the purpose of the microgrid, project updates and findings, and held an open dialogue for members to provide feedback. Project team members were given the opportunity to ask questions and ultimately chose five possible microgrid design scenarios that they determined would best suit the site and community.

The microgrid components in this study include:

- Load: Sauk Prairie Police Station (+Proposed EV Fleet)
- Ground-Mounted Solar PV
- Battery Energy Storage System (BESS)
- Diesel Generation
- Microgrid Controller
- Level 2 Dual Charging Stations
- Distribution System

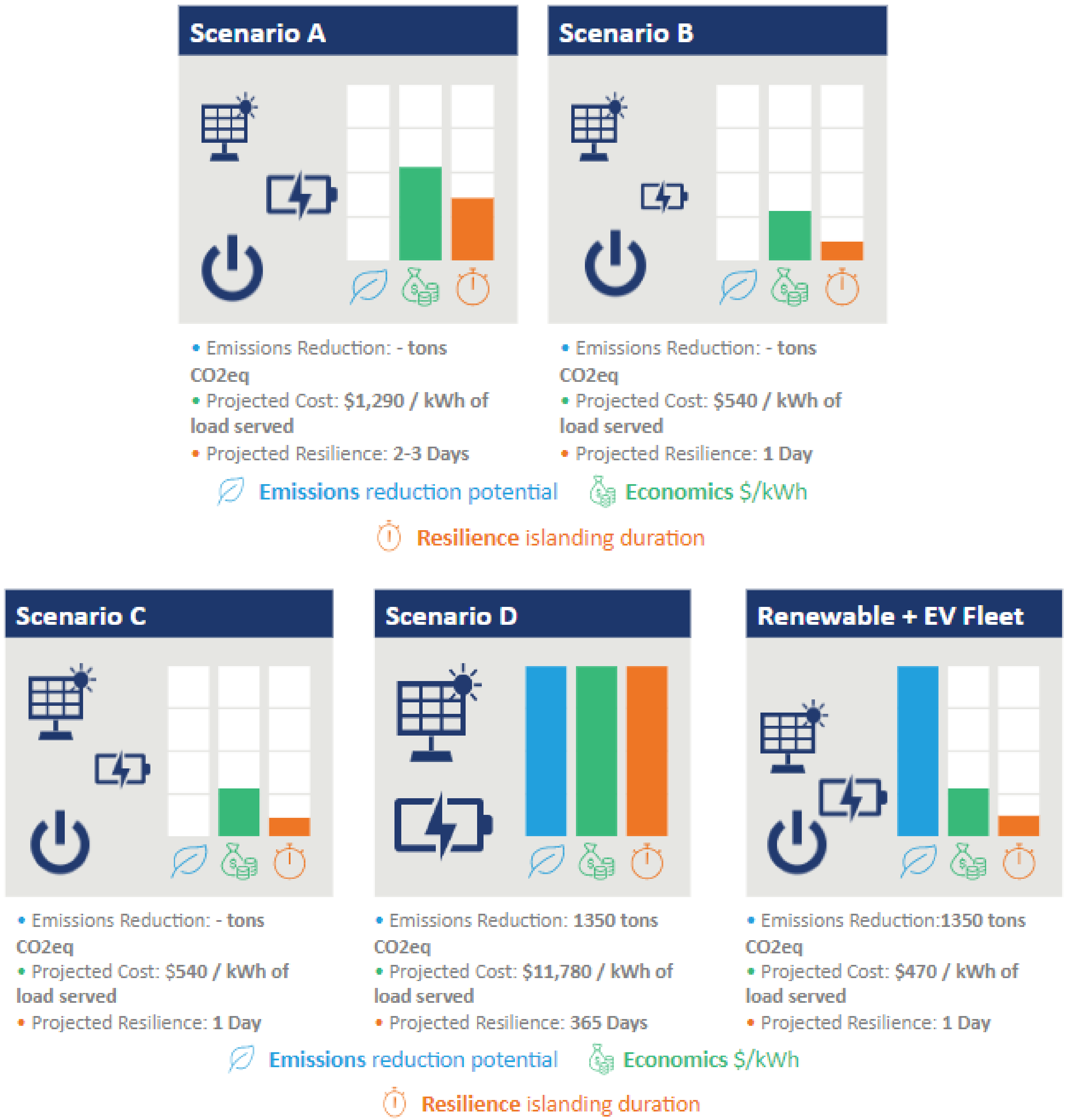
Table 0.1 - Microgrid Scenario Summary

Scenario	Load	Solar	Solar kW-DC[1]	Battery kW-DC	Diesel kW-DC[2]
Scenario A	Police Station	Ground-Mounted Solar Only	94.5	360	154
Scenario B	Police Station		94.5	150	154
Scenario C	Police Station		94.5	150	154
Scenario D	Police Station	Rooftop + Ground-Mounted Solar	192	3,200	154
EV Scenario	Police Station + EV Fleet		192	75	154

Source: SEPA, 2022

[1] Only solar PV in addition to the 94.5 kWdc of planned solar PV is included in the BCA.
[2] The planned diesel generation is not included in the BCA.

Figure 0.2 – Overview of Proposed Microgrid Scenarios



Source: SEPA, 2022

The benefit-cost analysis (BCA) quantifies the net present value (NPV) of the benefits and costs associated with each proposed microgrid scenario as summarized in Table 0.2 below. The BCAs highlighted below assume a mid-range estimate for component costs and O&M. The benefits exceed costs over the project lifecycle if the benefit-cost ratio (BCR) is greater than 1.0. The analysis found that the BCR of each scenario was between 0.01 and 0.74, indicating that the NPV of costs outweigh the benefits in all scenarios. It is important to note that the value of resilience was implied from the BCA but was not included in the BCA itself, so BCR values presented in this report are likely to underestimate the actual BCR in each scenario. Also note that while the team found the costs to slightly outweigh the benefits in the five scenarios, the benefits of solar generation and BESS operation could change depending on future analysis around the business model and ownership structures of a microgrid project. Conversely, note that some of the emissions reduction benefits included in the BCA may not be directly realized by the Sauk Prairie Police Department, effectively reducing the BCR.

Table 0.2 - Summary of Costs and Benefits

Costs	Benefits*
● Generation (Solar Photovoltaic (PV) + Diesel Generator) ● Battery Energy Storage System (BESS) ● Controller and Communications ● Distribution Upgrades ● Operations & Maintenance	● Solar Generation (Demand savings, energy rate savings, and excess generation credits) ● BESS Economic Benefits (Energy arbitrage, demand savings) ● Emissions Reductions
Scenario A: BCR = 0.01	
Total NPV of Costs: $829,550	**Total NPV of Benefits:** $4,951
Scenario B: BCR = 0.01	
Total NPV of Costs: $345,646	**Total NPV of Benefits:** $4,973
Scenario C: BCR = 0.08	
Total NPV of Costs: $345,646	**Total NPV of Benefits:** $26,440
Scenario D: BCR = 0.03	
Total NPV of Costs: $7,570,119	**Total NPV of Benefits:** $214,642
EV Scenario: BCR = 0.66	
Total NPV of Costs: $369,198	**Total NPV of Benefits:** $242,093

*Note that an estimate of the value of resilience is implied from this BCA and noted in section 4 below, but it is not included in the BCA and is not reflected in the BCR.

Source: SEPA, 2022.

This study develops the groundwork for the Sauk Prairie Police Commission, WPPI Energy, the Village of Prairie Du Sac, and other local stakeholders to move to a more detailed benefit-cost analysis and ultimately to the implementation phase of microgrid development. The potential next steps include a determination of ownership and operation structures, further construction coordination, identification of financing and funding, and the development of a full engineering design and construction study. The continuation of strong engagement with community stakeholders through the implementation of the microgrid will facilitate the success of the project.

1.0 Introduction

A resilient energy system can absorb and recover in a timely manner from unavoidable external events, such as natural disasters. In recent years, the frequency and intensity of naturally occurring threats has substantially increased. Wisconsin suffered 32 billion-dollar disaster events costing over $166 billion in damages in the last 20 years. This is more than a 50% increase from eight such events costing $104 billion from 1980 to 2000.[3] Extreme weather events threaten the stability of the grid and cause power outages with attendant economic losses. In fact, national power outage data suggests a 67% increase in outages from weather-related events since 2000.[4]

A grid without resilience measures in place may suffer prolonged outages, which may render critical services inaccessible, such as communications, public safety, water treatment, healthcare, and emergency shelters. This microgrid project in Prairie Du Sac, Wisconsin would bolster resilience for the emergency operation center's critical functions during emergency events, utilize renewable power sources, and provide energy savings and increase affordability for the facility.

1.1 Project Overview

Site and Customer Background

This report assesses the feasibility of utilizing a microgrid in building resilience for the Sauk Prairie Police Station, an EOC in Prairie du Sauk, Wisconsin.

Existing Infrastructure

The site consists of a 3.6 acre parcel containing a planned 22,000 square foot police station, parking lot, and a road that connects to the police station. Once construction is complete, the police station will host a 94.5 kWdc solar array, a 154kW diesel generator, and a 595 gallon fuel tank. The site will host an interconnection point to the Village of Prairie Du Sac's electric distribution grid system.

Rationale for Microgrid

This report was commissioned by WI OEI through the CIMCRC to study the feasibility of including a critical infrastructure microgrid for the site as a means for innovative pre-disaster mitigation given its shelter designation and documented failure of existing backup generation. Such a microgrid might incorporate DERs, appropriately sized energy storage, and a grid-interactive controls schema which would allow the introduction of locally generated solar energy and increased resilience (i.e., the ability to operate independently even when the public

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[3] NOAA National Centers for Environmental Information (NCEI) U.S. Billion-Dollar Weather and Climate Disasters (2022).
[4] SEPA, Commonwealth of Kentucky Regional Microgrids for Resilience Study, p. 7 (2021).

grid is temporarily inoperable). This feasibility study included engagement with key stakeholders, energy, disaster, and site-specific data collection, preliminary microgrid system sizing and analysis, and financial and environmental impact analysis.

WI OEI defines a microgrid as "a group of interconnected loads and distributed energy resources within clearly defined electrical boundaries that acts as a single controllable entity with respect to the grid. A microgrid can connect and disconnect from the grid to enable it to operate in both grid-connected or island-mode."[5]

Identification of Critical Infrastructure

This project was proposed for Sauk Prairie Police Commission's new police station, which will house an EOC and serve Sauk Prairie Police Department, Prairie du Sac Fire Department, Sauk City Fire Department, Sauk Prairie EMS, Village of Prairie Du Sac, and Village of Sauk City during any major events. The EOC may also be used by other area emergency government or law enforcement agencies as needed, including Sauk County Sheriff's Department, Sauk County Emergency Government, and Sauk County Public Health Department.

Key Partners and Stakeholders

Within this report, the core project team comprises stakeholders who supported the evaluation of preliminary microgrid scenarios to best support the Sauk Prairie Police Station and analyze the financial, societal, and environmental benefits of the microgrid. The findings of this report may support future endeavors by the WI OEI to build energy resilience at sites similar to the Sauk Prairie Police Station.

SEPA, Sauk Prairie Police Commission, WPPI Energy, and Village of Prairie Du Sac are the primary partners leading the project. Table 1.1 summarizes the role of each organization in carrying out the project.

[5] https://apps.psc.wi.gov/ERF/ERFview/viewdoc.aspx?docid=420888

Table 1.1 - Core Project Team and Responsibilities

Project Partners	Responsibility	Role
Sauk Prairie Police Commission	Technical and strategic support	Applicant and microgrid customer
Village of Prairie Du Sac	Technical and strategic support	Local electricity distribution utility
Smart Electric Power Alliance (SEPA)	Stakeholder engagement and technical assistance	Microgrid feasibility study lead
WPPI Energy	Technical and strategic support	Electric wholesale supplier

Source: Smart Electric Power Alliance, 2022

Financial and Environmental Impact Analysis

This study includes a financial and environmental impact analysis of five proposed microgrid scenarios that serve the police station through different asset mixes including solar PV, battery storage, diesel generation, and EV charging stations. The scenarios represent a range of renewable resource intensities, islanding capabilities, and related costs and benefit propositions. The analysis aims to quantify the net present value costs and benefits associated with each scenario to determine a BCR for each. The specific costs and benefits of the analysis are detailed fully in 4.2 Financial and Environmental Impact, including costs associated with the development, design, components, and operation of the microgrids, and benefits associated with emissions reductions, demand and energy rate benefits, and solar generation credits.

1.2 Feasibility Study Methodology and Assumptions

Stakeholder Engagement

The core project team, composed of SEPA, Sauk Prairie Police Commission, WPPI Energy, and the Village of Prairie Du Sac discussed the resilience needs of the new Sauk Prairie Police Station site, and assessed feasibility in the development of a microgrid project. Each month, beginning in January of 2022, SEPA hosted virtual check-in meetings to build connections with the entire team, foster a collaborative project environment, and maximize engagement throughout the project. For summaries of each monthly check-in discussion, see Appendix 1: Project Team Check-In Summaries.

Fostering a collaborative relationship between project team members encouraged productive conversations and provided SEPA with key input regarding the study, microgrid site, and the microgrid design that would best serve the site's needs. Furthermore, the project team engagement provided members with the information they needed to engage in meaningful conversation, and communicate, via feedback, their input on project design.

Data Collection

The team collected data from a variety of sources to model preliminary microgrid scenarios. While the team was unable to gather detailed load profile data from the site, SEPA estimated Sauk Prairie Police Department's hourly load profile based on a historical hourly kW load profile from a nearby fire station that WPPI Energy provided. SEPA assumed that Sauk Prairie Police Station would have a similar load shape and adjusted the proxy load profile to match the estimated peak facility load (kW) and annual consumption (kWh) of the planned Sauk Prairie Police Station, as provided by WPPI Energy. The estimated load data helped to quantify a load duration curve, which determines how much designed load the microgrid scenarios should serve.

To plan where to construct the microgrid at the police station, Sauk Prairie Police Commission provided a site map and additional information regarding land availability for storage systems and solar PV. WPPI provided maps of existing electric distribution infrastructure. Multiple contributors supported the data collection effort, which was valuable in developing model assumptions and designing the microgrid scenarios.

System Sizing and Analysis

SEPA considered site area limitations identified in the site map provided by Sauk Prairie Police Commission, preferences vocalized by project team members, and internal expertise to inform the fuel source mix for each scenario. SEPA ensured that the scenarios reflected a range of options with respect to renewable assets, islanding capabilities, and project costs that adhered to site area limitations.

To determine solar PV site constraints, SEPA referenced a 2013 NREL study on land-use requirements for solar power plants which estimated the direct area capacity-weighted average land use of solar PV at 5.5 acres/MWac for a fixed-axis system. This value and the land available from the site assessment determined the maximum buildable solar capacity (kWac) on the site. To estimate the maximum buildable DC solar capacity, SEPA multiplied the maximum AC solar capacity by the conservative DC-to-AC ratio of 1.3 that was used in the study, instead of the ~1.18 value that was used in the NREL study.[6] As a result, estimates for maximum DC solar capacity might be slightly high, though this estimate would potentially only impact scenario D and the Renewable + EV Fleet scenario, which propose an additional 97.5 kWDC of ground-mounted Solar PV–well below the calculated limit noted in Table 2.3.1.[7]

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[6] The NREL study used a weighted-average PV derate factor of 0.85 that was calculated by dividing the AC reported capacity by the DC reported capacity for each project that was included in the study. This value implies a DC-to-AC ratio of 1 / (0.085) = 1.176.

[7] Using a DC-to-AC ratio of 1.176 instead of 1.3 would reduce the maximum DC solar capacity at Sauk Prairie Police Station from 130 kWdc to 118 kW DC. This situation would not require a reduction of the solar capacity in Scenario D and the Renewable + Fleet scenario. It is also likely that the site would have an AC-to-DC ratio closer to the 1.176 implied by the NREL study, and Sauk Prairie Police Department would be able to achieve a greater amount of generation than modeled in the scenario.

To a lesser extent, SEPA also considered land availability to site a BESS noting that the footprint of each is fairly insignificant compared to the requirements for solar PV. For a BESS, SEPA used reference data from a publicly available SCE battery storage project which assumed a footprint of ~0.2 sq ft/kWh.[8]

Financial and Environmental Impact Analysis

SEPA carried out a financial and environmental impact analysis for each of the five scenarios that compared the net present values of project costs and benefits, including emissions reduction benefits, over a presumed 20-year lifespan. This report shares the net present values of costs and benefits associated with each of the six scenarios and includes low-, medium-, and high- cost estimates for each scenario to compare to actual component costs in further analysis. This report also shares the BCR values related to each scenario and cost estimate to demonstrate whether each scenario would be cost-effective given the estimated costs and benefits over the life of the microgrid.

