CLEAN ENERGY AND RESILIENCY

(CLEAR)

PREPARED FOR

THE TOWN OF WEST TISBURY
MASSACHUSETTS

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CONVERGE
STRATEGIES

Clean Energy and Resiliency (CLEAR)

Prepared by:
Converge Strategies, LLC
Ridgeline Energy Analytics, Inc.
XENDEE Corporation
RAND Corporation

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www.convergestrategies.com
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About the Massachusetts Clean Energy Center (MassCEC)

MassCEC is a publicly-funded state economic development agency dedicated to accelerating the success of clean energy technologies, companies and projects in the Commonwealth—while creating high-quality jobs and long-term economic growth for the people of Massachusetts. Since it began operating in 2009, MassCEC has helped clean energy companies grow, supported municipal clean energy projects and invested in residential and commercial renewable energy installations, creating a robust marketplace for innovative clean technology companies and service providers.

About the CLEAR Program

An increase in the frequency and severity of severe storms associated with global climate change has increased the Commonwealth's need for resiliency in the face of major events and disturbances. The CLEAR Program seeks to support energy resilience investments in Massachusetts by advancing first-stage energy resilience system designs for critical facilities in Massachusetts communities. The findings of the CLEAR Program will also support the Commonwealth's consideration of energy resilience policy development in the future. The objectives of the CLEAR program are to:

1. Create resilient facilities to reduce economic losses from major power outage events.
2. Lower service interruption time for utility customers.
3. Provide a replicable model for outage recovery events.

Additional information on MassCEC's CLEAR program can be found here.

About the Project Team

- Converge Strategies, LLC (CSL) - Wilson Rickerson, Adair Douglas, Jack Graul, Rees Sweeney-Taylor, and Meredith Pringle. CSL Is a consulting company focused on the intersection of clean energy and resilience. CSL works with civilian and military partners to develop new approaches to energy resilience policy and planning in the face of rapidly evolving threats, vulnerable infrastructure, and determined adversaries.
- Ridgeline Energy Analytics - David Korn and Matthew Piantedosi. Ridgeline is a consulting firm that serves public and private clients in the energy field, providing energy engineering, data analysis, energy efficiency, and renewable energy services.
- XENDEE Corporation - Dr. Michael Stadler and Adib Naslé. XENDEE is a microgrid planning and techno-economic analysis platform that supports project decisions all stages: from opportunity discovery, pre-feasibility, and conceptualization through implementation.
- RAND Corporation - Benjamin Preston, Mike Wilson, and Liam Regan. RAND is a research organization that develops solutions to public policy challenges to help make communities throughout the world safer and more secure, healthier and more prosperous.

Summary - Energy Resilience Pathways Forward

The recent power and water outages in Texas have demonstrated once again the importance of energy resilience for critical community facilities as the climate changes. The Town of West Tisbury is pursuing clean energy as part of both its climate action and climate resilience strategies. The Town set a target of 100% renewable energy by 2040 and has also called for the use of solar energy and batteries to provide back-up power to Town buildings. This report presents the findings of an energy resilience analysis of town buildings conducted through the Clean Energy for Resiliency (CLEAR) program, supported by the Massachusetts Clean Energy Center. The CLEAR analysis finds that West Tisbury has opportunities to use solar and storage to support energy resilience, although there are potential tradeoffs between their renewable energy and resilience objectives that need to be balanced.

The scope of this project was to analyze six critical buildings for energy resilience upgrades that use clean energy technology. The analysis found that some sites are better suited for such upgrades than others. Some of the buildings' rooftops could not accommodate solar, and most buildings did not have adequate area for solar and storage (on their own) to carry critical loads for prolonged periods of time. Five of the six buildings have emergency generators, and the analysis found that there are challenges with the existing back-up power systems. Several of the Town's generators are over-sized for the critical loads they are intended to carry during power outages. Running in low load conditions can cause engine strain and cause generators to fail well before their fuel supplies run out.

This section presents three ideas that draw on the key findings of the study and address the Town's goals of being 100% renewable by 2040. These approaches are not intended to be mutually exclusive: they are intended to highlight and organize some of the choices that the Town could consider as it pursues a clean and resilient energy future.

1. "Electrification to the Rescue!" - Increase Electrification to Ensure Generator Performance. The Town can improve the function of their existing back-up power systems (generators) by adding load to these buildings. Climate-friendly technology examples include: high-efficiency cold climate heat pumps, electric vehicle chargers, and battery storage.

- *Pros:* The Town reduces carbon emissions through electrification while helping to ensure that their current back-up power systems can operate during longer-term power outages.
- *Cons:* Electrifying heating and transportation increases building load. This will impact annual energy bills unless thermal envelope improvements - insulation and airtightness and in some cases, windows - are done first. The size of solar and storage will need to increase to accommodate those loads during prolonged power failures or conversely, these systems can support these loads but for a shorter duration.

2. "Diversify your Portfolio" - Maximize Solar, Storage, and Efficiency. The Town has several good sites to install solar photovoltaic (PV) and battery storage at its critical facilities, and there are opportunities to reduce building energy consumption through energy efficiency improvements. Solar and storage can contribute to - but not replace - the need for additional back-up power systems even with energy efficiency upgrades due to site constraints: limited land and roof space, and historic preservation considerations. Under this strategy, the Town uses solar, storage, efficiency strategies, and "right sizing" of its generators to carry the critical loads.

- *Pros:* The Town reduces onsite carbon emissions with solar energy and enhances building performance through efficiency improvements. This idea conserves fossil fuel supplies and extends the amount of time that diesel or propane back-up power systems can operate when needed.
- *Cons:* This Pathway requires some existing back-up power systems to be traded out (i.e. scrapped or sold) in order to "right size" new generators that would better match the critical loads.

3. "Move the Mission"- Be Creative in Your Resilience Strategies. The analysis contained in the report assumes that the essential functions currently performed at each building would stay there during an outage. There may be opportunities to design contingency plans for longer-term outages in which the critical "missions" of each building might be either consolidated at different facilities or further distributed. The example strategies included below could allow the Town to prioritize its investment focus on specific buildings, which could result in more cost-effective resilience outcomes.

a. The Town could build a large-scale battery at the landfill to absorb power from the existing large-scale PV system there. In the event of a longer-term outage, a battery at the landfill could provide a fallback charging point for critical loads.
b. Many of the critical loads at the Public Safety Building and Fire Station One are inherently portable (or could be moved), and a storage system at the landfill PV site (or other fallback location) could serve as a charging location for response vehicles.
c. The Town could also consider creating contingency of operations plans that enable the functions of certain buildings to be moved to, or staged at, other buildings with robust and low carbon back-up systems. For example:
   - The Council on Aging could move its operations to the Public Safety Building to work more closely with the police liaison.
   - The Town Hall could establish back-up servers and designated office space for fallback use at the Library.
d. The Town could also examine opportunities to further distribute essential functions. Public water access is identified as an essential function for Town critical facilities. There may be non-critical buildings within the Town that could also be configured with small solar and storage back-up systems to specifically pump water for public access during longer duration outages.

- *Pros:* These strategies may be more cost-effective than attempting to harden each individual building. Some of these strategies may also create opportunities for quick wins and early paths to success. Installing storage at the landfill could have the additional benefit of alleviating the current issue of surplus solar energy generation (see Section 1.3).
- *Cons:* Alternative planning may address some, but not all of the Town's building-specific critical requirements. Additional planning and study would be needed since the scope of this study focuses primarily on building-specific upgrades.

1. Introduction

This report summarizes the findings of the energy resilience analysis conducted for the Town of West Tisbury under Clean Energy for Resiliency (CLEAR) program supported by the Massachusetts Clean Energy Center (MassCEC). The Town of West Tisbury was one of nine communities and institutions awarded support under the CLEAR program. This report is organized as follows:

- Section 1 summarizes West Tisbury's energy, climate, and emergency management policies and plans, and reviews the project approach, assumptions, and key findings.
- Section 2 presents the results of the energy resilience analysis for the Town buildings.
- Appendix 1 includes detailed information on the XENDEE economic analysis performed by the Project Team.

1.1. West Tisbury Energy Resilience Planning in Context

The Town of West Tisbury is located in the center of the island of Martha's Vineyard and has a population of close to 3,000. The town is vulnerable to a range of hazards, such as wildfires and hurricanes[1], which could cause significant disruptions to its electricity system and to its supply of delivered fuels: diesel, fuel oil, propane, and gasoline. These hazards are projected to become more severe as the climate continues to change in the coming years and decades.[2]

Disasters such as the wildfires in California, Hurricane Maria in Puerto Rico, and the Texas winter storm of 2021 have caused catastrophic power outages that have left communities without power and/or water for weeks or even months. The unprecedented scale of these events is prompting states, cities, and towns across the U.S. to contemplate longer duration outages in their emergency planning. The Town of West Tisbury's Comprehensive Emergency Management Plan[3] contemplates a power outage of five days or more, and the federal government suggests an "emerging standard" of 14 days for power outage preparedness.[4]

A major lesson learned from recent disasters is that resilient local power systems will be increasingly required to keep community lifeline services operating as environmental and weather conditions become more extreme. West Tisbury and its partners on the island have adopted a series of policies and plans that emphasize the need for local energy strategies to mitigate the hazards of climate change.