Costs in the financial impact analysis include component costs, microgrid design and construction costs, and long-term operating and maintenance costs for solar and BESS. Economic and environmental impact benefits included demand reduction, energy rate savings, and excess generation credits from solar and BESS, as well as emissions reduction benefits from solar. SEPA's processes for estimating specific microgrid costs and benefits for the financial and environmental impact analysis can be found in 4.2 Financial and Environmental Impact and Appendix 2: Detailed Benefits.

2.0 Site Assessment

2.1 Site Overview

Sauk Prairie Police Commission's new police station is located on a 3.6 acre lot. Solar will be installed on the police station, which is 22,000 square feet. For two of our scenarios, solar will also be deployed on the surrounding property, which is 24,101 square feet. The site parcel outline is shown in an aerial image below.

[8] https://insideevs.com/news/323829/sce-unveils-americas-largest-battery-energy-storage-site/

*Figure 2.1.1 - **Site Boundaries and Aerial Imagery***

Source: Statewide Parcel Map Initiative, V7 Statewide Parcel Data (2021) and GeoData@Wisconsin, WROC Aerial Mosaic (WTM) Prairie du Sac, WI 2020 (2020)

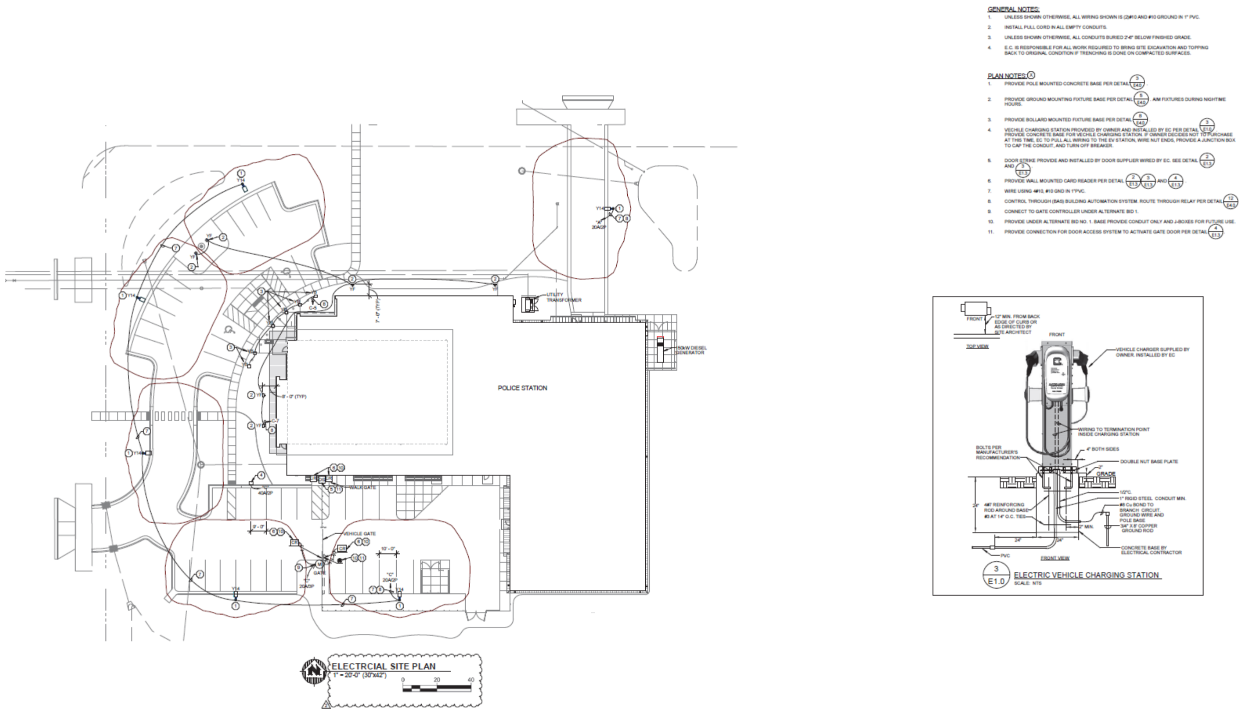
Available areas of the property are being considered for solar PV, battery energy storage, diesel back-up generation, and EV charging stations along with a microgrid controller functionality to allow for sustained islanding capabilities during a grid outage.

Detail infrastructure

The new Sauk Prairie police station was completed in 2022 with a 94.5 kW dc rooftop solar PV array. The solar PV will yield energy cost savings at the facility, and it will be paired with a 154 kW diesel generator to provide energy resiliency.

The planned generator, transformer, utility primary conductors, telephone and cable lines, and exterior lighting conduit are displayed on the map below.

*Figure 2.1.2 - **Site Infrastructure***

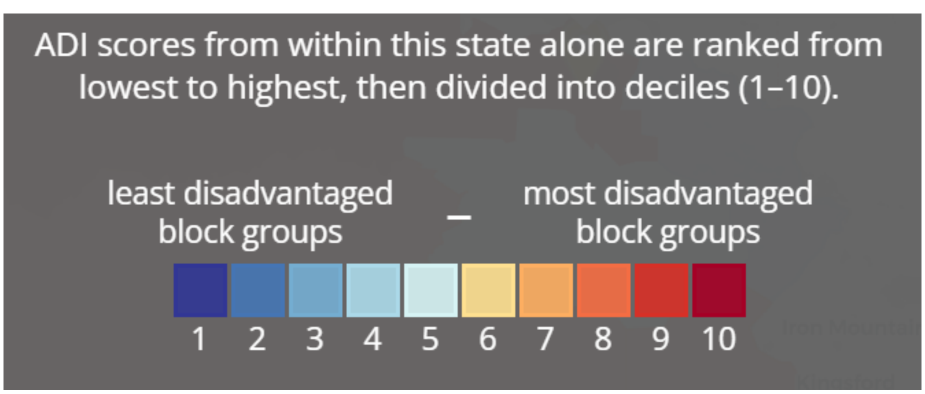


Source: SEPA, 2022

Community vulnerability indicators

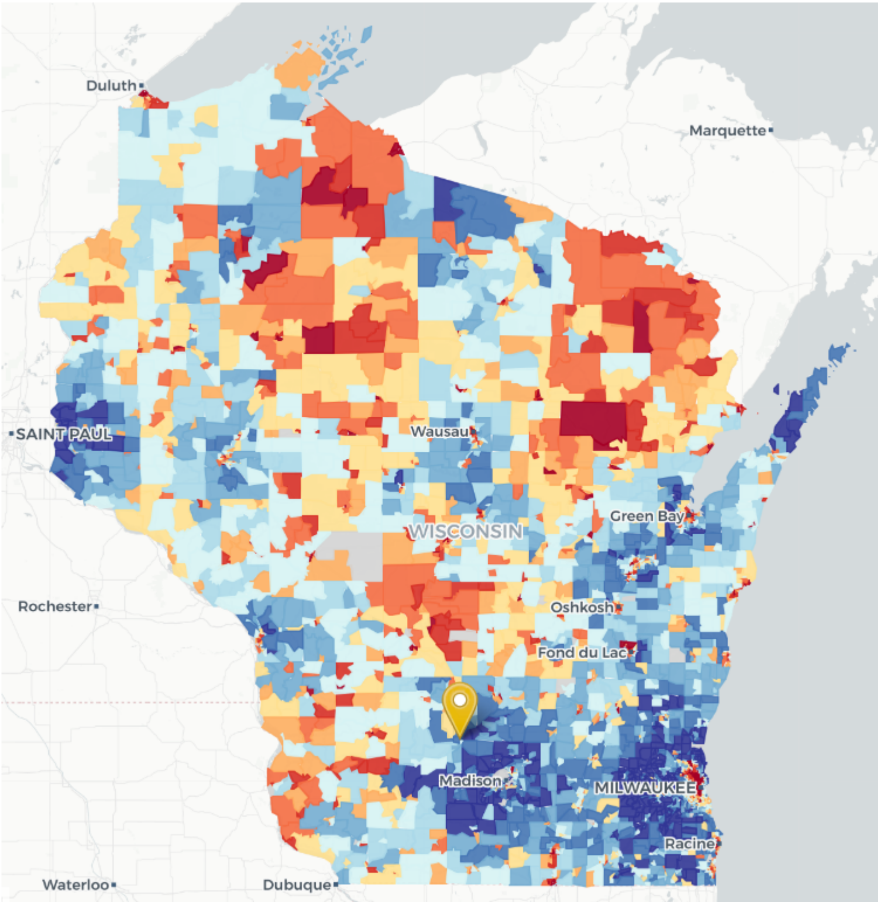
Figure 2.1.4 and 2.1.5 below show census block groups in Wisconsin categorized by their Area Deprivation Index score. The yellow marker on the map indicates the location of the site. The legend in Figure 2.1.3 can be used to read the following maps. The EOC site is located in a less disadvantaged block group.

*Figure 2.1.3 - **State View: Area Deprivation Index Legend***



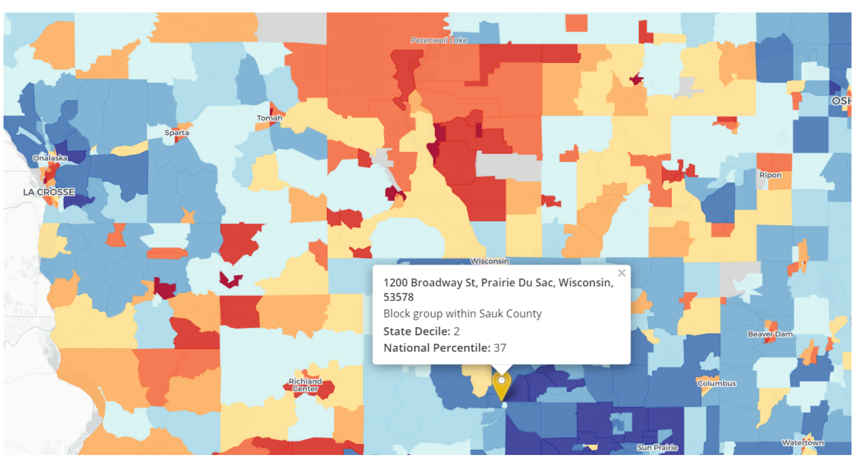
Source: University of Wisconsin-Madison, [Neighborhood Atlas Map](2021)

*Figure 2.1.4 - **State View: Area Deprivation Index by Census Block Group***



Source: University of Wisconsin-Madison, [Neighborhood Atlas Map](2021)

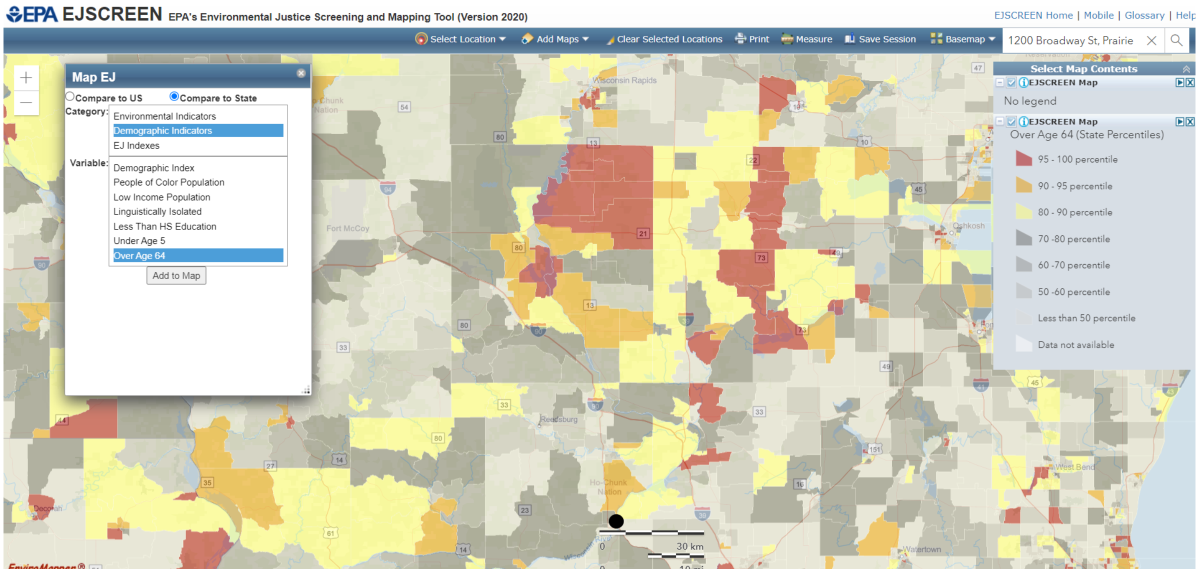
*Figure 2.1.5 - **Local View: Area Deprivation Index by Census Block Group***



Source: University of Wisconsin-Madison, [Neighborhood Atlas Map](2021)

The EPA's Environmental Justice Screening and Mapping tool, highlighted in Figure 2.1.6 below, shows that the EOC site is located in an area where the percent of the population that is over the age of 64 is in the 70-100th percentile of the state, making it a strong candidate for equitable resilience benefits.

*Figure 2.1.6 - **Percentile of Population over 64 by Census Block***

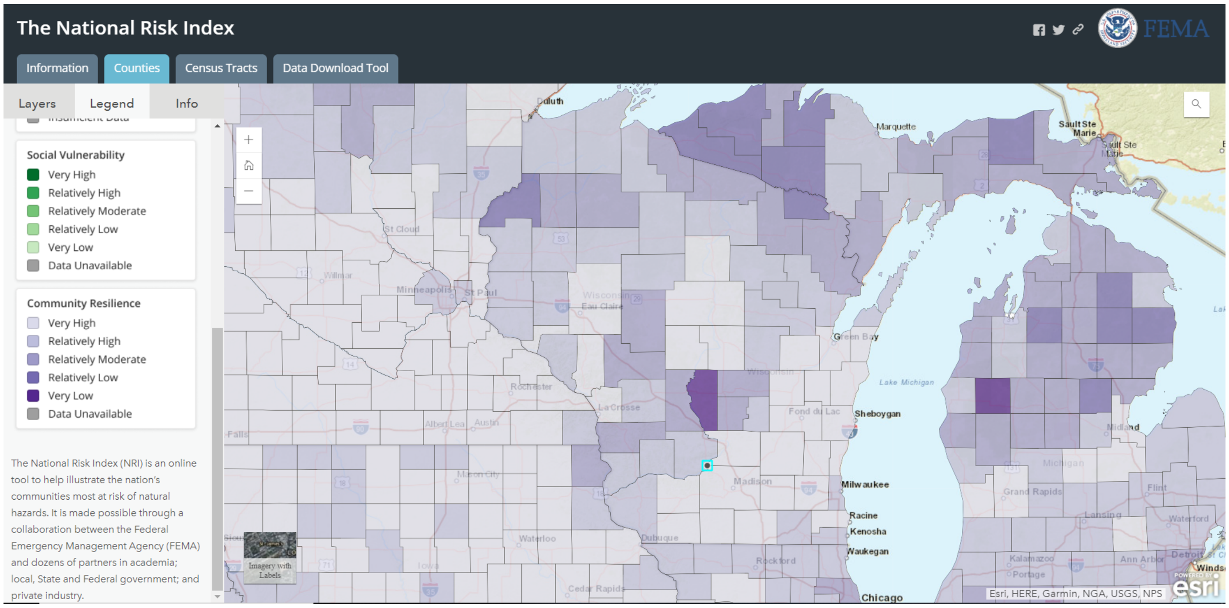


Source: Environmental Protection Agency, EJSCREEN (2020)