- **100% renewable energy.** The Town of West Tisbury adopted a resolution in October 2020 to reach a goal of having 100% of its energy supply come from renewable energy sources by 2040.[5] The Town's resolution is consistent with the Martha's Vineyard Commission *Climate Crisis Resolution*[6], which was adopted in 2019.
- **Island Energy Plan.** The Martha's Vineyard Commission Climate Action Task Force's Energy Working Group[7] developed a series of working papers to outline a pathway to 100% renewable energy by

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[1] Dukes County Multi-Jurisdiction Hazard Mitigation Plan Update 2020 (Draft) (2020)

[2] Looking Forward - Climate Change Adaptation Context: West Tisbury (2020)

[3] Comprehensive Emergency Management Plan

[4] The President's National Infrastructure Advisory Council (2018). Surviving a Catastrophic Power Outage: How to Strengthen the Capabilities of the Nation.

[5] 100% Renewable Initiative

[6] Martha's Vineyard Commission 2019 Climate Crisis Resolution

[7] Martha's Vineyard Commission Climate Action Task Force Climate Action Task Force Annual Report 2020

2040. The *Island Energy Plan 2020* emphasizes energy efficiency, building upgrades, and the widespread adoption of zero-carbon energy technologies.[8]

- **Municipal Vulnerability Preparedness (MVP).** West Tisbury completed a community climate resilience assessment in partnership with the Town of Chilmark in 2018. The Town subsequently created a Climate Advisory Committee to address the actions identified by the MVP effort. A key recommendation from the assessment was to study microgrids to keep critical infrastructure and services operating during power outages.[9]
- **Hazard Mitigation Plan.** The 2020 Dukes County Hazard Mitigation Plan summarizes the current and future weather extremes faced by West Tisbury, and identifies microgrids and batteries as strategies to reduce reliance on the electricity grid.[10]
- **2019 West Tisbury Annual Town Report.** The Annual Report also emphasized the opportunity to support town critical services using clean energy technologies, by noting that "For Town properties in particular, the first priority will be to establish enough solar power with battery backup (vs. generators) to keep functioning regardless of the weather[11]."

Building on these policies and plans, the Town of West Tisbury identified six critical facilities for analysis under the CLEAR program, listed below. Based on the available data some of those buildings have been analyzed in more detail regarding economics and outage modelling with XENDEE. The detailed XENDEE analyses include Public Safety Building, the West Tisbury Library, and Fire Station One. Detailed summaries of the findings related to energy resilience opportunities at each facility are included in Section 2.

1. Public Safety Building
2. West Tisbury Library
3. Fire Station One
4. West Tisbury School
5. West Tisbury Town Hall
6. Up-Island Council on Aging

The Town prioritized facilities that provide public safety, shelter, and social service since evacuation off the island following a catastrophic outage will be difficult, and residents will need to shelter in place.

1.2. Project Approach

The CLEAR Project Team conducted the energy resilience analysis in several phases during 2020-2021. These included:

- **Stakeholder interviews.** The Team conducted structured interviews with representatives from each of the critical facilities to develop a preliminary assessment of the critical functions that the buildings would need to play during an emergency. The interviews also sought to characterize the electrical loads necessary to support those critical functions. These interviews set the stage for an in-person site visit.
- **Policy assessment.** In addition to reviewing local policies related to energy, climate, and emergency preparedness, the Team also conducted an extensive analysis of how incentive and grant programs available from state, federal, and utility partners could be combined to support the investment

[8] Island Energy plan 2020
[9] West Tisbury and Chilmark, MA Community Resilience Building Workshop Summary of Findings
[10] Dukes County Multi-Jurisdictional Hazard Mitigation Plan Update 2020
[11] 2019 West Tisbury Annual Town Report

opportunities identified. The assessment considered both programs to support clean energy, as well as programs that can support back-up power for emergency management purposes. A detailed summary of the policy assessment is contained in a separate PowerPoint presentation submitted to the West Tisbury Energy Committee.

- **Site visit.** In November 2020, Ridgeline Energy Analytics conducted an in-person site assessment of all six facilities. Ridgeline conducted an in-depth energy audit to characterize the electricity and heating systems within each building. The audit identified how each of the building energy systems is configured, how they function in both normal and emergency operating conditions, and where there might be opportunities for solar PV systems, battery storage, and energy efficiency improvements. The solar PV analysis was completed using the HelioScope solar design software suite.[12] An overview of the findings is contained in Section 2, and detailed findings for each building are included in a separate PowerPoint presentation submitted to the West Tisbury Energy Committee.
- **Board of Selectmen presentation.** Converge Strategies delivered a presentation on the CLEAR program and preliminary findings from the Project Team's analysis at the December 9, 2020 Selectmen's meeting.[13]
- **Economic analysis.** Using the inputs from the policy assessment and site visits, the Project Team conducted an economic feasibility analysis and carbon emissions reduction estimate for the three buildings that had suitable sites and sufficient data. The XENDEE platform identifies optimal configurations (size and operation) for energy resilience at a given site, using detailed load profiles, technology, and electricity tariff data. The XENDEE analyses are intended as preliminary, and additional analysis and engineering design would need to be completed before building the proposed systems. In the process of such an engineering design more data points need to be collected or provided (e.g. load data measurements instead of estimates). Summary results of the XENDEE analysis are included alongside the site visit findings in Section 2. A more detailed overview of the XENDEE approach is included in Text Box 1 below.

1.3. Assumptions

The following assumptions informed the analysis and proposed system designs:

- **Emissions-free energy systems.** West Tisbury adopted a 100% renewable energy goal, and the analysis in this report attempts to maximize the use of zero carbon emissions energy solutions.
- **Generating technology.** West Tisbury does not have a lot of land on which to site energy projects. As a result, the study focused primarily on solar PV since it can be readily installed on rooftops or small parcels. The study considered ground mounted systems located within the center of the town, but this report does not focus on them in depth given historic preservation concerns.
- **Battery technology.** The study focuses on lithium-ion battery storage given its cost advantages over other technologies and its commercial availability. As discussed in Text Box 1 below, the study analyzes two battery scenarios: one in which the battery is sized to be economically optimal, and a second that assumes a larger battery size for longer outage duration. For the larger battery, the study assumes a 500 kilowatt-hour (kWh)[14] / 200 kilowatt (kW) battery to be consistent with the battery

[12] *See* HelioScope

[13] West Tisbury Board of Selectmen Meeting Agenda. A copy of the presentation to the Board of Selectmen is on file with the Town Administrator.

[14] Battery sizes are typically expressed in terms of a power rating in kW and an energy rating in kWh. The power rating indicates how much power can flow in or out at any time. The energy rating is the measure of how much electricity the system can deliver or absorb over the course of an hour. Batteries are designed to maximize either the power rating or energy rating depending on the use case. If the battery needs to charge and discharge frequently over short periods of time, it should be designed with a higher power rating. Since West Tisbury would

size under consideration for installation within the town by the Vineyard Transit Authority (Section 2.5).

- **Policy.** The economic analysis assumes that the solar PV systems would take advantage of the Solar Massachusetts Renewable Target (SMART)[15] incentives and that the battery storage systems would participate in the Cape Light Compact ConnectedSolutions program.[16]
- **Ownership model.** The analyses assume that the Town of West Tisbury will own the energy systems in order to highlight the payback trade-offs between different system configurations. West Tisbury could also work through the Cape and Vineyard Electric Cooperative[17] (CVEC), which manages solar procurements on behalf of its municipal partners. Under a CVEC model, the solar and storage system would instead be owned and operated by a third-party provider on the Town's behalf under contract with CVEC - rather than owned by the Town.
- **Net metering credit offtake.** CVEC previously supported the development of a 708 kW PV system at the West Tisbury landfill. West Tisbury and eight other municipalities share the benefits of the landfill's solar PV system output in the form of virtual net metering credits, which reduce the municipalities' electricity bills.[18] The landfill PV system has reduced the Town of West Tisbury's electricity bills close to zero. An unintended consequence of this success is that additional solar PV development on the Town of West Tisbury's property would not be able to further reduce the electricity consumption of Town buildings. There are several potential policy and project development solutions to this issue. For example, the Town could install a battery storage system at the landfill in order to absorb excess PV electricity. A centralized battery could generate revenue through the Cape Light Compact ConnectedSolutions program, and could also serve as a charging station for police, fire, and emergency management devices and vehicles during emergencies. A full discussion of strategies to absorb surplus solar energy, however, is beyond the scope of this report. This report assumes that the Town of West Tisbury and/or other partners on the island are able to realize the full benefit of any solar PV output.
- **Power interruption timing.** West Tisbury identified the need for resilience to power outages that occur in the late summer to early fall as a result of hurricanes and wildfires. The analysis also focused on mapping the heating systems and on estimating winter peak loads. The XENDEE economic analyses focus on outages in the winter with higher loads in order to be conservative.
- **Critical loads.** The analysis attempted to identify the loads that would be required to support the community lifeline functions performed by each building. It is important to note that these "estimated critical loads" are not necessarily the loads that are currently connected to the buildings' emergency electrical panels. In some cases, the building would have to be re-wired to connect the estimated critical loads to the emergency panel so that the back-up generator could power them.
- **Outage duration.** The report provides a rough number for the amount of time that the existing back-up generator could support the estimated critical loads. This amount, referred to as the "theoretical outage duration," is calculated by comparing the estimated critical load to the amount of fuel storage that the back-up power system has, and the rate at which the back-up power system consumes fuel. This calculation is intended to provide an order of magnitude comparison, and is not an accurate reflection of how the back-up power system will *actually* perform during an outage. As discussed

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plan to discharge the batteries over longer periods of time, they should be designed with a higher energy rating. *See* National Renewable Energy Laboratory Batteries 101 Series.

[15] https://www.mass.gov/solar-massachusetts-renewable-target-smart

[16] https://www.capelightcompact.org/business/commercial-connectedsolutions/

[17] www.cvecinc.org

[18] CVEC. West Tisbury Annual Presentation.

elsewhere in this report, many of the back-up power systems are oversized, which could degrade their performance and cause them to fail during an outage.

- **Standalone systems vs. microgrids**. The analysis focused primarily on systems designed to provide energy resilience to specific facilities, rather than analyzing community microgrids that could serve multiple facilities. Community microgrids are more complex and may raise concerns with Eversource related to interconnection with the grid and to connections between buildings. However, the analysis did consider opportunities to enhance resilience by connecting buildings without solar PV roof potential (e.g. Town Hall and the Up-Island Council on Aging) to buildings with stronger solar PV potential nearby (e.g. the Library and Grange Hall).

Text Box 1. XENDEE Analysis in West Tisbury

The Project Team conducted a range of economic and resilience analyses of the West Tisbury sites using the XENDEE tool to reflect different siting scenarios, system configurations, and available policy options. The primary focus of the XENDEE analysis was to determine the potential energy resilience capabilities of onsite systems. The team also conducted sensitivity runs in order to explore the impact of different policy options. These analyses focused on, for example, the comparative economic performance of the proposed systems under the SMART incentive program, depending on whether the systems are interconnected behind the meter (i.e. directly supplying electricity to the buildings) and in front of the meter (i.e. supplying power into the grid). Although the XENDEE platform can automatically recommend optimal system sizes for economic performance and for resilience, the sites themselves introduced constraints on the system designs because of their available rooftop space, historic preservation considerations, and existing back-up power infrastructure. In order to provide an upper bound for the analysis, the Team assumed a larger battery size to be used in a "resilience case." For the Public Safety Building and the Library, the assumed battery size is consistent with the system currently under consideration by the Vineyard Transit Authority. For Fire Station One, a 25 kWh battery was assumed given the building's smaller load. The Team examined how the system would perform if carrying the entire building load during a power outage and how it would perform carrying only the identified critical loads. The Team also identified the economically optimal system configuration - i.e. the configuration that would have the quickest payback. In each case, the economically optimal system design included a much smaller battery that could provide only a short amount of back-up power (i.e. 2-3 hours). The economically optimal configuration can be viewed as a lower bound for battery sizing at the proposed buildings. A more detailed description of the XENDEE assumptions, as well as more detailed model outputs are included in Appendix 1.

1.4. Key Findings and Design Considerations

- **There are opportunities to install clean energy for energy resilience in West Tisbury**. There are opportunities for solar and storage to cost-effectively support emergency operations at several of the public facilities. The Library is the strongest near-term candidate for an energy resilience system, and the Town is working with CVEC to explore how to include the Library in upcoming energy procurements. There are also opportunities for the Town to pursue energy efficiency, solar energy, battery storage, and energy resilience upgrades on their own. This report highlights the potential for both integrated clean energy resilience solutions, as well as stand-alone energy upgrade investments that the Town may wish to pursue.
- **West Tisbury can cost-effectively install PV at multiple sites, although PV siting is limited by historical preservation considerations**. There are good opportunities for rooftop solar PV at several of the Town buildings, including the Library, the Public Service Building (PSB), and Fire Station One (FS1), although the PSB and FS1 would require a roof reshingling before PV could be installed. The other buildings do not have adequate roof sites for solar PV. The report does not consider ground mounted PV systems in depth, since in some cases they would require historic preservation consideration and approval.
- **West Tisbury can cost-effectively install batteries at multiple sites, although siting is limited by historic preservation considerations.** Each of the sites could install a battery energy storage system, although it is likely that these system sizes would need to be limited within the historic preservation district. The XENDEE analyses in Section 2 focuses on batteries that are sized for resilience and for economic performance.
- **The Town will likely need to preserve some fossil-fueled generators since there is insufficient space to install PV and batteries to support critical loads in longer-duration outages**. The Town's 100% renewable energy commitment would require that the Town move beyond fossil fueled back-up power by 2040. However, the solar PV and storage systems would not be sufficient to carry the estimated critical loads of town facilities during a long-duration power outage because of siting limitations. The Town's push to electrify heating, cooling, and transportation will intensify these tradeoffs. The more loads that need to be carried within specific buildings, the shorter the duration of time that the back-up power systems can supply power during outages. The Town may wish to keep some fossil fuel back-up capability available support for resilient solar and storage systems.
- **Many of the Town's existing generators are oversized and require additional loads to operate efficiently**. In the near-term, the Town will need to continue to rely on its existing generators. The existing generators have ample fuel storage that in most cases could theoretically support the operation of Town buildings for days to weeks. However, most of the generators that serve Town buildings are over-sized, meaning that the generators are much larger than the loads they serve. Generators operate best when they serve loads that total 80%-90% of their capacity. In other words, a 100 kW diesel generator operates best serving a total load of 80-100 kW. Diesel generators should serve loads equal to at least 50% of their nameplate capacity. Generators that operate in "low load" conditions below 50% of their capacity operate less efficiently, experience engine strain, and could potentially fail. The Town could replace its existing generators with smaller systems, or could find ways to add load to the building by, for example, connecting electric vehicle charging stations to the building electrical panels, electrifying the heating system, or adding batteries.
- **Many of the Town's emergency panels need to be re-wired to support critical loads.** All of the buildings except for the Council on Aging have back-up power generators. The PSB and FS1 each have generators that serve the entire load of the building. The other three buildings have back-up generators that serve a subset of loads connected to dedicated emergency electric panels. In some cases, the identified critical loads, such as the Library's HVAC system, are not connected to the

emergency panels. In other cases, such as the School, it is unclear whether the loads written on the electrical panels are actually the loads connected to the panels. When moving forward with energy resilience investments, the Town should map, test, and re-wire its emergency panels to ensure that the back-up power systems would support the intended loads in an outage.

- **There are tradeoffs between battery size and greenhouse gas emissions.** West Tisbury could improve the economic case of proposed solar and storage systems by building large batteries that could maximize revenue from incentives such as the ConnectedSolutions program. The batteries would also be able to provide back-up power for longer time periods when fully charged. However, these batteries would be larger than the PV systems could supply alone - the batteries would also need to draw electricity from the grid in order to effectively participate in the markets during non-emergency periods. Since the grid is not currently supplied by 100% renewable electricity, these batteries could result indirectly in net positive carbon emissions by using grid power to charge. However, the Massachusetts grid is rapidly decarbonizing through policies such as the renewable portfolio standard[19], the clean energy standard[20], and the clean peak standard[21]. The Commonwealth has also issued a roadmap to achieve net-zero emissions by 2050.[22] Batteries on Martha's Vineyard can also support power grid reliability and can help defer carbon-intensive investments to manage peak loads on the electricity distribution grid. The Town would need to weigh the outlook for the rapidly evolving electricity system and the economic benefits of installing large batteries against the near-term carbon emissions from charging batteries from the grid.

2. Results

This Section profiles the energy resilience and clean energy investment opportunities identified at each of the six critical facilities, based on the findings of the site assessment and the XENDEE analysis (where sufficient enough data was available). The building profiles are structured using these standard categories:

- **Energy requirements** - the energy needs of the building under both normal and emergency operating conditions. This includes the essential community functions that the building is intended to provide, and a summary of the electrical loads required to perform those functions.
- **Energy capabilities** - the *existing* energy generation and back-up power systems (i.e. generators) that are already installed at the building, including the functions and loads that the back-up power is designed to sustain, and the length of time that the estimated critical loads can be sustained using the existing back-up power systems. This category also details whether the back-up power system is connected to critical loads through a dedicated electrical panel, or whether the back-up system is designed to support the whole building during a power interruption.
- **Resilience opportunities** - opportunities to improve the energy resilience of the facility through changes in operations or through new investment. This includes a summary of potential energy efficiency upgrades to reduce the load of the building (and make it easier to sustain or restore during an emergency), recommended solar PV and battery storage configurations, and adjustments to the existing back-up power system.
- **Economics and system performance** - the results of the XENDEE analysis of the proposed solar and storage energy resilience systems, as applicable.