Flood hazards

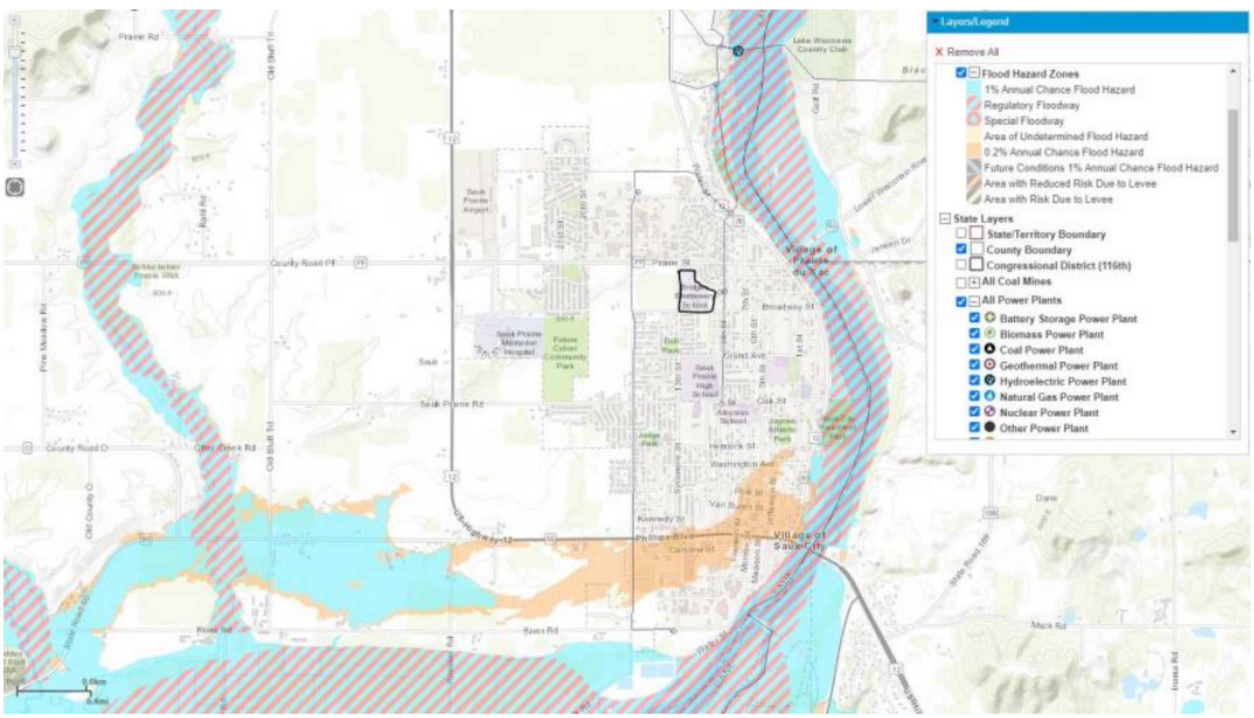
Figures 2.1.7 and 2.1.8 indicate the EOC site is located near a floodway and areas with 1% Annual Chance Flood Hazard and 0.2% Annual Chance Flood Hazard. The FEMA National Flood Hazard map also indicates where existing energy infrastructure is in relation to the EOC site. The site is surrounded by areas of high and medium flood hazard. A microgrid in this location may be ideal to support emergency services when critical infrastructure is inundated.

*Figure 2.1.7 - **Level of Community Resilience by County***



Source: FEMA, [The National Risk Index](#)(2021)

*Figure 2.1.8 - **Flood Hazards Near Proposed Site***

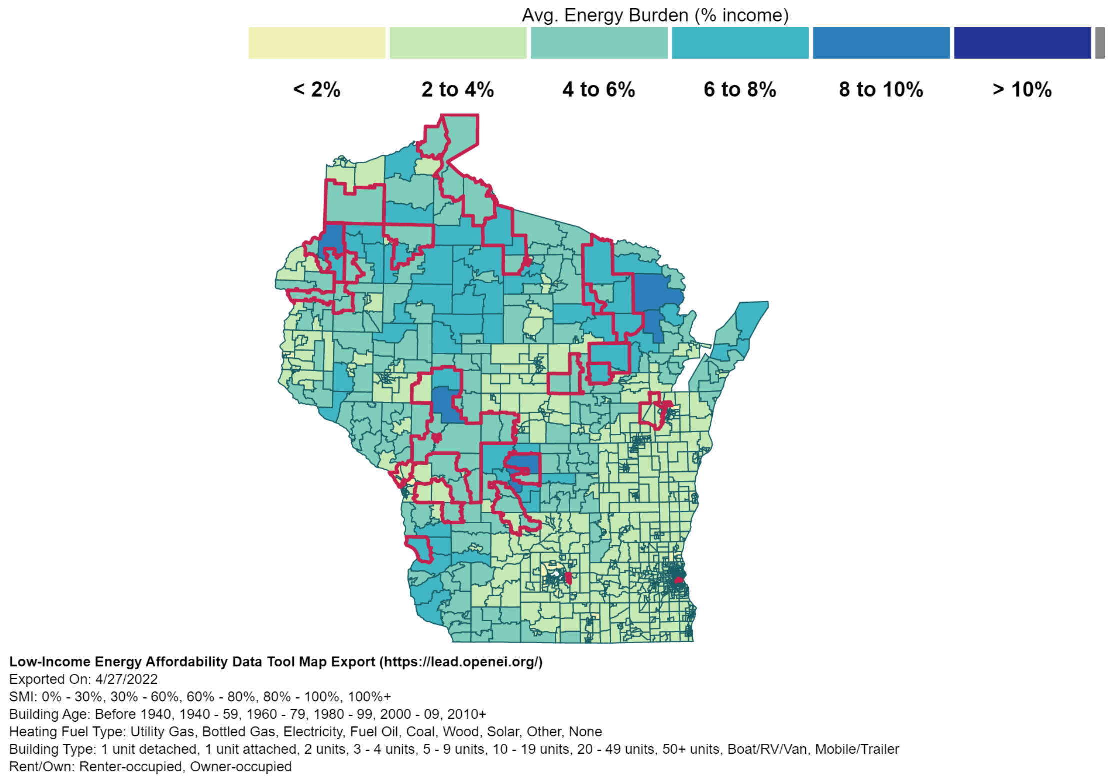


Source: GeoData@Wisconsin, The National Risk Index (2018)

Below, Figure 2.1.9 indicates that the EOC is located in an area where the energy burden is lower (3%). The red outline on Figure 2.1.9 delineates indigenous land, which is not located near the emergency operations center.

The prevalence of vulnerable populations, such as elderly communities, indigenous tribes, and low-moderate income customers, make SPPD all the more important to have resilient power. Therefore, a microgrid solution could benefit the community tremendously by providing uninterrupted power during grid power outages.

*Figure 2.1.9 - **Average Energy Burden Near Proposed Site***



Source: Department of Energy, Low-Income Energy Affordability Data (LEAD) Tool (2021)

Site application and functionality

Sauk Prairie Police Commission is interested in improving resilience for the EOC for the Sauk Prairie police station. The Prairie du Sac Fire Department covers 2 square miles serving a population of 4,193. The Sauk Prairie EMS covers 196 square miles serving a base population of 14,983. Additionally, Sauk City Area Fire District covers 175 square miles serving a base population of 10,000. Based on the number of customers that the EOC can serve, the inclusion of redundant power capabilities is critical in serving communities particularly during an outage.

Critical services

The EOC will be utilized by Sauk Prairie County and the Village of Prairie Du Sac during grid outages and other events. Examples of critical services to be provided by the EOC are as follows:

- Emergency call response and dispatch
- Radio communication from EOC to officers and emergency responders
- Television monitoring
- GPS mapping capabilities
- Facility lighting, heating and HVAC equipment
- Security cameras
- Freezers and refrigerators in the evidence room

The station will have a diesel generator available as backup during power outages, but this system is not as environmentally friendly as the solar option.

Customer information and historical outage information

Neither Prairie Du Sac Municipal Electric and Water nor WPPI energy indicated that any significant outages have impacted the circuit to which the police station will be connected, though this may not fully reflect the possibility of future outages. Solar PV and a diesel generator are already planned to avoid short- and medium- term outage impacts at the new police station and EOC. Due to its designation as an EOC for emergency services in Prairie Du Sac, it is imperative that the facility is able to operate during outage events.

Prior to December 2020, Prairie du Sac and Sauk City were served by the American Transmission Company (ATC) via a radial line. ATC identified an opportunity to increase reliability and flexibility to these customers. As a result, substation upgrades and an additional 69 kV radial line were put into service in December 2020, which created a looped system.

Rate schedule

Given the estimated load at the facility, Prairie Du Sac Municipal Electric and Water will likely serve the EOC under the Small Power Time-of-Day Service – Cp-1 electric rate (Figure 2.1.10).

Figure 2.1.10 - Prairie Du Sac Municipal Electric and Water Small Power TOD Service (Cp-1) Rate Structure

Small Power Time-of-Day Service

Application: This rate will be applied to customers for all types of service if their monthly Maximum Measured Demand is in excess of 40 kilowatts (kW) per month for three or more months in a consecutive 12-month period, but not greater than 200 kW per month for three or more months in a consecutive 12-month period.

Customers billed on this rate shall continue to be billed on this rate until their monthly Maximum Measured Demand is less than 40 kW per month for 12 consecutive months.

Customer Charge: $50.00 per month.

Distribution Demand Charge: $1.50 per kW of distribution demand.

Demand Charge: $8.00 per kW of on-peak billed demand.

Energy Charge: On-peak: $0.0855 per kilowatt-hour (kWh).
Off-peak: $0.0510 per kWh.

Power Cost Adjustment Clause: Charge per all kWh varies monthly. See Schedule PCAC.

Pricing Periods:

On-peak: 8:00 a.m. to 8:00 p.m., Monday through Friday, excluding holidays, specified below.

Off-peak: All times not specified as on-peak including all day Saturday and Sunday, and the following holidays: New Year's Day, Memorial Day, Independence Day, Labor Day, Thanksgiving Day, and Christmas Day, or the day designated to be celebrated as such.

Prompt Payment of Bills: Same as Rg-1.

Minimum Monthly Bill: The minimum monthly bill shall be equal to the customer charge, plus the distribution demand charge.

(Continued on next page)

Small Power Time-of-Day Service (continued)

Determination of Maximum Measured Demand and On-Peak Maximum Demand: The Maximum Measured Demand in any month shall be that demand in kilowatts necessary to supply the average kilowatt-hours in 15 consecutive minutes of greatest consumption of electricity during each month. Such Maximum Measured Demand shall be determined from readings of permanently installed meters or, at the option of the utility, by any standard methods or meters. Said demand meter shall be reset to zero when the meter is read each month. The Maximum Measured Demand that occurs during the On-peak period shall be the On-peak Maximum Demand

Determination of On-Peak Billed Demand: The Maximum Measured Demand that occurs during the On-Peak period shall be the On-Peak Billed Demand.

Determination of Distribution Demand: The Distribution Demand shall be the highest monthly Maximum Measured Demand occurring in the current month or preceding 11-month period.

Discounts: The monthly bill for service will be subject to the following discounts applied in the sequence listed below.

Primary Metering Discount: Customers metered on the primary side of the transformer shall be given a 2.00 percent discount on the monthly energy charge, distribution demand charge, and demand charge. The PCAC and the monthly customer charge will not be eligible for the primary metering discount.

Transformer Ownership Discount: Customers who own and maintain their own transformers or substations shall be given a credit of $0.25 per kW of distribution demand. Customer-owned substation equipment shall be operated and maintained by the customer. Support and substation equipment is subject to utility inspection and approval.

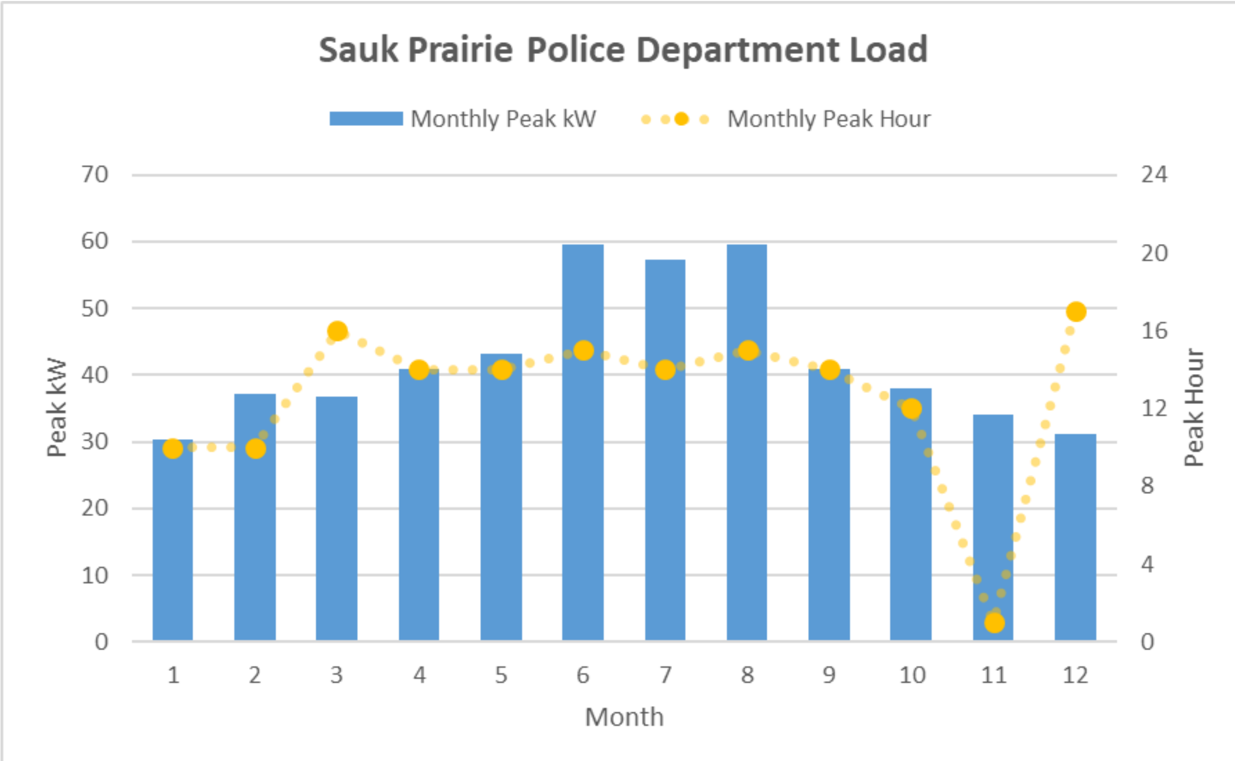
2.2 Initial Load and Solar Analysis

Load Analysis

Several different load and asset mix scenarios served as additional inputs in the microgrid sizing, siting, and financial analysis processes. For this study, SEPA considered two load scenarios. In the first scenario, the microgrid would serve the EOC's load only. In the second scenario, the microgrid would also serve the load of an EV fleet consisting of six police vehicles.

The load depends on the time of year and time of day. The EOC's load clearly peaks in the summer. Throughout the year, the load peaks in the afternoon, though in January and February, it peaks in the morning. In November, we observed a load peak in the middle of the night, but that could be the result of an anomaly in the base data from the fire station. Note that this data is based only upon a proxy load profile and energy consumption estimates, and the true facility load profile may deviate from the load analysis laid out in this report. Figure 2.2.1 illustrates the variation of the EOC's load throughout the year.

Figure 2.2.1 - Sauk Prairie EOC Load by Month



Source: Smart Electric Power Alliance, 2022

EV Charging Analysis

In addition to the estimated base load profile of the new EOC facility, Sauk Prairie Police Department suggested that it would be valuable to consider a scenario in which the vehicle fleet is transitioned to plug-in electric vehicles (PEVs) and fleet charging loads would need to be considered when building a microgrid. In order to estimate a charging load profile for this scenario, SEPA worked with the Sauk Prairie Police Department to gather assumptions about potential vehicle specs and planned EV charging stations at the EOC. Vehicle and charging station assumptions are highlighted in Table 2.2.1.