[19] https://www.mass.gov/renewable-energy-portfolio-standard
[20] https://www.mass.gov/guides/clean-energy-standard-310-cmr-775
[21] https://www.mass.gov/clean-peak-energy-standard
[22] https://www.mass.gov/info-details/ma-decarbonization-roadmap

● **Potential alternatives** - summarizes additional technical configurations for the energy resilience system that could be explored at a future date or that were contemplated during the course of the project and not selected for the final analysis.

2.1. Public Safety Building (PSB)

2.1.1. Energy Requirements

Essential community functions

The PSB provides multiple critical public safety services:

● **Fire department.** The PSB houses three fire trucks.
● **Police department.** The PSB houses five police vehicles.
● **Emergency medical service (EMS).** The PSB houses an ambulance that is part of the Tri-Town Ambulance Service.[23] The ambulance is staffed with full time paramedics and volunteer EMTs.
● **Emergency management services.** The PSB is the central coordination point for Town emergency management and its role in mutual assistance to other towns island-wide.
● **Water access.** The building has a spigot which can allow the public to fill containers during an outage.

Energy Usage and Demand

● The PSB consumes approximately 92,300 kWh of electricity on an annual basis. The primary electrical loads include lighting for both the Fire and Police Stations, climate control from a heat pump system in the Police Station, air handler units in the Fire Station, water heating in the Police and Fire Stations, and miscellaneous loads across both departments, such as radio and flashlight chargers and computers.
● The estimated peak load for the building is 32 kW in winter and 25 kW in summer.
● The Fire Station and its garage are heated by an oil boiler that consumes approximately 1,200 gallons annually.

[23] The Tri-Town Ambulance service serves West Tisbury, Aquinnah, and Chilmark

Critical Loads

The critical missions supported by the PSB require that the building be operational during power outages. The total estimated critical load is estimated to be 16 kW in winter and 12.5 kW in summer. The critical loads include:

- **Communications.** The portable communications radios used by the fire, police, and ambulance services require charging.[24]
- **Equipment charging.** Emergency response also requires a range of equipment to be charged and ready, including flashlights, carbon monoxide detectors, cameras, batteries, and tasers.
- **Refrigeration.** The evidence refrigerator requires back-up power over the long-term since relevant cases can be months in duration.
- **Lighting, water, and HVAC.** Basic lighting, climate control, and water access (e.g. the water and septic pumps) are required to support overnight staff and operations. The water system could also enable the public to fill water containers from a spigot on the building in a prolonged power failure.

2.1.2. Energy Capabilities

Back-up Generator

- The PSB is connected to a 100 kW Kohler diesel generator that was purchased by the Town in 2019.
- The generator is supplied from a 448-gallon storage tank.

Emergency Panel

The PSB does not have a dedicated emergency panel to separate out critical loads. The entire building is connected to the diesel generator.

Outage Duration

- The generator could theoretically power the PSB for 15 days if the diesel storage tank was full at the time of the outage.
- The generator is oversized for the loads of the building, however, with 100 kW of generator capacity to serve 32 kW of load. As discussed in Section 1.4, generators can ramp down to operate in "low load" conditions, but low load operations can cause premature wear on the generators, and low load conditions over a longer period of time can cause irreversible generator damage and failure. This damage can be neutralized if the generator is periodically run with higher loads. For example, It is recommended that diesel generators serving 30% load operate for no more than 8 hours before ramping up to operate at 50% load.[25]

2.1.3. Resilience Opportunities

Back-up power

Generator oversizing. The PSB would need to find additional electrical load for its diesel generator to serve under longer-duration power outages. This could include converting the heating system to heat pumps, charging electric vehicles, adding battery storage, or connecting in loads from adjacent properties

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[24] The PSB does not serve as the central hub for emergency communications for West Tisbury. Central dispatch for all emergency services - ranging from police and fire to animal control - is conducted by the Regional Emergency Communication Center managed by the Dukes County Sheriff at the Martha's Vineyard Airport. Fire Station One serves as the secondary, back-up communications hub for the Town.

[25] Fehr, Stephen J. "Emergency Diesel-Electric Generator Set Maintenance and Test Periodicity" (2017). Doctor of Philosophy (PhD), Dissertation, Engineering Management, Old Dominion University,

(e.g. the Highway Department). The Town could also sell the diesel generator on the secondary market in order to purchase a smaller, 40-50 kW generator.

Building Upgrades

- **Roof reshingling.** The Fire Station portion of the PSB would require roof reshingling in order to install a PV system since the roof is nearing the end of its useful life and PV systems can operate for more than 30 years.

Energy Efficiency Upgrades

Energy efficiency upgrades at the PSB could reduce peak demand by more than 2 kW and reduce fuel oil consumption at the Fire Station.

- **Insulation.** The entire building should be reviewed for insulation and air sealing improvements, with particular attention paid to the insulation in the Fire Station.
- **Lighting.** The interior lighting in both buildings could be replaced in both buildings with LED lamps, which would cut peak load by roughly 2 kW.
- **Water heating.** A 50-gal heat pump water heater for the Fire Station would also cut peak load, but deliver low- to moderate-savings due to low usage. Reducing the Police Station heat pump water heating set point from 150 degrees to between 125-130 degrees is advised. The hot water temperature at the Fire Station could also be set back at the boiler to reduce oil usage.

Solar PV

- The PSB has a southwest-facing rooftop that could accommodate a 32 kW solar PV system (Figure 1).
- The PV system would produce 40,570 kWh of electricity, or the equivalent of 44% of the annual electricity consumption. There are trees located to the south of the building, but they would not significantly shade the PV system.[26]

Figure 1. Solar PV Siting at the PSB

[26] The impacts of shade on solar PV systems can be mitigated through the use of microinverters, although such systems cost more than standard inverters.

2.1.4. System Performance - XENDEE Summary

- The XENDEE resilience analysis assumes a 500 kWh battery installed at the site.
- The proposed solar and storage system would be able to carry 100% of the building load for one day without needing to rely on the diesel generator. After the first day, the diesel generator would need to contribute to carrying the building load while the PV recharged the battery.
- The system could carry the 16 kW estimated critical load for approximately three days.
- The simple payback of the proposed energy resilience system would be 14 years (which is close to the battery's lifetime).
- As a comparison, the economically optimal system would include a battery of only 11 kWh and would have a simple payback period of eight years.
- The details of this analysis can be found in Appendix A.

2.1.5. Potential Alternatives

- **EV charging.** The Fire and Police departments currently do not have any electric vehicles in their fleet, although there is an EV charger in the lot behind the PSB. An electric vehicle charged from a resilient clean energy system could support response capability in the event of a longer duration power outage where gasoline deliveries to the island are disrupted. An electric vehicle charging station could also add load to the building and ease strain on the generator during power outages.
- **Air-source heat pumps.** The Police Station already has full heating and cooling with high efficiency heat pumps. The Fire Station has a large boiler (estimated to provide 20 tons of heating) that it uses to heat both the buildings as well as the fire truck bays. The boiler could be replaced with 20 kW of air-source heat pump capacity.
- **West Tisbury Highway Department connection.** It might also be possible to connect the PSB with the Highway Department building that is located nearby. In the near term, the Highway Department's loads could be connected to the diesel generator and help alleviate strain on the generator from operating in low load conditions. As the Town moves away from diesel generation in the future, however, a connection between the PSB and the Highway Department would decrease the amount of time that a solar PV and battery back-up system could serve both buildings during an outage.

2.2. West Tisbury Library

2.2.1. Energy Requirements

<u>Essential community functions</u>

The Library is a certified cooling center for extreme heat days. The building provides climate control, water, and light snacks during heat waves, and also has an emergency medical technician onsite for consultation. The Library also serves as a *de facto* shelter for the elderly and lower income residents during summer days. The Library also has a well pump that supplies a water bottle filling station in front of the building that can be used when power outages disable other water pumps in the town.

<u>Energy Usage and Demand</u>

The Library consumes approximately 120,000 kWh annually in electricity. The Library uses a high-efficiency heat pump for its heating, ventilation, and air conditioning (HVAC). The HVAC system is the largest driver of electricity consumption in the Library, with the highest usage in the winter to provide heating. Lighting is the second largest single source of electricity demand, followed by the 40-gallon electric water heater.

<u>Critical Loads</u>

In order to function as a cooling center, the Library needs to maintain its HVAC, lighting and domestic hot water systems. The well and sewage pumps and the composting toilets also each have smaller electricity loads that must run. Table 1 below summarizes the kW demand for each load, as well as the load reduction strategy that could be utilized in an emergency situation.

Table 1. Estimated Building Electrical Loads under Normal and Emergency Operating Conditions

Load	kW - Normal Operations	Emergency Operations	kW - Emergency
HVAC	32	Lower heating seat point and raise cooling set point	28
Lighting	11	Use half of the lights Install LEDs (see below)	3
Hot water	4.5	Replace water heater with heat pump and set water heater to "heat pump only" once replaced	1.5
Misc. loads (water and sewer pumps, fire pump, refrigerator, office equipment, composting toilets)	8	Reduce office equipment to bare minimum Eliminate under-desk heaters Turn off elevator	3
Total (Normal Operations)	55.5	Total (Emergency Operations)	35.5

2.2.2. Energy Capabilities

Back-up Generator

- The Library has a 52 kW propane fueled emergency generator made by Kohler.
- The generator is supplied from a 1,000 gallon propane tank

Emergency Panel

- The Library has an emergency panel that allows the generator to directly power certain loads during grid outages.
- The emergency panel is currently connected to a small handful of loads that include, for example, the well pump, sewage pump, the compost toilets, some lighting, and a few wall plugs.
- As currently configured, the emergency generator would supply public water access, but would not support the operation of the heating and cooling systems. The Library currently cannot operate as a cooling center during power outages.

Outage Duration

- The generator could theoretically support the small loads connected to it through the emergency panel for months.
- If it is assumed that the generator is connected to the loads described in Table 1, the Library generator could theoretically power its emergency loads for 21 days if its propane tank was full at the time of the outage.

2.2.3. Resilience Opportunities

<u>Back-up power</u>

Electric panel rewiring. As discussed above, the loads that the Library would need to operate as a cooling shelter are not currently wired into the emergency panel and therefore cannot be powered by the existing back-up power system. The Library's electrical system architecture should be updated to include the emergency loads identified in Table 1 in the emergency panel.

<u>Energy Efficiency Upgrades</u>

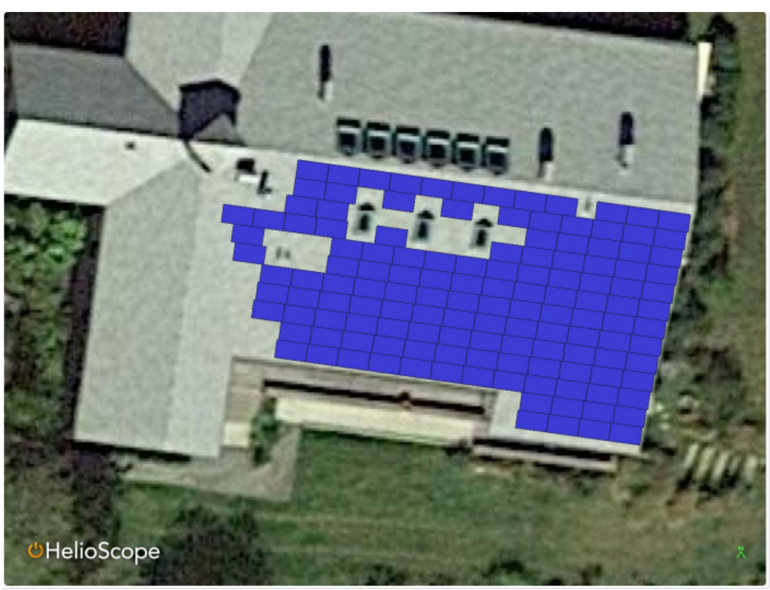
The Library is one of the most energy efficient town buildings, and there is the potential for an additional 8 kW in peak load reduction. The efficiency opportunities include:

- **LED lighting**. Replace the interior and exterior lighting with LED lamps and reduce the load by 5 kW.
- **Occupancy sensors**. Place sensors in selected shelving areas to reduce constant lighting loads.
- **Water heater.** Replace the existing 40 gallon heater with a 50 gallon high efficiency heat pump water heater.
- **Set points.** Double check the set points on the heating system, since high settings of 75 degrees were observed during the energy audit. The set point should instead be 68-70 degrees.

<u>Solar PV</u>

- The Library has the best solar roof potential of the buildings surveyed by the study.
- The Library roof can accommodate at least a 50 kW system, and could potentially accommodate up to 65 kW if higher efficiency panels were used. Figure 2 shows an image of a potential rooftop system configuration.
- The solar PV system would generate an estimated 64,500 kWh per year, and produce the equivalent of 70% of the full summer load and 25% of the winter peak consumption (since the PV production would decrease while the building heating load increases).

Figure 2. Solar PV Siting at the Library



Battery Storage

The Library could site a 500 kWh / 200 kW lithium-ion battery in the lot behind the building. A larger system would likely not be feasible given the Town's historical preservation regulations. The battery could be located behind the Library building so that it would not be seen, although the area behind the Library is limited.

2.2.4. System Performance - XENDEE Summary

- The XENDEE resilience analysis assumes a 500 kWh battery installed at the site.
- The proposed solar and storage system would be able to carry 100% of the building load for almost one day without needing to rely on the existing back-up generator. After the first day, the generator would need to contribute to carrying the building load while the PV system recharged the battery.
- The system could carry the estimated critical load for almost two days.
- The simple payback of the proposed energy resilience system would be 12 years (which is close to the battery's lifetime). The project would result in a net savings of 20% over its lifetime, compared to the cost of utility bills.
- As a comparison, the economically optimal system would include a battery of 15 kWh and would have a simple payback period of eight years.
- The details of this analysis can be found in Appendix A.

2.2.5. Potential Alternatives

The following alternative designs were also considered for the system.

- **Electric vehicle charging.** The Town is installing a ChargePoint Level 2 electric vehicle charger in the Library parking lot. The EV charging station would add roughly 6-8 kW of load to the building if the charger could be connected to the proposed energy resilience system.
- **Solar PV parking lot canopy.** An additional 40 kW of PV could be installed as a free-standing car canopy in the north side of the parking lot. This would require approval by the Historic District Committee and the Library Trustees.
- **Microgrid with the Council on Aging.** Since the Library and the Council on Aging (Section 2.6) are situated closely together, there may be opportunities to extend the energy resilience system proposed for the Library to the Council on Aging. This solution would require approval from Eversource, the distribution grid system owner that serves the Town. There may also be opportunities to connect the Library's existing back-up power generator to the Council on Aging.

2.3. Fire Station One (FS1)

2.3.1. Energy Requirements

Essential community functions

FS1 houses two of West Tisbury's fire trucks, as well as a boat and a dive vehicle. The station also serves as the secondary communications center for the island and a back-up for the Regional Emergency Communication Center managed by the Dukes County Sheriff at the Martha's Vineyard Airport.

Energy Usage and Demand

- FS1 consumes 14,800 kWh of electricity annually. The average peak load of the building is 4 kW, driven by lighting and water heating. The building contains a broad range of emergency equipment and other miscellaneous loads that together total 27 kW of load, but the equipment is only used periodically.
- The emergency equipment and miscellaneous loads include the communications system, an air filling station SCUBA equipment and air packs, an equipment dryer, clothes washers, kitchen equipment, and an ice maker.
- FS1 is heated by a propane furnace, which consumes 660 gallons of propane annually.

Critical Loads

The critical loads include the lighting, the communications system, and charging for response equipment, such as radios, flashlights, and carbon monoxide detectors. The average daily critical load would be 2-3 kW. The critical load could spike significantly, however, if equipment such as the air filler is required for response.

2.3.2. Energy Capabilities

Back-up Generator

FS1 has a 33 kW diesel generator supplied by a 264 gallon diesel tank.

Emergency Panel

FS1 does not have a dedicated emergency panel.

Outage Duration

- The diesel generator could theoretically support the critical loads in the building for 80-100 days since the average daily load is low (i.e. 4 kW), and the larger loads (e.g. the 15 kW air filler) are only intermittently utilized.
- As with other buildings analyzed in this study, the diesel generator is oversized for the loads that it serves and extended low load operations could damage the generator or cause it to fail.

2.3.3. Resilience Opportunities

Back-up power

Generator oversizing. FS1 would need to find additional electrical load for its diesel generator to serve under longer-duration power outages. This could include converting the heating system to heat pumps, charging electric vehicles, installing a battery, or connecting in loads from adjacent properties.

Building Upgrades

The FS1 roof would need to be reshingled before a solar PV system could be installed. This might also be a good opportunity to increase the amount of roof insulation.

Energy Efficiency Upgrades

- The interior and exterior lighting could be replaced with LED lamps, which would cut load by roughly 1 kW.
- The 60 gallon water heater could be replaced with a 50 or 65 gallon heat pump water heater, which would further cut peak load (but would not generate significant energy savings).
- The icemaker should be shut off (and drained and cleaned), if not continuously needed.
- Propane use could be reduced if the building's insulation and airtightness are improved.