Table 2.2.1 - Sauk Prairie EOC PEV and Charging Station Assumptions

Vehicle Assumptions	
Vehicle Type	Tesla Model Y Long-Range AWD[9]
Battery Size	75 kWh 350 V lithium-ion
Efficiency (kWh/mi)	0.30[10]
Daily Mileage (mi)	100
Number of Vehicles	6
Recommended Max Charge	90%[11]
Charging Station Assumptions[12]	
Charging Station Model	ClipperCreek HCS-D50, Level 2 Dual Charging Station
Charging Power	32 Amp (7.7kW max)
Supply Circuit	240 V, 40 A
Number of Chargers	3
Charging Efficiency	90%[13]

Source: Smart Electric Power Alliance, 2022

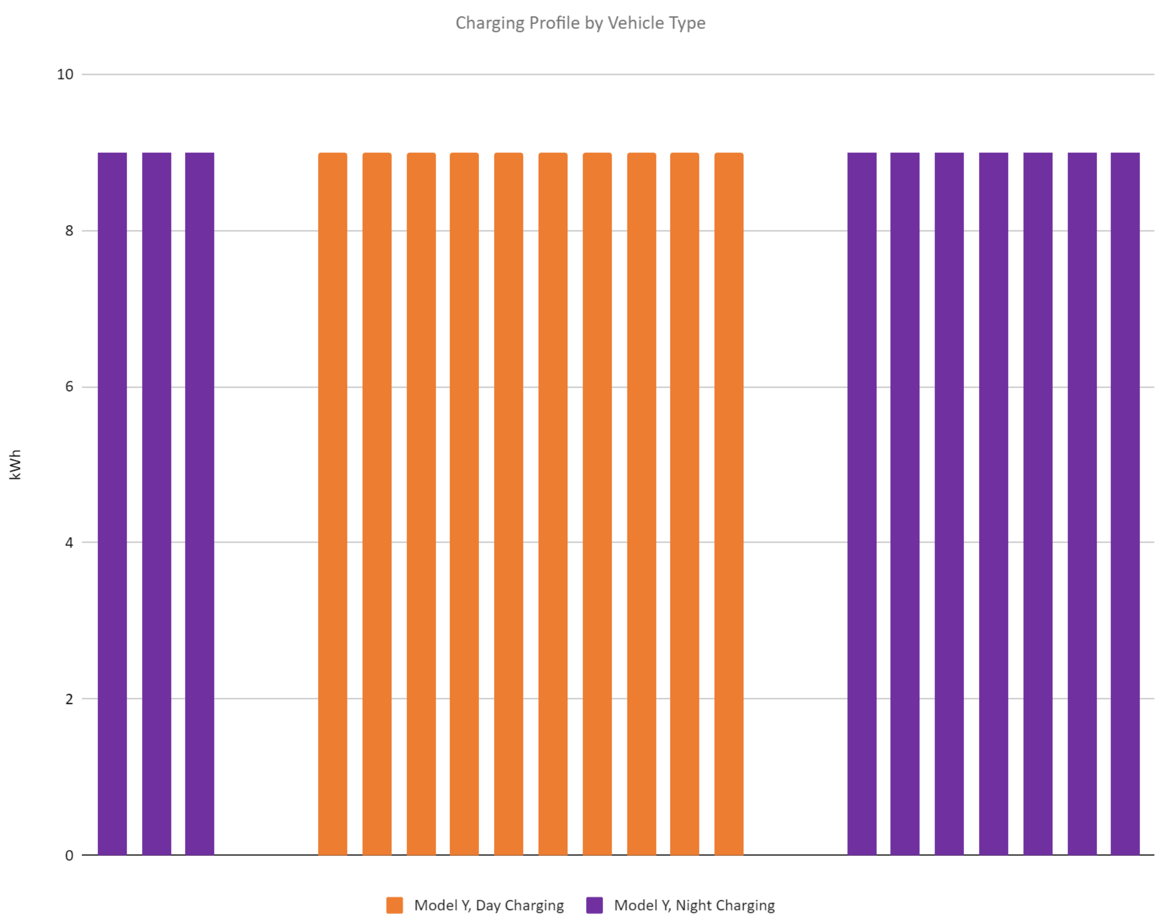
To estimate the additional facility load resulting from charging an EV fleet, SEPA worked with the Sauk Prairie Police Department to make final assumptions about charging schedules based on department needs. The team sought to maximize charging time across 5am - 5pm shifts in order to avoid significant hourly load increases that would result from more rapid vehicle charging. In order to achieve this charging schedule, SEPA assumed that three of the six vehicles would charge during each shift between 6am - 4pm and 6pm - 4 am, respectively. Note that the three dual chargers would only be used to charge one vehicle each at any given time. Finally, SEPA

[9] Selected in coordination with Sauk Prairie Police Department. This vehicle has been selected for use in several EV pilot programs at police stations across the United States. Notably, in Boulder, CO (https://www.bouldercounty.org/news/boulder-county-sheriffs-office-is-testing-out-use-of-tesla-as-a-patrol-vehicle/), Eden Prairie, MN (https://www.edenprairie.org/Home/Components/News/News/10271/28), and Cary, NC. (https://www.cbs17.com/news/local-news/wake-county-news/cary-police-department-to-show-off-new-tesla-model-y-cruisers-at-thursday-media-event/)
[10] From 2022 Tesla Model Y long-range per fueleconomy.gov; added a buffer of 0.02 kWh/Mile to account for increased weight from modifications
[11] Per Tesla Support - Home Charging - Frequently Asked Questions
[12] Specifications gathered from https://store.clippercreek.com/dual-ev-charging-station?gclid=Cj0KCQjwpv2TBhDoARIsALBnVnlqdq7v4pyHEf6t_5Xb6UQfhVJ3IBeN6Cw02QhgvXj_xl29rmRNSXcaAps6EALw_wcB unless noted otherwise
[13] Assuming 90% charging efficiency (89.4% per https://ieeexplore.ieee.org/document/7046253)

assumed that vehicles would begin charging with a 65% charge and would charge to 90% per recommendations noted in Table 2.2.1.[14]

SEPA leveraged an internal EV fleet charging model and the assumptions noted above to estimate the daily charging profile for the fleet. SEPA's analysis estimated that the EV fleet charging would add 9 kW to the EOC's hourly load during the hours of 6am - 4pm and 6pm - 4am each day. Figure 2.2.2 illustrates the daily charging profile of the proposed EV fleet.

Figure 2.2.2 - Estimated Daily EV Fleet Charging Load

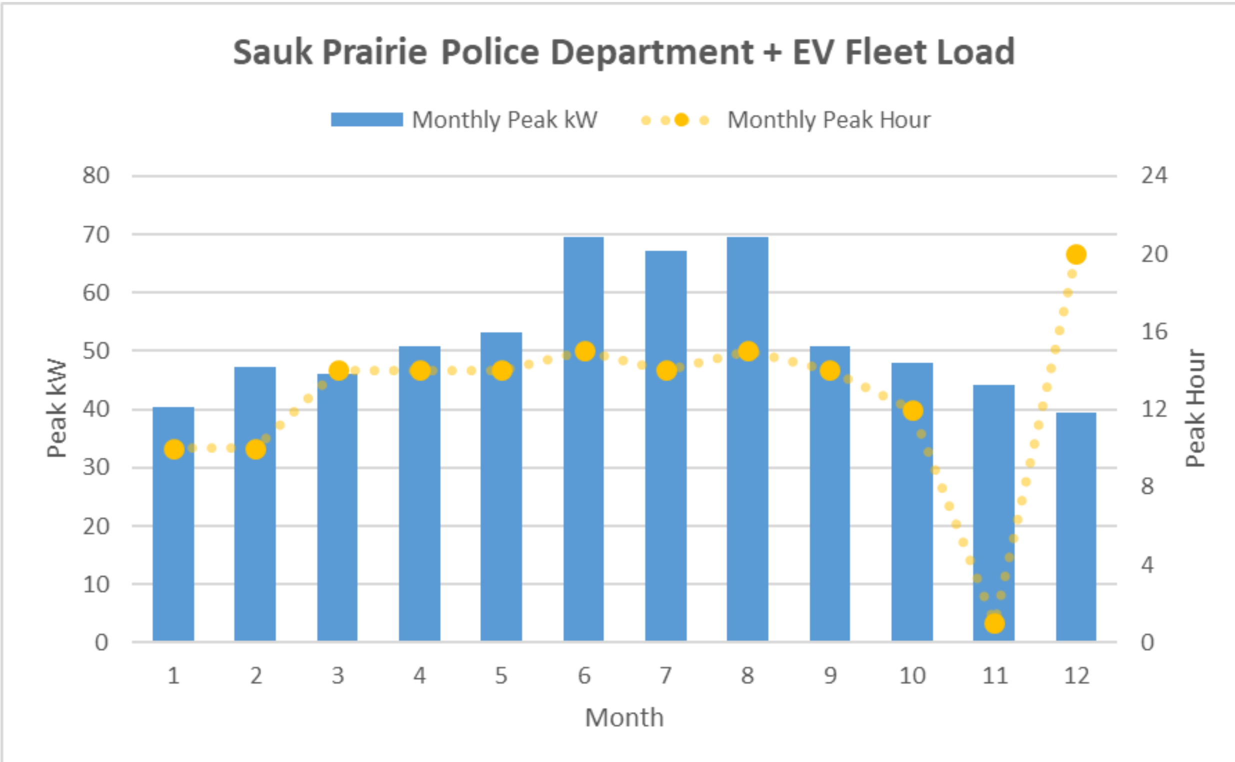


Source: Smart Electric Power Alliance, 2022

With the addition of the EV fleet, the new EOC facility load, as shown in Figure 2.2.3, still peaks in the summer and experiences similar load peak hours, with the exception of December's peak hour shifted to 8pm. That said, the monthly load peaks are increased by 9 kW from the site's base load as they occur in coincidence with EV charging.

[14] SEPA used the charging calculator available at https://evadept.com/calc/ev-charging-time-calculator to estimate the beginning battery charge given the daily mileage estimate and recommended max charge.

Figure 2.2.3 - Sauk Prairie EOC and EV Fleet Charging Load by Month



Source: Smart Electric Power Alliance, 2022

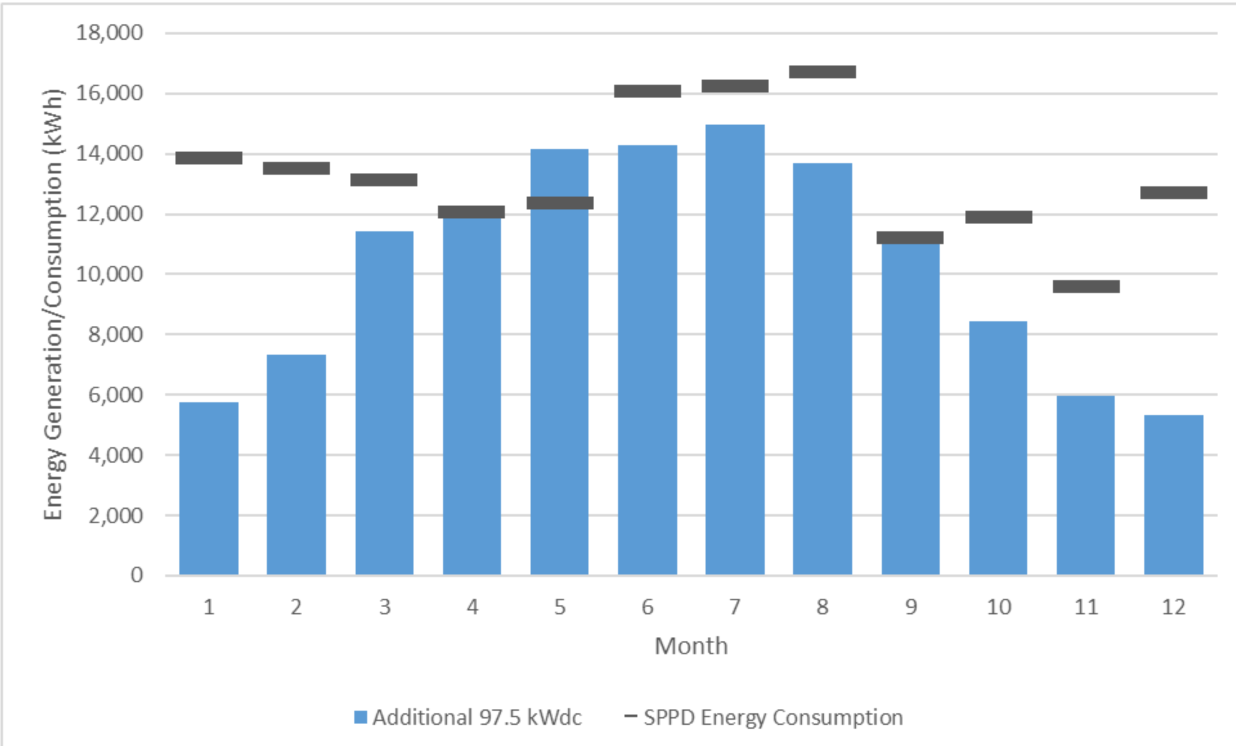
Solar Analysis

Within the asset mix scenarios, SEPA evaluated various combinations of solar PV, battery storage, and islanding duration. The Sauk Prairie police department already plans to include 94.5 kWDC of roof-mounted solar PV, which was excluded from the BCA along with the planned 154 kW diesel generator. In addition to the roof-mounted solar PV, two of our scenarios; Scenario D and the Renewable + EV Fleet scenario, included an additional 97.5 kWDC of ground-mounted solar PV which was included in the BCA. To estimate hourly solar production at the site throughout the year, SEPA used NREL's PV Watts Calculator and the following inputs to build an annual baseline solar generation profile:

- **Solar Resource Data Site:** Lat, Lon: 43.29, 89.74 W
- **DC System Size:** 1000 kW
- **Array Type:** Fixed (open rack)
- **System Losses:** 14.08%
- **Tilt:** 20°
- **Azimuth (deg):** 180°

First, SEPA adjusted the baseline solar profile to match the proposed solar capacity. SEPA then modeled each of the asset mix scenarios in order to estimate financial and environmental benefits related to that solar generation. Figure 2.2.4 highlights the average monthly solar generation for each scenario alongside monthly energy consumption at the site.

Figure 2.2.4 - Proposed Solar Generation and Energy Consumption at Sauk Prairie Emergency Operations Center by Month



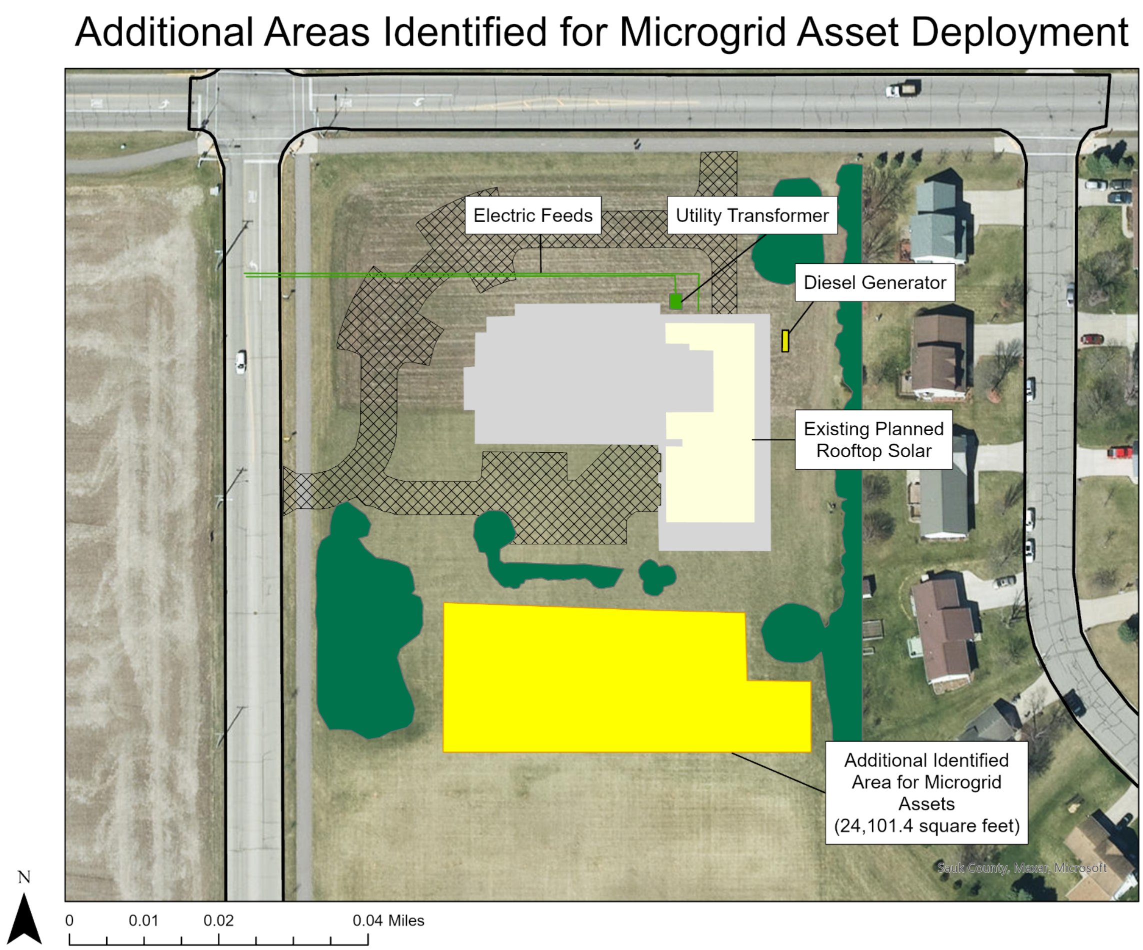
Source: Smart Electric Power Alliance, 2022

Following the initial solar and load analysis, SEPA sized different variations of battery energy storage to shape solar production and provide back-up emergency generation during outages. In cases where solar and battery storage scenarios were unable to serve the site's entire load, SEPA ensured that they were sized so that the planned 154 kW diesel generator would be able to meet the project team's desired islanding duration.