Solar PV

- FS1's has two suitable rooftop segments that could together accommodate a 20 kW system, which would be capable of producing 25,110 kWh (Figure 3). The PV output could supply 100% of facility demand in both summer and winter.
- The south-facing rooftop has superior solar production capability. If solar PV were installed on just the south-facing roof, the system would be 13 kW.

Figure 3. Solar PV Siting at FS1

2.3.4. System Performance - XENDEE Summary

- The XENDEE resilience analysis assumes a 25 kWh battery installed at the site and assumes that the back-up power system would carry the entire load of the building (rather than dedicated critical loads) since the building load is so small.
- The proposed solar and storage system would be able to carry 100% of the building load for almost two days without needing to rely on the existing back-up generator while the PV system recharged the battery.
- The energy resilience solution is also close to the optimal economic design. The simple payback of the proposed energy resilience system would be 3 years. The project would result in a net savings of 67% over its lifetime, compared to the cost of utility bills.
- The details of this analysis can be found in Appendix A.

2.3.5. Potential Alternatives

- **Heating and cooling.** FS1 could install air source heat pumps to replace the current propane heating system. A ducted, 4-ton system would add 4 kW of load to the building.

2.4. West Tisbury School

2.4.1. Energy Requirements

Essential community functions

The school is the largest building in the town and might serve as the Town's emergency shelter at times. Martha's Vineyard has two regional Red Cross-certified emergency shelters at the Oak Bluffs School and the Aquinnah Tribal Center. The Martha's Vineyard Regional High School is another possible location, depending on the availability of trained personnel.[27] The West Tisbury school is not an official regional shelter, but it might serve as a local shelter function for vulnerable populations in West Tisbury on a short-term basis. The island's existing shelters can host an estimated 750 people total, but the island may have up to 100,000 visitors at peak times in the summer. If a regional catastrophe or power outage were to occur, the existing shelters would be overwhelmed, and there would likely be an expanded role for the West Tisbury School to serve as a secondary shelter to handle the overload and to store and distribute supplies.

Energy Usage and Demand

- The School is the largest Town-owned energy consumer in West Tisbury. The School was built in 1973, and expanded and renovated twice. The second renovation was completed in 1995 and the building is now 61,000 square feet in size.
- The School consumes approximately 370,000 kWh annually, with peak usage in the winter, and lower usage in the summer when school is not in session.
- The overall load of the school is estimated to be 100 kW in the winter and 80 kW in the summer. The largest electricity load in the school is lighting at 50 kW. The other loads include electric heating from space heaters and a heat pump (20 kW in winter), pumps to circulate water in the building (20 kW), and miscellaneous loads such as office equipment, IT equipment, kitchen equipment, and water pumps (10 kW total).

[27] The Town of West Tisbury is currently surveying residents about their interest in completing Community Emergency Response Team (CERT) trainings in order to expand the personnel available to staff shelters.

- The School is primarily heated by three oil-fired boilers that were installed in 2008 and that consume an estimated 20,000 of fuel oil annually. The boilers are supplied from a 6,000-gallon fuel oil tank.
- The school has two on-demand propane water heaters in the kitchen area, supplied by a 325-gallon propane tank. The School also has two smaller electric hot water heaters.

Critical Loads

The desired shelter area of the school encompasses the gym, the dining room, the kitchen, and the middle school wing. In order for the shelter area to function, it would require a steady source of power for lighting, plug loads and charging, water heating, and electricity-dependent ventilation loads (since the gym has no windows). A small refrigerator could be plugged in for medications. Well pumping is also a critical load that should be powered during outages both for the shelter and to allow the public to fill water containers from spigots. It is estimated that the critical load required to support the shelter function would be 60 kW in the winter and 40 kW in the summer.

2.4.2. Energy Capabilities

Back-up Generator

- The school has an existing 60 kW diesel-fueled back-up generator made by Kohler, which replaced an older 30 kW model.
- The diesel generator is supplied with a 275 gallon diesel tank that is integrated with the unit.
- Although the generator would not be oversized to serve the estimated critical loads in the desired shelter area, the generator may be significantly oversized for the loads currently connected to the emergency panel. Just as with the PSB, the low load conditions on the generator during emergency operations could lead to engine strain and failure.

Emergency Panel

- The back-up generator is currently connected to three separate emergency panels that serve a set of relatively smaller loads, such as corridor lighting, start-up for the heating systems, sump pumps, and kitchen equipment (e.g. refrigeration).
- The Project Team provided the Town of West Tisbury with an updated electrical one-line diagram of the School's electrical system.
- The loads that would be needed within the desired shelter area are not the ones currently connected to the diesel generator, and the emergency panels would need to be rewired.

Outage Duration

- The current fuel supply could support the school's electricity consumption for the critical loads required in the desired shelter area for approximately three days in the winter and four days in the summer.
- The energy efficiency measures discussed in below could increase the number of days to five in the winter and six in the summer.
- The School has large supplies of heating fuel storage that would allow the heating systems to run for long periods of time. The oil boilers could supply heat for 40-50 heating days, or approximately a third of the heating season. The propane tanks could similarly support water heating for a 40-50 period. As discussed below, electrifying the space and water heating would reduce carbon emissions and create energy savings - but there would be a tradeoff in that the new heating systems would not be able to operate during a power outage for similarly long periods.

PV System
The School has a small grid-tied solar array installed on its roof, but the system does not currently function. The PV system is also not currently configured to be available during power outages.

2.4.3. Resilience Opportunities

Back-up Power
Emergency panel rewiring. The Town should confirm the critical loads that would be necessary to support within the desired shelter area and verify that those loads are connected to one of the three subpanels served by the emergency generator.

Building Upgrades
Fenestration. In order for the School to effectively function as a storm shelter, it is necessary to upgrade the windows in the shelter area to withstand high winds (e.g. from tornados). The upgrades would also enhance student safety even in non-catastrophic events.

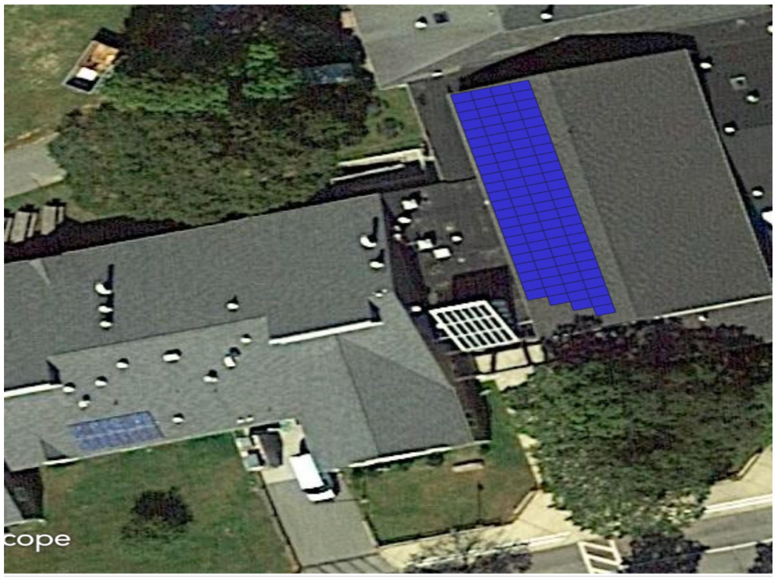
Energy Efficiency Upgrades
There are a number of energy efficiency upgrades at the school that could lower both the electricity consumption (kWh) and total demand (kW) by 20%, and reduce oil and propane usage. These include:

- **Lighting.** Replace interior with LED lights, which would reduce load by ~25 kW, and install occupancy sensors in hallways for additional savings.
- **Refrigeration.** Install electronically commutated motors (ECMs) to enable more efficient operations for walk-in cooler fans in the walk-in coolers.
- **Building envelope.** Review the thermal enclosure. Improve insulation, upgrade windows and air sealing as necessary, minimize the use of space heaters, and reduce the climate control setpoints for unoccupied areas.
- **Water distribution.** Install ECMs and variable speed drives for the pumps that circulate water within the building for space heating and for domestic hot water.
- **Ventilation.** Replace parts in the unit ventilators installed in classrooms and improve their controls.
- **Water heating.** Replace the electric hot water heaters with 80-gallon heat pump water heater
- **HVAC.** Install variable refrigerant flow (VRF) ductless HVAC systems in some areas of the building (see below) in order to reduce fuel oil consumption.

Solar PV

- **Existing Rooftop PV System.** The existing PV system should be assessed to determine the cause of its malfunction. If the inverter needs replacement, the price to replace it may be relatively modest given the declines in inverter prices over the past decade.
- **New Rooftop PV System.** The School southwest facing rooftop on the gym could accommodate a 36 kW PV system (Figure 4), but the location is not ideal. The system is partially shaded by trees to the west and south, and the system would only produce 34,790 kWh annually and would have a longer simple payback. The rooftop PV system could produce approximately 20% of summer load and 5% of winter load. Other rooftops, including the School’s south facing roof, were considered the current configuration of the ventilation system does not allow for enough contiguous roof area to support additional PV.

Figure 4. Solar PV Siting at the School



<u>Battery Storage</u>
The school could host a large battery since it would not be subject to historic preservation considerations. A XENDEE analysis to specifically size a battery was not performed for the school during this study.

2.4.5. Potential Alternatives

- **High efficiency HVAC systems.** The School could explore a room-by-room approach to installing high-efficiency VRF and air-source heat pumps for heating and cooling. As a rough estimate, installing a 1.5 ton HVAC unit in 10 classrooms would increase the electric load of the building by 15 kW and would put additional demand on the back-up power system.

2.5. Town Hall

2.5.1. Energy Requirements

Essential community functions

West Tisbury Town Hall houses the town government. During emergencies, the Town Hall performs a range of vital functions, including approving and conducting purchasing for emergency supplies and services. The Town Hall is a public water source with outdoor spigots that can be used by the townspeople to fill water containers in prolonged power failures.

Energy Usage and Demand

- The Town Hall consumes approximately 56,000 kWh of electricity annually. The electricity usage is relatively consistent across winter and summer and is driven by lighting, office equipment, and HVAC use.
- The building is heated with propane furnaces located on each floor and cooled by three air conditioning condensers. The building also has a propane water heater. The building uses roughly 1,400 gallons of propane each year, supplied from a 1,000 gallon tank. The building also has a small ductless heat pump that can provide heating and cooling.

Critical Loads

In order to sustain its critical services, the Town Hall needs to maintain its IT servers, some its lighting, office equipment, and climate control clustered mostly on the 1st and 3rd floors of the building. The well pump and propane boilers each have small electricity loads that would need to be powered in order to run. Table 2 below summarizes the kilowatt (kW) demand for each load, as well as the load reduction strategy that could be utilized in an emergency situation.

Table 2. Estimated Building Loads under Normal and Emergency Operating Conditions

Load	kW - Normal Operations	Emergency Operations	kW - Emergency
Lighting	6	Install LEDs to reduce lighting load Use only half the lights	1.5
Space and water heating	3.4	Lower heating set point and raise cooling set point on climate control systems Lower water heater temperature	0.5
Miscellaneous loads (servers, office equipment, well pump, electric vehicle charger, kitchen, water coolers).	8	Reduce office equipment to bare minimum Reduce under desk heaters Open windows and use fans Turn off the elevator, hand dryers, water coolers, etc.	4
Total (Normal Operations)	17.4	Total (Emergency Operations)	6

2.5.2. Energy Capabilities

Back-up Generator

The Town Hall has a 45 kW propane-fired generator that is supplied by a 1,000 propane tank that is shared with the propane-fired heating systems.

Emergency Panel

The Town Hall has two emergency panels connected to lighting throughout the building, some of the outlets, the well pump, and other miscellaneous loads.

Outage Duration

- The generator could theoretically supply the loads attached to the Town Hall emergency panel for ~60-70 days, depending on the season, if the fuel tank was full and used only for electricity (i.e. not for space or water heating).
- The Town Hall generator is oversized compared to the critical loads connected to the emergency panel. Similar to the diesel generators, the low load conditions would cause the propane generator to run less efficiently and potentially fail. If fully loaded, the generator could carry the Town Hall for roughly 10-14 days.

PV System

The Town Hall has a small grid-tied 2.5 kW system installed on its roof. It is not currently configured to be available for use during power outages.

2.5.3. Resilience Opportunities

Back-up power

Panel rewiring. In order to raise the load carried by the generator during emergencies and mitigate low load operations and engine strain, the Town Hall could connect the electric vehicle charger (and potentially add 2-3 more) to the emergency panel. This would also enable the Town to utilize its two EVs in its fleet if the gasoline supply to the island were to be disrupted during a disaster. Electric vehicle charging would reduce the theoretical number of days that the Town Hall could ride through an event on back-up power, but the Town Hall has a substantial amount of propane storage. Installing new heat pumps for climate control could also increase load (Section 2.5.5)

Energy Efficiency Upgrades

- **Lighting.** The lighting could be replaced with LED lamps to cut load by roughly 3 kW.
- **Office equipment.** Ensure that non-server computers and monitors are off at night.

Solar PV

The Town Hall does not have suitable roof space on which to site additional solar PV panels. Several alternative ground mount installations were evaluated (Section 2.5.5).

Battery Storage

- **Vineyard Transit Authority (VTA) battery.** The Town Hall is a transit hub for the VTA bus system. The VTA is exploring siting a 500 kWh / 200 kW battery at the Town Hall in order to provide interim charging for their electric bus fleet when they stop there. The VTA plans to also connect the Town Hall to the battery and use the battery to provide additional back-up power to the building in case of emergencies.
- **Storage for existing PV system.** The Town could install a small battery that could be connected to the existing 2.5 kW PV system and provide emergency power to some of the Town Hall loads. The economic performance of this smaller system was not analyzed as part of this study.

2.5.4. System Performance

If the VTA battery were connected to the Town Hall, it could supply approximately 80 hours of back-up power to the building - without using the existing back-up generator - assuming that the battery was fully charged at the time of the power outage.

2.5.5. Potential Alternatives

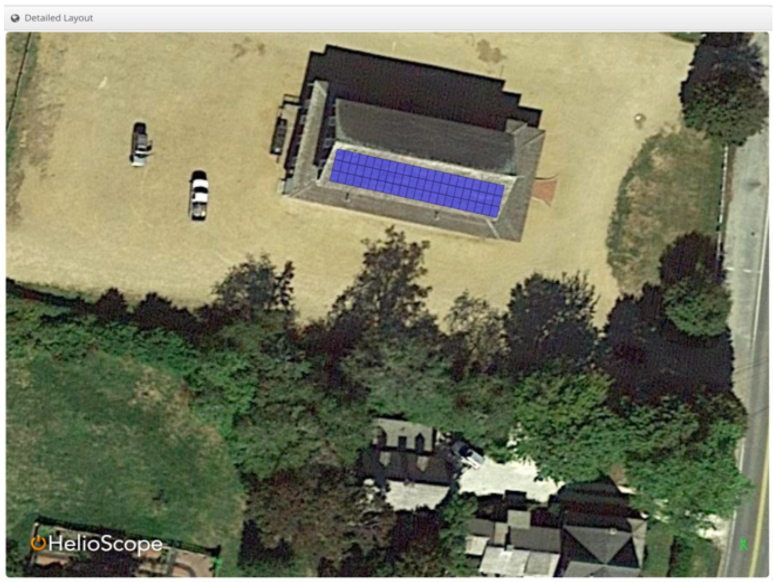
Two alternative solar energy systems were evaluated:

- **Solar PV canopies.** The land behind Grange Hall, which is adjacent to the Town Hall, could accommodate 472 kW of solar PV systems installed as canopies that would produce more than 580,000 kWh annually. This is by far the largest PV site analyzed under this study. This design would require permission from both the Preservation Trust and Historic District Commission. In addition, it would require approval by Eversource to interconnect a solar array on one property to an electric service on an adjacent property.
- **Grange Hall rooftop PV system.** The Town Hall is also close to Grange Hall, which hosts the West Tisbury Farmers Market, the Vineyard Artisans Festivals, and private events. The south roof of Grange Hall could accommodate 24 kW of PV (Figure 5), which could be integrated into the Town Hall back-up power system. As with the canopies, this design would require permission from both the Preservation Trust and Historic District Commission, as well as Eversource approval to connect

adjacent properties.

- **Heat pumps.** The Town Hall could also install three 4-ton ducted heat pumps that would total 12 kW.

Figure 5. Solar PV Siting at Grange Hall



2.6. Up-Island Council on Aging

2.6.1. Energy Requirements

Essential community functions

The Council on Aging is located in the Howes House and is the center for elderly services for the up-island region, which includes the towns of West Tisbury, Aquinnah, and Chilmark. The Council provides year-round in-person and phone-based services to a network of 1,000 individuals across the three towns. Under normal operating conditions, the Council is able to host community meetings and to provide meals, prescription handling services, and other medical services to its clients. The Council also serves as a liaison to the police department to inform its response to elderly residents.

Energy Usage and Demand

- The Council on Aging uses 22,600 kWh per year and has an estimated average daily winter peak load of 14 kW and a summer peak load of 4 kW. The primary electricity loads are for heating, and include a 5 kW ducted air source heat pump for heating and cooling, as well as a separate 16 kW back-up electric resistance heater. The use of the 16 kW heater would drive hourly winter peak load above the estimated 14 kW average daily load. The other loads include 1 kW of lighting, 2 kW of office equipment, and 2 kW of kitchen loads.
- The building has a new high-efficiency propane boiler that was installed in 2020 and provides both space and water heating. The boiler is supplied by propane tanks totaling 240 gallons, and the system consumes approximately 750-800 gallons of propane each year.