2.3 Site Availability

The team calculated the site availability of solar energy, battery energy storage, and diesel generation with the support of the Sauk Prairie Police Department. As illustrated in Figure 2.3.1, Sauk Prairie Police Department and the Village of Prairie Du Sac provided SEPA with the site layout, and electrical plans, which were used to identify a potential section of the property that could host microgrid assets. The section for potential microgrid asset installation were identified in accordance with relevant building and fire codes. The site assessment considered areas located at least 10 feet away from landscaping and 100 feet from the road, and in sections of the property not demarcated for stormwater management.

Figure 2.3.1 - Sauk Prairie Police Station Site Map



Source: SEPA, 2022

Site Assessment for Solar PV

In addition to cost and load analysis outputs, SEPA considered site availability when proposing solar capacity for each scenario. As noted in the Solar Analysis above, the team used NREL's PVWatts Calculator to estimate the anticipated solar output at the site. Ground mounted solar siting estimates are summarized in Table 2.3.1.

Table 2.3.1 - Sauk Prairie Emergency Operations Center Site Map Key

Parcel	Usable Ground Area	Potential Solar PV (kW DC)
Additional Identified Area for Microgrid Assets	**24,101 sq. ft**	**130**

Source: Smart Electric Power Alliance, 2022

Site Assessment for Microgrid Assets

Potential spacing for microgrid assets is available in the southern end of the site just below the planned police station. The feasibility of this location is subject to review by the Sauk Prairie Police Department and other stakeholders. A required site review will also assess site civil limitations and clearances to safely operate the equipment. Additionally, the facility would likely choose to install screening planting around the electrical service equipment. Screening planting was not considered in the scope of this assessment.

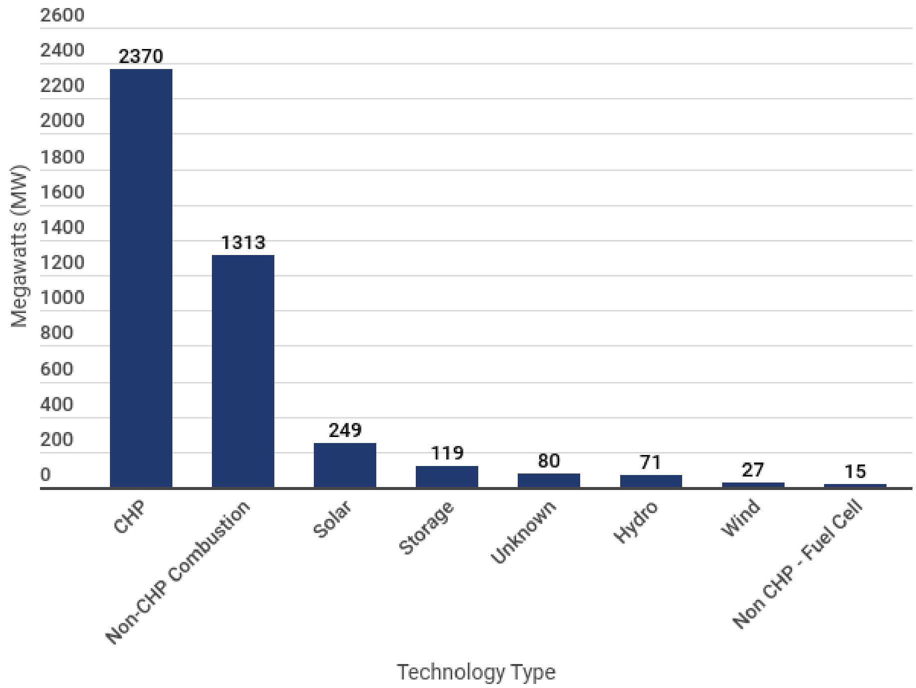
Existing Electric Feeders

The Village of Prairie Du Sac identified the location of the planned electric distribution feeder on the north end of the police station off 13th Street to support the preliminary siting of the battery storage system. This asset is tentatively sited near the southern edge of the facility due to the available space for microgrid assets.

3.0 Microgrid Scenarios Development

Microgrids across the country vary significantly in both their average capacity and fuel source, as shown in Figure 3.1. According to a study by NREL in 2019, U.S. microgrid projects totaled 729 MWs in capacity. The most widely used energy source is combined heat and power, which powers 51% of the microgrid projects. After CHP, the most widely used energy source is diesel, which powers 17% of microgrid projects. Natural gas powers 12% of microgrid projects and supports 91 MW on average, making fossil fuels the energy source of the vast majority of microgrid projects. Renewable energy fuels about 18% of microgrid projects, which may be a result of a number of factors including local regulations, budget restrictions, or preferences. Solar photovoltaic (PV) energy is the most abundantly used renewable fuel source, powering 11% of microgrid projects. Wind energy is only utilized in 1% of U.S. microgrid projects. Other microgrid fuel sources include energy storage and fuel cell technology.

Figure 3.1 - Current Microgrid Installations by Technology



Source: ICF International, U.S. Department of Energy Combined Heat and Power and Microgrid Installation Databases, 2022.

3.1 Stakeholder Process and Findings

When determining potential asset mix and load scenarios for a Sauk Prairie Police Department microgrid, SEPA engaged with the project team to adequately consider the needs of the site, WI OEI grant guidelines, and the preferences of key stakeholders.

Process

The core team, especially members from the police department and local utility, provided input regarding project requirements to meet resilience, sustainability, and environmental goals. SEPA met with the full project team on a monthly basis to discuss scenario development considerations and study progress. During the January and February check-in meetings, the team held discussions around microgrid resilience needs at the police station with respect to the percentage of load served, islanding duration, asset location and sizing, ownership models, and the use of standby back-up generation to establish microgrid scenarios. Project team members considered a number of questions as highlighted in Figure 3.2.

Figure 3.1.1 - Key Microgrid Scenario Development Questions

What % of the site's load should be served by a microgrid?
Does the site have any short-term plans to reduce load?

Where should additional solar generation be located?
How much solar generation should be installed at the site?

How long will the site be able to operate as an island?
Will the site consider any backup generation options?

What size battery should be installed as part of the microgrid?
Where will the battery be located?
Who will own the battery energy storage system (BESS)?
How will the BESS be used (resilience, economic gain)?

Source: Smart Electric Power Alliance, 2022

Findings

From these discussions, SEPA identified several key findings.

1. A microgrid would need to serve at least 50% of the site's load to ensure that the facility can provide critical services that ensure the computer servers and evidence room refrigeration remains on.
2. Our scenarios B and C would incorporate a relatively small BESS into the existing site that could serve as a demonstration project for how a battery could be used for BTM economics to reduce risk of using diesel.
3. Given that electric vehicles will be part of the fleet at the Sauk Prairie Police Department, SEPA was able to incorporate the projected load from the planned fleet and identify charging profiles.
4. An ideal EV scenario might look at adding additional solar or storage in phases to align with the adoption of EVs for the police department.
5. Providing frequency regulation to MISO using an oversized battery would not provide a significant enough benefit to justify the costs of such a significant investment. Notably, given the solar development limits at the site, a developer would likely be unable to monetize the federal investment tax credit. Additionally, providing frequency regulation to MISO would not provide a significant enough benefit to justify the costs of such a significant investment, even under optimal conditions.

6. Strategic load shedding could be used to reduce the emergency operations center's energy consumption during a long-term outage.

3.2 Microgrid Scenarios

Overview

Scenario modeling produced the preliminary asset mix design for five microgrid scenarios, which Table 3.2.1 summarizes.

Table 3.2.1 - Microgrid Scenario Components

<table>
<tr><th>Scenario</th><th>Load</th><th>Solar</th><th>Solar kW-DC*</th><th>Battery kW-DC</th><th>Island Days[15]</th></tr>
<tr><td>Scenario A</td><td>Police Station</td><td rowspan="3">Rooftop Solar Only</td><td>-</td><td>360</td><td>2-3**</td></tr>
<tr><td>Scenario B</td><td>Police Station</td><td>-</td><td>150</td><td>1**</td></tr>
<tr><td>Scenario C</td><td>Police Station</td><td>-</td><td>150</td><td>1**</td></tr>
<tr><td>Scenario D</td><td>Police Station</td><td rowspan="2">Rooftop + Ground-Mounted Solar</td><td>97.5</td><td>3,200</td><td>365**</td></tr>
<tr><td>EV Scenario</td><td>Police Station + EV Fleet</td><td>97.5</td><td>75</td><td>1**</td></tr>
</table>

*This table (and the BCA) only includes solar in addition to the 94.5 kWdc already planned at the site. Note that the islanding capacity in Scenarios A-C is calculated with the assumption that a total of 94.5 kWdc is available to reduce load during the day and charge the battery during an outage. Scenario D and the EV scenario is calculated with the assumption that a total of 192 kWdc is available to reduce load during the day and charge the battery during an outage

**Battery Only - Islanding capacity only includes battery capacity. The 154 kW diesel generator can provide an additional 5-6 days of islanding capacity assuming that the 595 gal tank is full and the generator is operating at ~25% load. In the EV scenario, this capacity is reduced to 4-5 days.

Source: Smart Electric Power Alliance, 2022

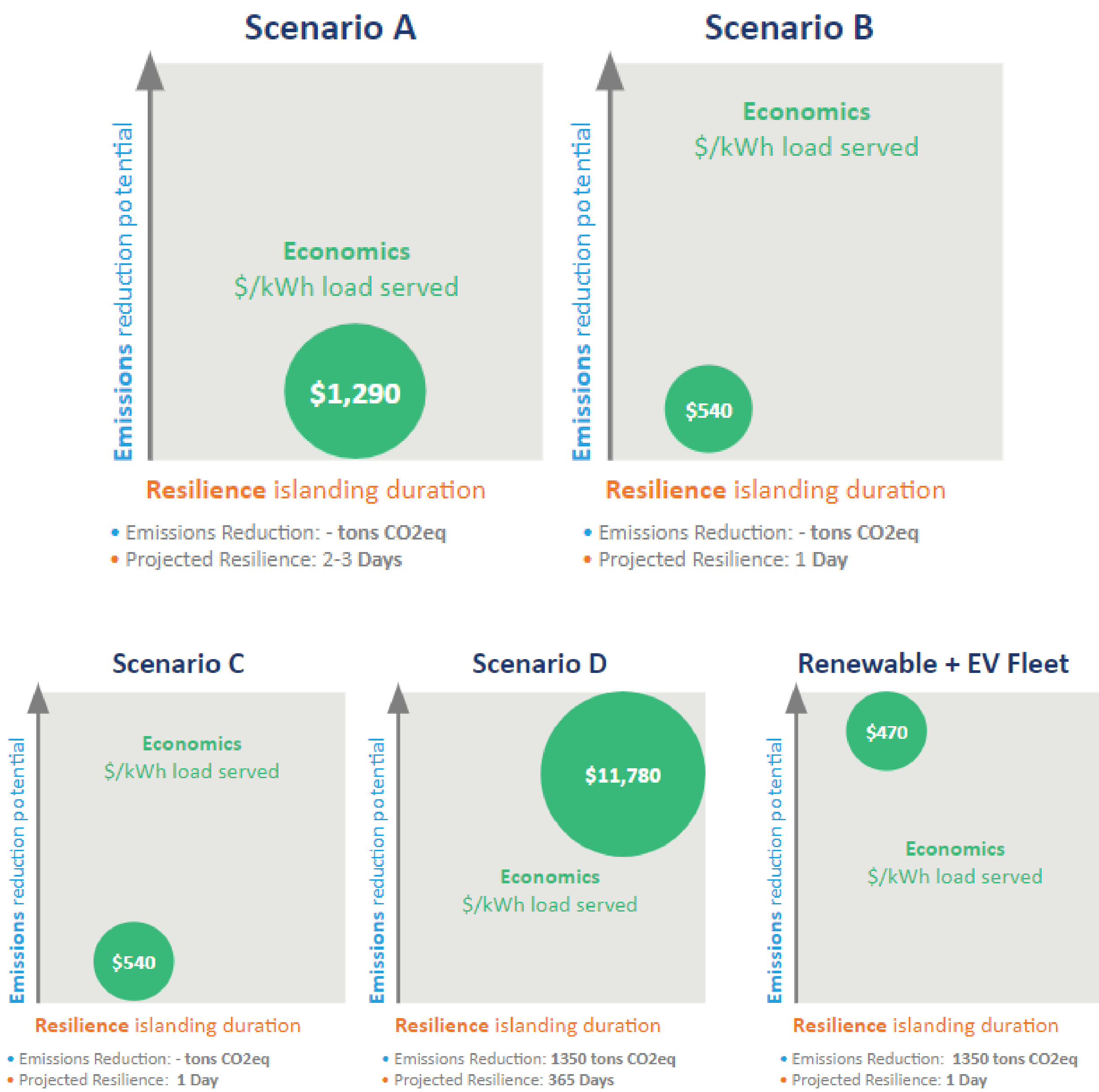
[15] This value is an estimate of the duration of islanding capability that the microgrid can provide on a typical day during the peak load month, August. Estimates may be given as a range to account for fluctuations in islanding capability based on instantaneous weather and grid conditions. Islanding duration at any given time is based on the ability of the on-site PV generation to meet the facility's load and charge the battery, the facility's demand during an outage event, and the time of day and year that the outage occurs.

Preliminary Economic Analysis

The preliminary economic analysis included an initial high-level look at each preliminary draft scenario. The analysis included some easy-to-calculate estimates of the costs and benefits of each scenario, especially as related to the generation and resilience characteristics of each. The preliminary economic analysis included order of magnitude estimates of solar and emissions benefits, as well as capital costs and O&M estimates. Select cost and benefit highlights were then presented to the project team to demonstrate the unique and relative value propositions of each scenario, and to validate each scenario prior to the final economic analysis.

Figure 3.2.1 summarizes relative emissions reductions, projected costs (per kWh load served), and resilience capabilities for each microgrid scenario. The costs, carbon emissions, load coverage and grid support all vary in each of the five designs. The designs range from inexpensive to most expensive, carbon free to significant diesel generation.

Figure 3.2.1 - Scenario Asset, Load Coverage, Outage Capability, and Cost Overview



Source: Smart Electric Power Alliance, 2022

The initial normative cost considerations above for the five microgrid scenarios came from the NREL 2019 Annual Technology Baseline, vendor quotes, and NREL's Phase I Microgrid Cost Study: Data Collection and Analysis of Microgrid Costs in the United States.

Scenario Pros and Cons

The five microgrid design scenarios present their own benefits and drawbacks.

Scenario A proposes a microgrid that adds a moderately-sized battery to the planned 94.5 kWdc solar PV and 154 kW diesel generator planned for the site. During normal operations, the battery is capable of providing some additional economic benefit, as 25% of the battery's capacity is reserved for demand reduction. Paired with the planned solar PV, the battery can provide a few days of carbon-free islanding capacity.

Scenarios B and C propose more economical microgrid designs that provide limited carbon-free resilience while minimizing costs and optimizing the economic benefits of a battery energy storage system. These scenarios suggest deploying a smaller battery in addition to the planned 94.5 kWdc solar PV and 154 kW diesel generator planned for the site. During normal operations, these two scenarios compare the benefits of using the battery for demand reduction versus energy arbitrage. Paired with the planned solar PV, the battery can provide one day of carbon-free islanding capacity.

Scenario D, the most costly and only 100% renewable design, serves the load of the entire site and maximizes on-site generation by deploying an additional 97.5 kWdc ground-mounted solar PV at the site. During normal operations, the battery is capable of providing an economic benefit, as 25% of the battery's capacity is reserved for demand reduction. Paired with the proposed and planned solar PV, the battery can provide indefinite carbon-free resilience.

The **EV Scenario** proposes a microgrid that maximizes on-site generation by deploying an additional 97.5 kWdc ground-mounted solar PV at the site. The additional generation, paired with a small battery, serves to ease the demand burden of the additional EV fleet charging at the facility, and provide additional economic and resilience benefits. During normal operations, the battery is capable of providing an economic benefit through energy arbitrage. Paired with the proposed and planned solar PV, the battery can provide one day of carbon-free resilience.

4.0 Microgrid Feasibility

4.1 Preliminary Engineering Considerations

In addition to the loads and DER assets noted in the scenarios above, several other factors must be considered during the engineering design phase of a microgrid project including a microgrid controller and the distribution system. The components of a microgrid include facility load, generation (solar PV or diesel generation), battery energy storage, a microgrid controller, and interconnection to an existing distribution line.

For the purposes of this analysis, it is assumed that Prairie Du Sac Municipal Electric and Water will own and operate the medium voltage distribution infrastructure, while the other infrastructure including solar facilities, battery storage and diesel generation would be owned by the Sauk Prairie Police Department. In general, the scope of the necessary fieldwork is largely agnostic to the ownership model.

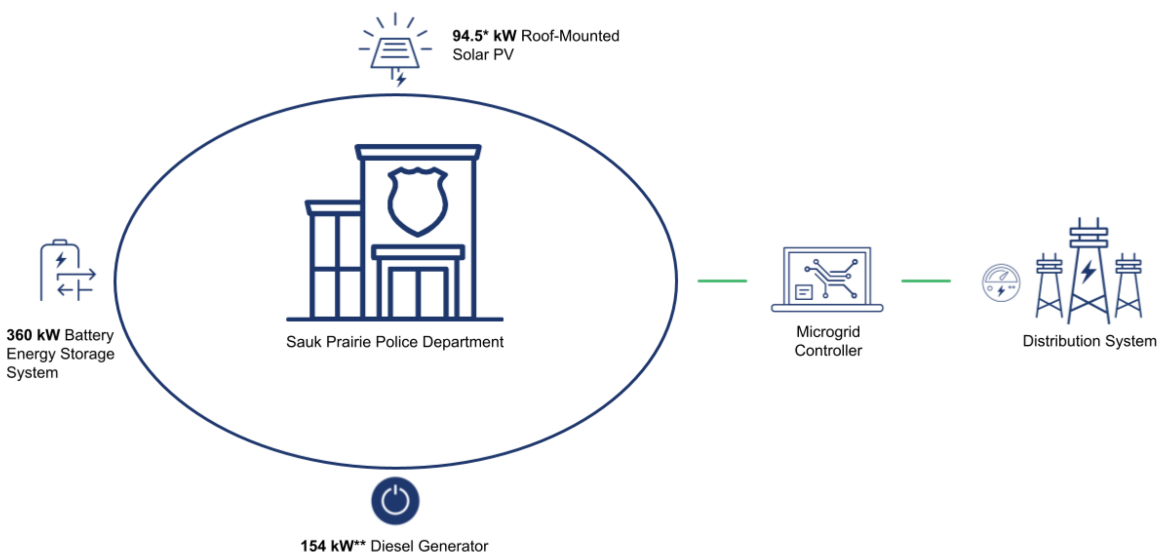
SEPA designed scenarios A-D to serve the EOC, and one additional scenario to serve both the EOC and an EV fleet through a mix of ground-mounted solar, battery storage, and diesel generation. Each of the preliminary sizing estimates for each scenario enable the microgrid to rely significantly on generation from solar PV during the summer and utilize battery storage and the diesel generator for islanding during periods of low solar output.

Note that SEPA estimated the EOC's loads using the historic load profile data for a nearby fire station and, therefore, the site's load could change once real-world data becomes available. This could lead to different results for the load analysis.

Site Layout

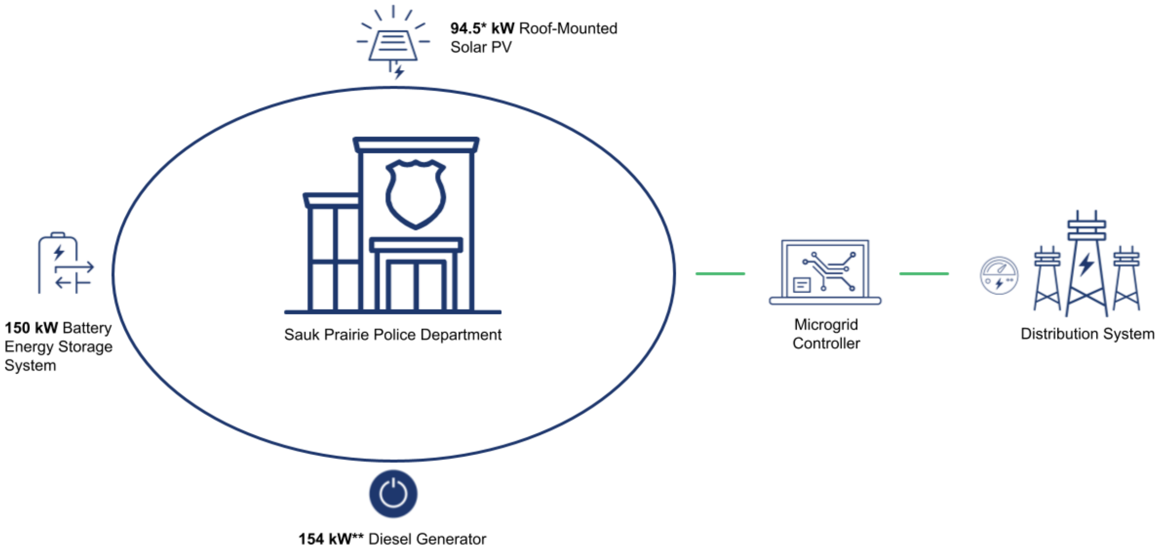
SEPA developed a conceptual microgrid configuration for each scenario, but suggests that stakeholders reference 2.3 Site Availability and coordinate with an engineering design team to develop a site layout that best suits the final project. Microgrid configurations are noted below for each scenario.

Scenario A



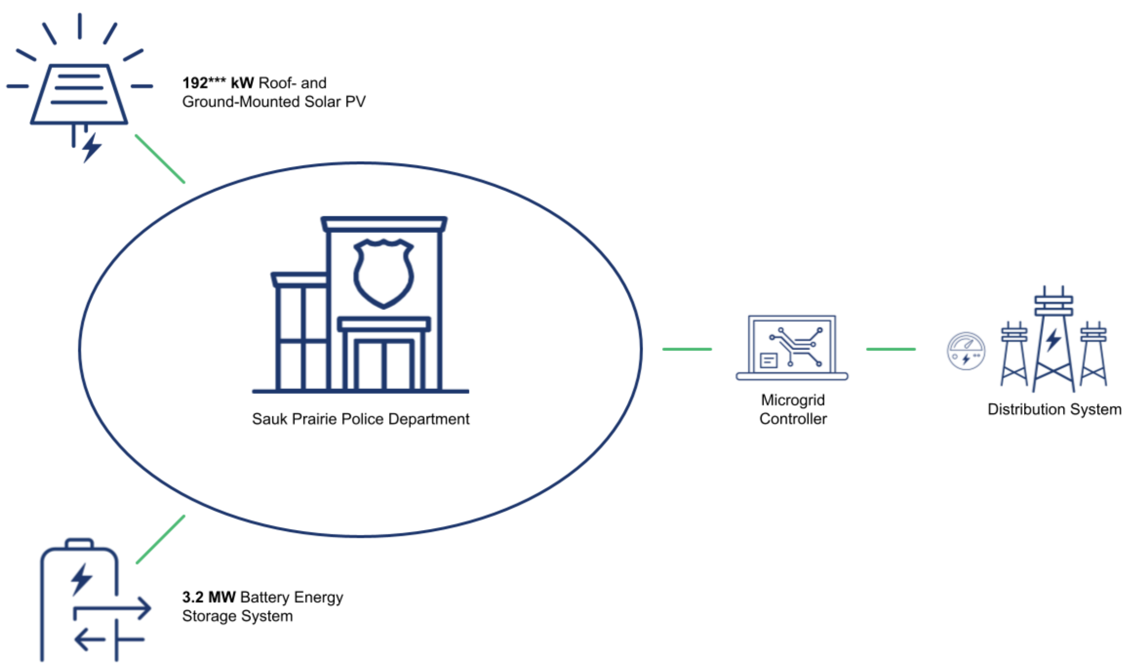
*BCA does not include the costs and benefits associated with the planned 94.5 kW Solar PV
**BCA does not include the costs and benefits associated with the planned 154 kW diesel generator

Scenarios B and C



*BCA does not include the costs and benefits associated with the planned 94.5 kW Solar PV
**BCA does not include the costs and benefits associated with the planned 154 kW diesel generator

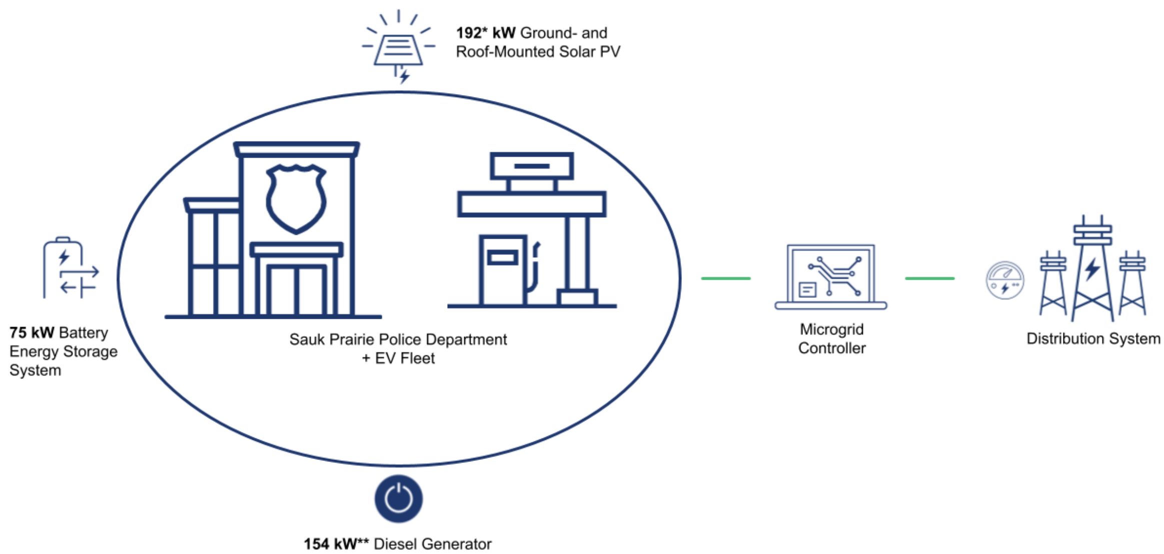
Scenario D



*BCA only includes additional 97.5 kWdc ground-mounted PV proposed beyond the planned 94.5 kWdc roof-mounted PV

Wisconsin Office of Energy Innovation

EV Scenario



*BCA only includes additional 97.5 kWdc ground-mounted PV proposed beyond the planned 94.5 kWdc roof-mounted PV
**BCA does not include the costs and benefits associated with the planned 154 kW diesel generator

Microgrid Operations

Prairie Du Sac Municipal Electric and Water will own and operate all medium voltage equipment, which includes disconnecting and reconnecting the microgrid from Prairie Du Sac's distribution system. The microgrid will have three modes described below. During each scenario, the microgrid controller will ensure proper voltage and frequency levels, manage loads and generation, and optimize battery charge/discharge schedule and charge levels.

Operating Mode 1: Normal Operation/Blue Sky

During normal operation, the solar PV system will operate in parallel with Prairie Du Sac's distribution system. Where relevant, the diesel generator will only operate for maintenance purposes. A schedule of maintenance operations will need to be provided to Prairie Du Sac's Systems Operations. The microgrid controller will ensure that the battery storage system maintains a full charge.

The battery storage system would also be used to reduce demand charges, or engage in energy arbitrage, bringing in revenue to offset costs. WPPI's Systems Operations Center will only need to be alerted if energy is being discharged to the grid.

Operating Mode 2: Microgrid Operation - Disconnecting from the Grid

During a scheduled or unplanned outage, Prairie Du Sac Municipal Electric and Water will initiate the microgrid isolation from the distribution grid. During a scheduled outage, this will be a seamless transition. During an unscheduled outage, the facility will be served by the BESS until the outage is repaired, or until the battery is drained and the diesel generator comes online, if included in the scenario. The BESS and diesel generator, where relevant, will operate to stabilize load and maintain voltage and frequency. Once voltage and frequency levels have stabilized, the solar will resume operation. During a long-term outage, battery storage will operate to manage variations in voltage or frequency and reduce peak load times. The scenario assumes that the battery will be fully charged when microgrid operation is initiated. Once initiated, the battery can temporarily suspend energy arbitrage or demand reduction capabilities to ensure that the battery is fully charged in preparation for a forecasted outage-causing event. Once the microgrid is in operation, the controller will manage the charge and discharge of the battery storage based on microgrid conditions and available solar output. The controller will act to maximize the usage of PV energy and minimize the use of the diesel generator.

Operating Mode 3: Microgrid Operation – Resuming Normal Operation

Once the distribution grid has been restored, the facility will be re-connected to the larger distribution grid. To do this, the microgrid will re-synchronize and operate in parallel with the distribution grid and the generator will power down. The battery storage system will discontinue operation except to re-charge or carry out economic functions. This will be designed to be a seamless transition.

Interconnection

All resources will follow Prairie Du Sac's standard interconnection process for distributed generation.

Microgrid

To house the microgrid controller, manage the electrical isolation of the facility from Prairie Du Sac's distribution system, and provide an interconnection point for the battery storage system and/or diesel generator, an upright switchgear may need to be installed at the site. Since this is the isolation point for the microgrid from Prairie Du Sac's distribution system, it will need to be connected at the point where Prairie Du Sac's distribution enters the facility.

Typical dimensions for an upright 13 kV switchgear would be approximately 10' wide, 9' deep, and 9.5' tall.

Solar, Diesel, and Battery Storage

The solar, BESS, and diesel generation unit, if included, will interconnect to the microgrid isolation switchgear. The solar, BESS, and diesel generator may require step-up transformers to convert to the distribution line voltage. For layout purposes, SEPA assumed that the battery storage system and the diesel generator were close enough to each other to use a single step up transformer. The solar PV ground-mounted system will not require separate metering or a separate service transformer.

For layout purposes, SEPA assumed the footprint of the battery storage system in each scenario to be between 60 and 2,520 sq ft. based on battery sizes and available references.[16] Exact dimensions will depend on the equipment vendor selected.

4.2 Financial and Environmental Impact

The financial and environmental impacts summarized in this section build on the technical analysis and focus on developing a high-level inventory of potential benefits and costs for the proposed microgrid scenarios to assess the net benefits of each.

Understanding the balance between benefits and costs can clarify whether the proposed investment (and other costs) of the project are justified by the resulting benefits. Such assessments are especially important when the investment is being made “for public benefit,” or when externalized or non-economized benefits (such as cleaner air, reduced greenhouse gas (GHG) emissions, or improved public health) are realized.

The goal of this study is to develop a high-level inventory of potential benefits and costs for this specific microgrid project, and to establish a foundation for a more formal benefit-cost assessment once additional project details are finalized. The study focuses on quantifying utility and societal benefits in economic terms, and determining how these economic benefits compare to the costs of implementing, operating, and maintaining the project over its lifespan. This report was prepared by project participants and written in a relatively non-technical way to support engagement with stakeholders.

All benefits and costs included in the analysis are quantified, and the multi-year cash flow (over an assumed project life of 20 years) is translated into a Net Present Value (NPV). A simple benefit-cost ratio can then be computed based on the NPV of all benefits divided by the NPV of all costs. A benefit-cost ratio of 1.0 would indicate that benefits exactly match costs. A ratio of more than 1.0 indicates a net benefit in which benefits exceed costs, with higher ratios indicating a greater net benefit. A ratio of less than 1.0 indicates that costs exceed benefits, with lower ratios indicating a less favorable benefit-cost balance.

All five proposed Sauk Prairie EOC microgrid scenarios would provide uninterrupted power to the facility for a period of at least one day. The use of additional renewable generation assets beyond the 94.5 kWdc solar PV planned for the site will increase total benefits associated with clean on-site generation. These microgrid functions represent the basis for an inventory of both benefits and costs that can be used to quantify the net benefit of the project.

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[16] SEPA used reference data from a publicly available SCE battery storage project which assumed a footprint of ~0.2 sq ft/kWh.

Inventory of Benefits and Costs

Development of the benefit and cost inventory depends on detailed information about a proposed microgrid project, including possible microgrid configurations, microgrid asset sizing, necessary changes to the local distribution system serving the planned facility, islanding switchgear, and a specialized microgrid control system. Cost estimates include the initial capital costs of the microgrid assets and the expenses associated with operation and maintenance of the microgrid infrastructure over the long term.

The benefit-cost inventory assumes that the project will have a 20-year life-span and that, over that time, the solar production will decline by 0.4% annually, as is typical of photovoltaic systems. The solar system will supply renewable energy, and for the purpose of this analysis is assumed to be net-metered. The emissions reduction value associated with solar generation is the same regardless of interconnection method. No additional “grid services” are assumed for the microgrid components – such as dispatch of either the battery or diesel generator.[17]

The load served by this project consists of the Sauk Prairie EOC or the Sauk Prairie EOC and a fleet of six electric vehicles. For purposes of this analysis, all outages experienced by the facility are assumed to be the result of feeder-level failures – i.e., not the result of issues within the boundaries of the facility itself.

A formal benefit-cost analysis would make use of standardized tests. The protocols associated with those tests dictate what combination of benefits and costs are used in each case. Making those determinations depends upon knowing important details about ownership structure, which parties bear various real-world costs[18], benefits (often in the form of revenues) or avoided costs and to whom they accrue, and the role of the utility in the project. Many of those details are not known yet, as is typical for a feasibility study at this stage of development.

As a result, this study focused on developing an inventory of the benefits and costs that might be included in a formalized benefit-cost test. That inventory can provide early insight about the benefit-cost balance, and help establish the foundation for formalized benefit-cost assessment. It is important to note, however, that not all benefits or costs noted in the inventory below might be included in a particular test. Care is needed to ensure that a formalized test balances the group of benefits and costs included, and that issues such as double-counting and “transfer effects”[19] have been addressed.

The inventory summarized below has been developed with a focus on taking a “common sense” view of both benefits and costs, looking broadly at the “societal scale” of impact, and building upon the details about project implementation that are known at this time. The combination of

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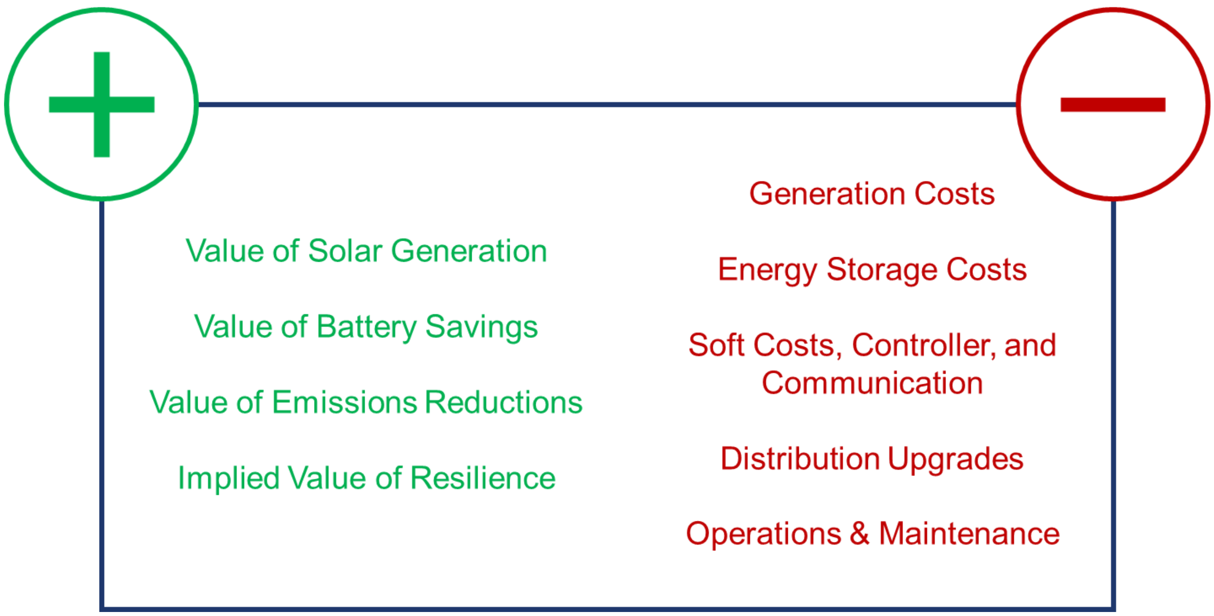
[17] Additional grid services, if added to the operating profile of the microgrid, might introduce additional benefits that could be quantified.
[18] Whether these affect the benefit-cost analysis depends on which test you use. For instance the utility test versus the societal test. If the societal test was used, these would not change the overall results.
[19] Transfers exist within a benefit-cost test when both the benefits and costs flow to and from the same impacted population considered by a particular test, thereby canceling each other out. The nature of transfer considerations depends on the test being used.

these benefits and costs used in a specific formal test will depend on the test being performed, and additional project details being specified.

Figure 4.2.1 - Overview of Benefits and Costs



Source: SEPA, 2022

Overview of Costs

The costs for the microgrid project relate primarily to the costs of construction, and long term operating and maintenance costs. These cost estimates were taken from a technical evaluation completed by the SEPA team, and are associated with each proposed scenario. The cost inventory includes:

1. **Generation (PV + NG):** Generation costs only reflect the purchase and installation of additional solar photovoltaic capacity beyond the newly commissioned 94.5 kWdc rooftop solar PV array at the site. In each scenario, a photovoltaic system has been proposed for the microgrid to generate clean electricity, and (with the support of the planned diesel generator and/or a BESS) allows the facility to operate independent of the grid. The PV system partially replaces traditional fuel use, providing significant emission reductions that are a key benefit of the overall project. The diesel generator can be dispatched on demand, and can be used to firm the solar generation, as well as provide power in parallel with the solar system or when no sunlight is available. This is a one-time construction cost. The costs for the solar system include a long-term warranty for the inverters to ensure their continued operation over the assumed lifespan of the project. The costs for the solar system do not include the Federal Investment Tax Credit (ITC). Further BCAs may need to reassess the value of the ITC, assuming that it would be available at the time of construction.

2. **Battery Energy Storage Systems (BESS):** This is a highly valuable component of a larger system that generates energy using intermittent sources of renewable energy such as solar, since it helps to balance the production and use of energy. The BESS is also important for a microgrid to handle transition events and to ensure power quality. For this study, initial BESS costs were captured in the first year as part of construction, but further BCAs may want to assume that the battery would need to be replaced partway through the life of the project, as the lifespan of a BESS is likely to fall short of the 20-year project life-span assumed in this study. Estimating the future costs of replacement must account for the net impact of inflation and expected reductions in battery costs over time, for example, a net cost reduction of 5% per year might be used to estimate replacement costs in a future year. Additionally, the costs for the BESS do not include the Federal Investment Tax Credit (ITC). Further BCAs may need to reassess the value of the ITC, assuming that it would be available at the time of construction and the system is eligible to receive the credit.
3. **Soft Costs, Controller, and Communications:** A specialized controller is used to manage the microgrid when in island mode, including direct interaction with the generation resources and the BESS. The costs of the controller, along with the costs of engineering, construction, commissioning, and regulatory affairs, are included as a one-time construction cost estimated at 16% of the component costs for each scenario.
4. **Distribution Upgrades:** In order to implement the microgrid, SEPA assumed that the existing distribution system at Sauk Prairie EOC will not require significant modifications. Construction costs for distribution upgrades **were not** included in this study, but may need to be incorporated into further BCAs.
5. **Operations & Maintenance:** Unlike other cost components, operations and maintenance is an ongoing, recurring cost. These costs were taken from the NREL Annual Technology Baseline (ATB) 2021 for commercial solar PV and 4hr Lithium Ion BESS on an annual basis for the lifespan of the project.

Overview of Benefits

Most of this study focused on identifying and quantifying the benefits from the microgrid project. All of these benefits are incremental to the baseline provision of service to the facility. As covered in more detail in Appendix 2: Detailed Benefits, the study modeled and estimated significant benefits associated with solar generation and improved resilience, including:

1. **Value of Solar Generation:** The value of solar generation was represented as the total annual value of:
    - **Energy Rate Savings:** Bill savings resulting from avoided energy purchases, as energy consumption at the facility is offset by on-site solar generation.
    - **Excess Generation Credit:** Bill credits resulting from solar generation in excess of the facility's load that is metered back to the grid at a predefined rate.

- **Demand Savings:** Bill savings resulting from the reduction of facility load peaks that coincide with on-site solar generation.

2. **Value of Battery Savings:** The value of battery savings was represented as the total annual economic benefits provided by a BESS through:

    - **Energy Savings:** Bill savings resulting from shifting on-peak energy purchases to off-peak hours as noted in the TOU rate by charging the battery from excess solar or from the grid during off-peak hours and discharging it for use during on-peak hours.

    - **Demand Savings:** Bill savings resulting from the reduction of facility load peaks by strategically discharging the battery during hours of peak load.
3. **Value of Emissions Reductions:** Solar PV generation reduces harmful emissions from burning fossil fuels that have local, regional, and global impact. Benefits include the total dollar value of reductions in mortality and morbidity from PM2.5, SO2, and NOx[20], and the CO2[21].
4. **Implied Value of Resilience:** The implied value of resilience focused on the ability of a microgrid to provide power to the facility when the public grid is inoperable. For the EOC, resilience value should be based on its ability to serve as an emergency operations center for a number of Sauk Prairie emergency services during major events, critical incidents, and man-made or natural disasters, especially when the power is out as a result of the event. In this study, the implied value of resilience is the remaining difference between the NPV of costs and benefits in each scenario when the costs outweigh the benefits. This value will not be included in the final BCRs for each scenario, but it can be used as a benchmark for stakeholders to consider when estimating the value of resilience at the site for future cost tests. In cases where the benefits exceed costs, this value will not be noted, as the project can be considered to be cost effective without the inclusion of this benefit.

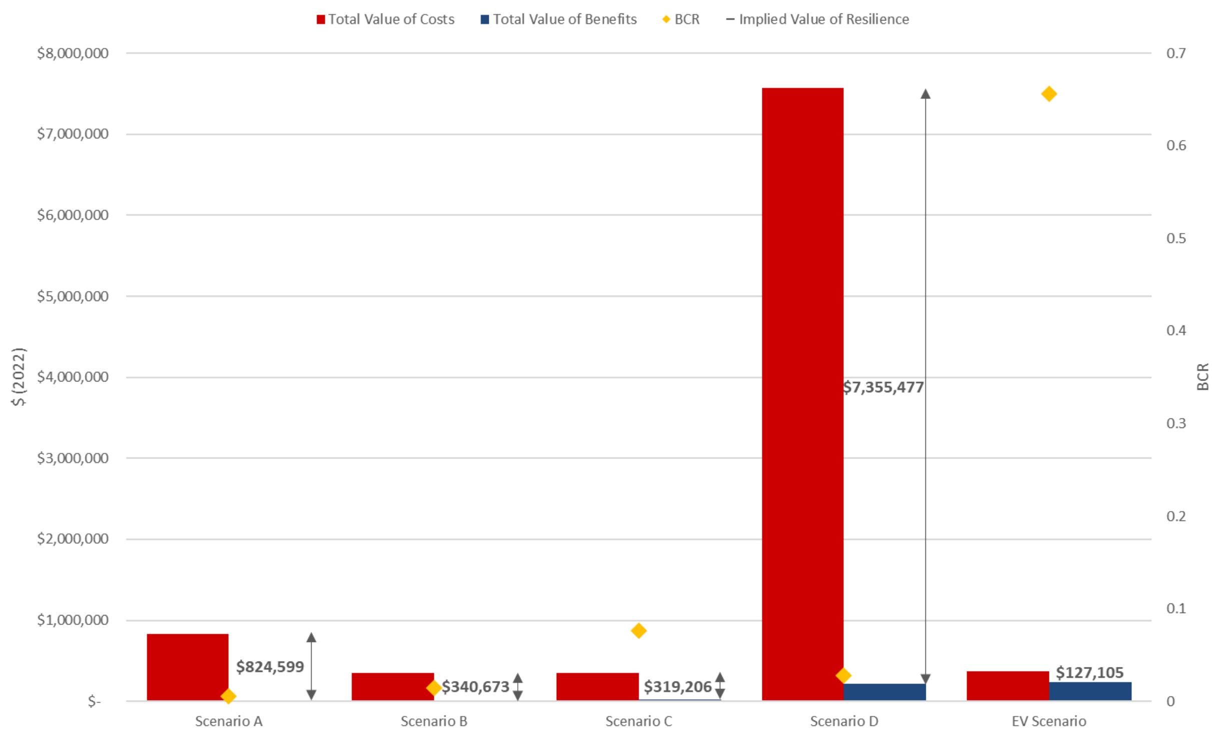
Summary of Results

The study quantified the economic valuation of both benefits and costs for the microgrid scenarios, including a nominal sum (i.e., the simple sum of annual costs), and a Net Present Value using a discount factor of 5%. That is, the weighted average cost of capital (WACC) is assumed to be 5%. A high-level summary of benefits and costs is displayed in Figure 4.2.2.

Figure 4.2.2 - Summary of Benefits and Costs

[20] https://www.epa.gov/sites/default/files/2018-02/documents/sourceapportionmentbpttsd_2018.pdf

[21] https://19january2017snapshot.epa.gov/sites/production/files/2016-12/documents/sc_co2_tsd_august_2016.pdf



Source: SEPA, 2022

Summary of Cost Results

The costs for each scenario are based on the initial construction costs and O&M costs each year over the 20-year period.

Table 4.2.1 - Summary of Costs

Microgrid Costs	Low Cost Scenario	Mid Cost Scenario	High Cost Scenario
Scenario A			
Generation (PV)	$0	$0	$0
BESS	$475,701	$583,280	$654,949
Soft Costs/Controller/Comms	$90,610	$111,101	$124,752
Operations & Maintenance	$95,246	$135,169	$171,670
Total	**$661,556**	**$829,550**	**$951,372**
Scenario B			
Generation (PV)	$0	$0	$0

BESS	$198,209	$243,033	$272,895
Soft Costs/Controller/Comms	$37,754	$46,292	$51,980
Operations & Maintenance	$39,686	$56,320	$71,529
Total	**$275,649**	**$345,646**	**$396,405**
Scenario C			
Generation (PV)	$0	$0	$0
BESS	$198,209	$243,033	$272,895
Soft Costs/Controller/Comms	$37,754	$46,292	$51,980
Operations & Maintenance	$39,686	$56,320	$71,529
Total	**$275,649**	**$345,646**	**$396,405**
Scenario D			
Generation (PV + NG)	$147,518	$151,551	$162,173
BESS	$4,228,453	$5,184,712	$5,821,770
Soft Costs/Controller/Comms	$833,518	$1,016,431	$1,139,799
Operations & Maintenance	$846,629	$1,201,503	$1,525,957
Total	**$6,056,118**	**$7,554,197**	**$8,649,699**
EV Scenario			
Generation (PV)	$147,544	$151,579	$162,202
BESS	$99,104	$121,517	$136,448
Soft Costs/Controller/Comms	$46,981	$52,018	$56,886
Operations & Maintenance	$34,217	$44,085	$55,461
Total	**$327,846**	**$369,199**	**$410,997**

Source: SEPA, 2022

Summary of Benefits Results

The following chart summarizes the economic value of the benefits associated with the microgrid scenarios.

Table 4.2.2 - Summary of Benefits

Microgrid Benefits	NPV of Benefits ($2022)	First Year Benefits (Nominal $)
Scenario A		
Solar Generation	$0	$0
Battery Savings	$4,951	$324
Emissions Reductions	$0	$0
Implied Value of Resilience*	$52,688 - $75,943	-
Total	**$4,951**	**$324**
Scenario B		
Solar Generation	$0	$0
Battery Savings	$4,973	$325
Emissions Reductions	$0	$0
Implied Value of Resilience*	$21,720 - $31,410	-
Total	**$4,973**	**$325**
Scenario C		
Solar Generation	$0	$18,109
Battery Savings	$26,440	$1,728
Emissions Reductions	$0	$0
Implied Value of Resilience*	$19,997 - $29,687	-

Total	**$26,440**	**$1,728**
Scenario D		
Solar Generation	$98,916	$6,693
Battery Savings	$5,239	$342
Emissions Reductions	$110,487	$6,921
Implied Value of Resilience*	$469,888 - $678,431	-
Total	**$214,642**	**$13,957**
EV Scenario		
Solar Generation	$104,101	$7,044
Battery Savings	$27,486	$1,797
Emissions Reductions	$110,507	$6,922
Implied Value of Resilience*	$6,881 - $13,553	-
Total	**$242,093**	**$15,763**

*The "Implied Value of Resilience" is an annual estimate, and displays a range of values for low, mid, and high-cost estimates. This value is not included in the "Total" benefits noted in the table, and does not impact the BCR values related to each scenario. A value of $0 suggests that the scenario is cost-effective without including resilience benefits in the BCA.
Source: SEPA, 2022

Summary of the Benefit-Cost Ratio

A typical benefit-cost analysis greater than 1.0 indicates that benefits exceed costs, and the project is generally beneficial. In the simple case where all the benefits identified above can be included in the benefit portfolio[22], the net benefit results are as follows.

Table 4.2.3 - Summary of Benefits and Costs

	Low Cost Scenario	Mid Cost Scenario	High Cost Scenario

[22]As noted in the introduction, a formal benefit-cost test would specify exactly which benefits and costs should be included for the benefit-cost calculation. Depending on the test, not all the benefits or costs identified in the inventory may be included in a particular test.

Scenario A			
Total Value of Costs (NPV)	$661,556	$829,550	$951,372
Total Value of Benefits (NPV)	$4,951		
Net Impact (Benefits minus Costs)	($656,606)	($824,599)	($946,421)
BCR	0.01	0.01	0.01
Scenario B			
Total Value of Costs (NPV)	$275,649	$345,646	$396,405
Total Value of Benefits (NPV)	$4,973		
Net Impact (Benefits minus Costs)	($270,676)	($340,673)	($391,432)
BCR	0.02	0.01	0.01
Scenario C			
Total Value of Costs (NPV)	$275,649	$345,646	$396,405
Total Value of Benefits (NPV)	$26,440		
Net Impact (Benefits minus Costs)	($249,208)	($319,206)	($369,965)
BCR	0.10	0.08	0.07
Scenario D			
Total Value of Costs (NPV)	$6,070,490	$7,570,119	$8,669,392
Total Value of Benefits (NPV)	$214,642		
Net Impact (Benefits minus Costs)	($5,855,848)	($7,355,477)	($8,454,751)
BCR	0.04	0.03	0.02
EV Scenario			
Total Value of Costs (NPV)	$327,846	$369,198	$410,997
Total Value of Benefits (NPV)	$242,093		

Net Impact (Benefits minus Costs)	**($85,752)**	**($127,105)**	**($168,903)**
BCR	**0.74**	**0.66**	**0.59**

Source: SEPA, 2022

Interpretation

The proposed Sauk Prairie EOC scenarios A-C provide limited benefits, solely through battery savings, as no additional solar PV is proposed to offset the costs of the additional battery storage. In these three scenarios, the benefits of the planned 94.5 kWdc solar PV (and the planned 154 kWdc diesel generator) were not included in the BCA as it only sought to provide insight into the benefits of introducing a battery to the planned on-site generation. The proposed scenario D and EV scenario provide more substantial benefits, mainly due to the additional solar production and associated emissions and rate benefits. However, due to the small scale of this project and the uncertainty associated with behind-the-meter solar and battery economic benefits, these benefits on their own do not balance the construction and operation/maintenance costs across all scenarios whether considering low-, mid-, or high- costs.

Although the benefit-cost ratios resulting from this high-level inventory of benefits and costs fall below 1.0, other considerations provide additional context for this outcome:

1. Benefit-cost analysis is highly sensitive to scale, and smaller projects almost always result in lower benefit-cost ratios. This is especially true when there are relatively fixed costs, as are evident for this project. In this case, the benefit-cost ratio is primarily a result of the small project scale, not a meaningful representation of intrinsic microgrid technology value.
2. Actual economic (demand and rate savings) benefits related to solar and battery storage are very difficult to quantify accurately beyond those that would result from the most conservative generation and load scenarios (i.e. maximum historic load and minimum expected solar generation). For this reason, real-world benefits from these economic functions could surpass those estimated in this study, and increase cost-effectiveness.
3. Development of microgrid technology, and improved resilience for all utility customers, is a strategic goal that is not easy to quantify. The strategic value of the project, including workforce development, customer education, and benefits to the community who have access to the EOC are not quantified in the benefits portfolio. These are qualitative factors that provide important context for the benefit-cost evaluation.

5.0 Conclusion

Despite providing significant measurable advantages, the net present value of benefits for the Sauk Prairie EOC do not exceed the costs of the project under any scenario before including resilience benefits in the analysis. That said, the EV scenario presents a situation in which a relatively modest valuation for the benefit of resilience at the site would make the additional battery storage and solar cost-effective, as noted by the “Implied Cost of Resilience” values in the previous section.

This analysis establishes a framework for assessing the economic value of the microgrid project, including a preliminary quantification of the value of emission reductions and increased resilience. Further formalized benefit-costs tests can build upon this foundation once additional details about the project and other similar projects are finalized.

However, the benefit-cost outcomes are not the whole story. Small-scale programs frequently result in unfavorable benefit-cost ratios, especially when the fixed costs are large. Trialing new technologies, strategies and programs offer learning opportunities, and may advance strategic goals that intrinsically hold value themselves, but are often not quantified or included in a feasibility analysis. Externalities, such as the value of reducing emissions are likely undervalued in these scenarios, despite providing important societal benefits. Most importantly, the research and methodologies for quantifying the economic value of resilience is relatively new and likely incomplete. As such, they may not capture the strategic value of improved resilience, especially as more extreme weather (and other) events become more common.

From the perspective of technical feasibility, Sauk Prairie EOC is a reasonable site to construct and install a microgrid project. Project team members believe that this project would increase resiliency in Prairie Du Sac, WI by serving as an EOC for emergency service providers in the community during major events or prolonged outages.

Key learnings from this study include:

- Given the open space at the site, the Sauk Prairie EOC is well suited to host additional ground-mounted solar PV for on-site generation.
- The solar and battery benefits are likely undervalued in the current benefit-cost framework and are dependent on real-world performance beyond the conservative estimates that were used for this study.
- A fully renewable scenario is not economically feasible at the site given solar capacity limitations which would force a large BESS charge mainly from the grid rather than on-site solar.
- Resilience benefits are likely to be significant given the facility’s role as an emergency operations center.

If the project partners decide to move forward, next steps include:

- Determine ownership and operation structures between Prairie Du Sac Municipal Electric and Water, Sauk Prairie Police Department, and a developer in order to have the appropriate information needed for the final BCA
- Identify potential funding sources to facilitate a public-private partnership (e.g., third-party finance, customer finance, utility investment and recovery in rates)
- Conduct a full engineering design and construction study
- Explore additional state and federal funding and grant programs (e.g., IIJA and FEMA BRIC)

6.0 Appendices

Appendix 1: Project Team Check-In Summaries

This appendix includes summaries of each monthly project team check-in.

January 2022

During the initial kick-off meeting with the project team, SEPA focused heavily on getting the group acquainted with each other. SEPA provided a background on the microgrid feasibility study and the grant, including information regarding project tasks, goals, and timeline. Project team members began to discuss the site, its role as an EOC, its critical loads, and its resilience needs. Sauk Prairie Police Department shared details surrounding the plans and timeline for the new EOC site construction, including the intention to build a roof-mounted solar PV array and incorporate a 154 kW diesel generator to provide backup power. SEPA started a discussion around data collection expectations and needs in order to begin the site analysis and develop preliminary microgrid scenarios. WPPI noted that since the site is not yet operational, SEPA and WPPI would have to discuss how to estimate the site's load using existing data from a similar facility. Following this meeting, SEPA began to gather relevant data and began an initial solar, load, and site assessments.

February 2022

The second project team check-in meeting included a discussion around the site's estimated load and solar production, especially which facility loads were critical or could be shed during an extended outage or emergency event. The project team also brainstormed potential microgrid scenarios, considering the possibilities of incorporating additional solar PV at the site, introducing battery storage to the planned solar PV and backup generator, or proposing a 100% renewable scenario. Following this meeting, SEPA began to develop preliminary microgrid scenarios and finalized the site assessment.

March 2022

The third project team check-in meeting focused on validating the site assessment and discussing the proposed preliminary microgrid scenarios. SEPA shared its site assessment with the project team, and had a discussion surrounding the footprint of additional solar or a BESS. SEPA also shared an outline of four initial microgrid scenarios in order to discuss the pros and cons of each with the project team. The project team also discussed the possibility of including an additional scenario that includes the added load of transitioning to an EV fleet. Following this meeting, SEPA finalized the microgrid scenarios and shared them with the project team.

April 2022

The fourth project team check-in meeting was fairly brief, but included a short discussion about how the value of resiliency would be determined by the analysis. Additionally, the project team suggested resizing the EV scenario to make it more cost effective by downsizing the battery and relying on the diesel generator to provide backup power. Following this meeting, SEPA finalized the BCAs for each microgrid scenario in preparation for writing the final report.

Appendix 2: Detailed Benefits

This appendix includes the quantification of significant benefits associated with solar generation, battery storage, and improved resilience for the facility.

Value of Solar Generation

The Value of Solar Generation was determined on an hourly basis, then aggregated for annual values. This represents the total annual value of:

- **Energy Rate Savings:** Bill savings resulting from avoided energy purchases, as energy consumption at the facility is offset by on-site solar generation.
- **Excess Generation Credit:** Bill credits resulting from solar generation in excess of the facility's load that is metered back to the grid at a predefined rate.
- **Demand Savings:** Bill savings resulting from the reduction of facility load peaks that coincide with on-site solar generation

PV Watts, developed by the National Renewable Energy Laboratory (NREL) was used to provide an estimate of solar generation on an hourly basis for the first year. This tool is widely accepted in the industry, and accounts for the location of the solar installation, local weather patterns, the size of the system, characteristics of the array, system losses, tilt, azimuth, and other parameters. The tool is commonly used to estimate the energy production and performance of potential photovoltaic energy systems. SEPA provided a PV Watts production profile for the site, which was the basis for estimating solar generation value for each scenario.

Energy rate savings were estimated by calculating the average site load that would be met by on-site solar for each hour of the year and multiplying that value by the energy rate during that time to determine the rate savings (or avoided costs) associated with purchasing that energy from the grid to meet the site's load. When estimating this benefit, SEPA assumed an annual solar degradation rate of 0.4% and an annual rate increase of 2.5%.

Excess generation credits were estimated by calculating the average on-site solar generation in excess of the facility's load for each hour of the year and multiplying that value by the buyback rate to determine the benefit associated with delivering energy back to the grid after meeting the site's load. Again, SEPA assumed an annual solar degradation rate of 0.4% and an annual rate increase of 2.5%.

Demand savings were estimated by examining the new load peaks for each month after considering the load peak reductions that would result from on-site solar generation. In order to avoid over-valuing this benefit, SEPA only considered demand reductions that would occur from the least favorable circumstances, that is days in which load is at its highest and solar generation is at its lowest. In order to achieve this, SEPA created sample hourly profiles for each month that represented the lowest observed solar generation for each hour during that month (from the PV Watts profile), and the highest observed site load for each hour during that month. SEPA subtracted the hourly minimum solar generation figures from the corresponding hourly maximum load figures for each month to generate a net hourly site load profile for each month under the least favorable circumstances. SEPA compared the new monthly and annual load peaks to those in the original load profile to estimate a conservative, but plausible estimate for demand savings.

Value of Emissions Reduction

Electricity generation that results from the burning of fossil fuels results in harmful emissions that have local, regional, and global impact. Over recent decades, renewable energy, like solar power, has emerged as a key strategy in reducing these emissions to improve air quality (especially key criteria pollutants like NO_X, SO_2, and $PM_{2.5}$) and avoid the release of greenhouse gasses that contribute to climate change.

The avoided emissions are quantified by determining the emission output that would have been produced on a "pounds per MWh" basis had that energy been generated at a traditional fossil fuel plant. The Emissions and Generation Resource Integrated Database (eGRID) provided region-specific emissions factors as "Pounds per MWh" values which were used to determine the environmental or emissions reduction impact of the avoided fossil fuel plant generation.[23] This process was repeated for four criteria pollutants which all have their own unique environmental impacts and behave differently in the atmosphere: carbon dioxide (CO_2), nitrogen oxides (NO_x), sulfur dioxide (SO_2), and particulate matter ($PM_{2.5}$). The economic impact of emissions was quantified using parameters from the Federal Interagency Working Group on the Social Cost of Carbon (for CO_2), and a separate study from the U.S. Environmental Protection Agency for impact factors on NO_x, SO_2, and $PM_{2.5}$.[24] These conversion factors translate the emissions reductions (in tons) to an economic benefit (in dollars) to society at large.

Value of Battery Savings

The value of battery savings was represented as the total annual economic benefits provided by a BESS through:

- **Energy Arbitrage:** Bill savings resulting from shifting on-peak energy purchases to off-peak hours as noted in the TOU rate by charging the battery from excess solar or from the grid during off-peak hours and discharging it for use during on-peak hours

[23] United States Environmental Protection Agency (EPA), Emissions & Generation Resource Integrated Database (eGRID).
[24] The Interagency Working Group on the Social Cost of Greenhouse Gases, Technical Support Document:- Technical Update of the Social Cost of Carbon for Regulatory Impact Analysis - Under Executive Order 12866 (2016).

OR

- **Demand Savings:** Bill savings resulting from the reduction of facility load peaks by strategically discharging the battery during hours of peak load

Note that each scenario assumed that the battery was being used for either one of the economic functions, but not for both. Energy arbitrage benefits were estimated by calculating the minimum value of either:

- The annual net energy consumption during peak hours as defined in the TOU rate schedule (i.e. the annual total (kWh) of energy consumption after estimated solar generation for all hours between 8:00 AM and 8:00 PM) multiplied by the difference between the on-peak and off-peak rates. This demonstrates the maximum annual savings that could result from charging the battery during off-peak hours and discharging it during on-peak hours to meet the facility's load, given that the battery has sufficient capacity to do so.

OR

- The sum of the capacity of the battery (kWh) or the capacity of the battery designated for energy arbitrage multiplied by the difference between the on-peak and off-peak rates for each day of the year. This demonstrates the annual capacity-limited maximum given that the battery does not have sufficient capacity to mitigate all on-peak energy purchases and deliver maximum annual savings from energy arbitrage. Each day, the battery would be fully charged during off-peak hours and fully-discharged during on-peak hours.

It is worth noting that this value does not take into account additional benefits that would result from on-site solar generation charging the battery and further reducing off-peak energy purchases.

Demand savings benefits were estimated by assuming that the battery would be discharged strategically to reduce site demand by avoiding going above a certain set demand peak for each month. SEPA calculated the value of that demand peak for each month by maximizing the annual savings that could be achieved given the limits defined by the capacity of the BESS, the extent to which on-site solar generation is able to charge the battery under unfavorable conditions, and the costs associated with charging the battery from the grid in order to reduce demand peaks.

When estimating this benefit, SEPA assumed an annual rate increase of 2.5% for both energy and demand rates.

Implied Value of Resilience

A primary focus of this project was to quantify the value that a microgrid could bring to the facility in terms of resilience (i.e., the ability to provide power when the utility grid is inoperable).

In order to quantify resilience value as part of the benefit portfolio, it must be expressed in economic terms. Valuation of resilience is relatively new and the study team found that there is little research and few precedents upon which to base the analysis. For that reason, SEPA presented an “Implied Value of Resilience” that is equivalent to the annualized benefit required to make each microgrid scenario cost-effective.

The implied value of resilience should be compared to the project team’s own valuation of the ability of a microgrid to provide power to the facility when the public grid is inoperable. For Sauk Prairie Emergency Operations Center, this real-world resilience value should be based on its ability to provide emergency services to the community during an extended outage or emergency. In this study, the implied value of resilience was noted as the remaining difference between the NPV of costs and benefits in each scenario, annualized over the 20-year project lifecycle. In cases where the benefits exceed costs, this value was not noted, as the project can be considered cost-effective without the inclusion of this benefit. This value was not included in the final BCRs for each scenario, but it can be used as a benchmark for stakeholders to consider when estimating the value of resilience at the site for future cost tests. That is to say, if stakeholders perceive the actual value of resilience at the site to be greater than the implied value of resilience noted here, then it is more likely that the project would be cost-effective in further BCAs.