Critical Loads

- During a prolonged power outage, the Council on Aging would not plan to provide food, medical, and prescription services to its clients.
- The primary function of the Council on Aging during an outage would be for administrative staff to reach out to elderly residents by phone and to liaise with the police. These functions could be accomplished with a bare minimum of office equipment, half of the current lights, and a reduced amount of climate control. The peak load under emergency conditions could be reduced to 6 kW in

winter.

- As an alternative, the Council on Aging could develop a contingency plan in partnership with other Town agencies to move its outreach operations during a power outage to a designated area or other buildings with back-up capabilities, such as the Library, Town Hall, or the PSB.

2.6.2. Energy Capabilities

- The Council on Aging does not currently have a back-up power system.
- The back-up generator at the Library is located adjacent to the Howes House, but the Library has a three-phase electrical service, whereas the Howes House has a single phase electrical circuit. It is technically feasible to connect a three-phase generator to a single phase circuit, as long as the circuit does not serve certain types of loads that can't tolerate a range of voltage (such as motors). The Howes House does not appear to have loads that would prevent such a connection. The connection, however, would also require Eversource to grant permission to connect adjacent properties.

2.6.3. Resilience Opportunities

Energy Efficiency Upgrades

- Heating loads are the primary driver for electricity consumption and propane usage at the Council on Aging. The Howes House should prioritize insulation and airtightness for the 2nd and 3rd floors, the attic spaces, the walls, and the roof.
- There are particularly high electricity spikes in the winter, which could indicate that the electric resistance back-up heater may be being used excessively.
- It is most cost-effective under the current configuration to use the heat pumps during mild periods (generally above freezing) and the propane boiler during periods below freezing.
- The Council should be advised by a specialist about turning off the breakers for the back-up electric resistance heater, so that only the heat pump and the boiler are used. This should be done carefully to avoid freeze-up issues.

Solar PV

The Council on Aging does not have a suitable rooftop or available land to site a solar PV system.

Battery Storage

The propane boiler could generate heat for 90 days given the size of its storage tanks. The boiler, however, requires a small amount of electricity to start-up and to operate its pumps. In order to prevent damage to the building (e.g. frozen pipes) during a prolonged winter outage, a small battery could be installed to kick-start the heating system.

2.6.4. System Performance

The Project Team did not conduct an economic analysis of the Council on Aging facility as a result of the lack of onsite solar PV opportunities.

2.6.5. Potential Alternatives

As discussed in Section 2.2.5, several alternatives were explored to connect the Council on Aging to the proposed solar PV and battery system at the Library and/or to the Library's existing diesel generator. The Howes House could also be connected to a solar canopy in the parking lot shared with the Library, which could either add to the Library's resilience system or be configured to provide power to the Howes House. These alternatives would require permission and approval from the Town as well as from Eversource.

Appendix 1. XENDEE Analysis Summary

The XENDEE microgrid and distributed energy resources (DER) model was used to assess the economics and the carbon dioxide (CO2) emissions reduction potential for multiple scenarios. The XENDEE microgrid and distributed energy resources (DER) model assesses the economics and the carbon dioxide emissions reduction potential for multiple scenarios. XENDEE employs and enhances the Distributed Energy Resources Customer Adoption Model (DER-CAM) that has been created by the U.S. Department of Energy to determine the optimal mix, capacity, placement, and operation of DER resources within a new or existing microgrid under real constraints such as climate, regulations, utility structure, and financial realities.[28] XENDEE delivers the optimal technology mix as well as operation (when to charge or discharge a battery for example) while considering tariff data, weather date, subsidies, technology parameters, or outage scenarios among others.

Description of Economic and Resilience Runs from XENDEE

Multiple economic and resiliency scenarios have been performed with XENDEE. The cases summarized here include:

- **Resilience case.** Behind the meter PV and batteries, assuming a larger-scale battery that is configured to carry either 100% of the building load or the estimated critical load of the building.
- **Economic case.** Behind the meter PV and batteries, with the size optimized for economic performance.

Assumptions

The following inputs were used for each of the XENDEE analyses. A complete list of assumptions is available from the Project Team.

PV installation costs ($/kW)	2500		Backup generation lifetime (years)	20
PV lifetime (years)	20		Backup generation electrical efficiency (%)	28
Tariff	33 – General Optional Seasonal from Eversource		Backup generation O&M costs per year ($/kW)	9.33
Battery total installation costs without any subsidy ($/kWh)	826		Diesel price ($/gallon)	2.5
Battery lifetime (years)	15		Propane price ($/MMBTU)	45

[28] For power system design and analysis, XENDEE uses the Open Distribution System Simulator (OpenDSS) power system analysis tool as the engine for time-based load-flow analysis, a critical step in the microgrid design process. This project only assessed the economic feasibility and did not focus on power flow analysis.

Battery charging / discharging efficiency (%)	95		Interest rate for investments (%)	3
ConnectedSolutions considered	Yes		SMART considered	Yes

Table A1: Major assumptions for XENDEE analyses.

Results PSB Resilience Case Full Load Coverage in the Event of an Outage

Change in total annual energy costs (including amortized investment costs), (%)	**+5 (more expensive than current situation due to large investments)**
Utility cost reduction compared to baseline scenario (%)	42
CO2 Savings compared to baseline scenario (%)	45
Installed PV (kW)	32
Installed battery (kWh)	500
Upfront capital costs (k$)	493
SMART payments per year (k$)	5.5
ConnectedSolutions payments per year (k$)	22.5
Payback period (including SMART and ConnectedSolutions) (years)	**14 (close to battery lifetime)**

Table A2: PSB outage scenario with full load and a forced 500 kWh battery, detailed results.

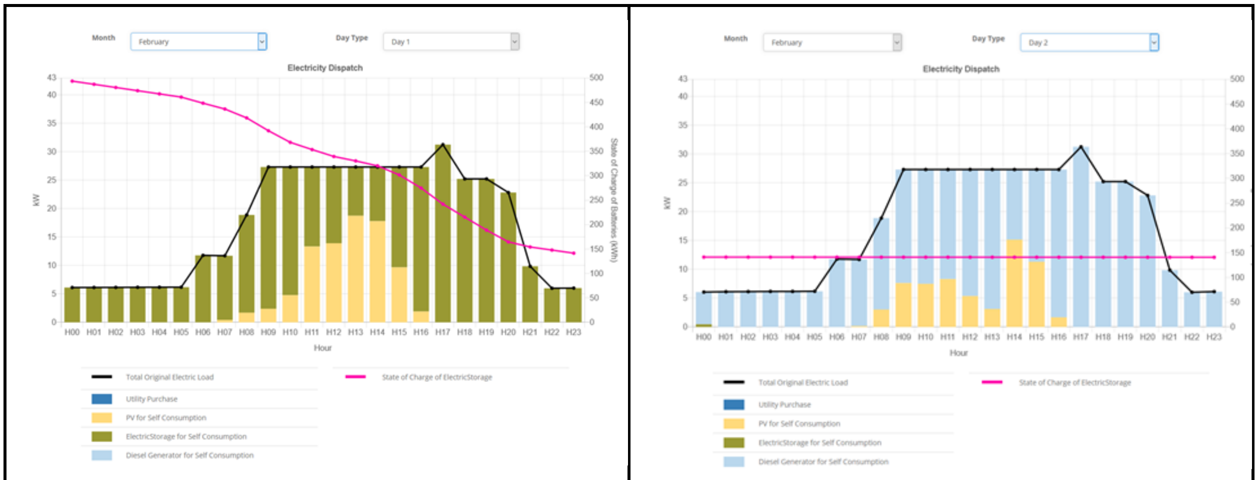


Figure A1: PSB outage scenario with full load and a forced 500 kWh battery size. The Figure on the left represents the first outage day, which can be supplied completely with the battery if PV generation is available. Starting with the second day the backup diesel generator needs to be used since the battery will be empty.

Legend:
Green bars - battery output
Blue bars - diesel backup generation output
Yellow bars - PV generation
Black line - full electric load
Pink line: State of the charge of the battery

Results PSB Resilience Case 16kW Peak Load Coverage in the Event of an Outage

Change in total annual energy costs (including amortized investment costs), (%)	**+4 (more expensive than current situation due to large investments)**
Utility cost reduction compared to baseline scenario (%)	43
CO2 Savings compared to baseline scenario (%)	45
Installed PV (kW)	32
Installed battery (kWh)	500
Upfront capital costs (k$)	493
SMART payments per year (k$)	5.5
ConnectedSolutions payments per year (k$)	22.5
Payback period (including SMART and ConnectedSolutions) (years)	**14 (close to battery lifetime)**

Table A2: PSB outage scenario with a 50% load coverage (on outage days) and a forced 500 kWh battery, detailed results.

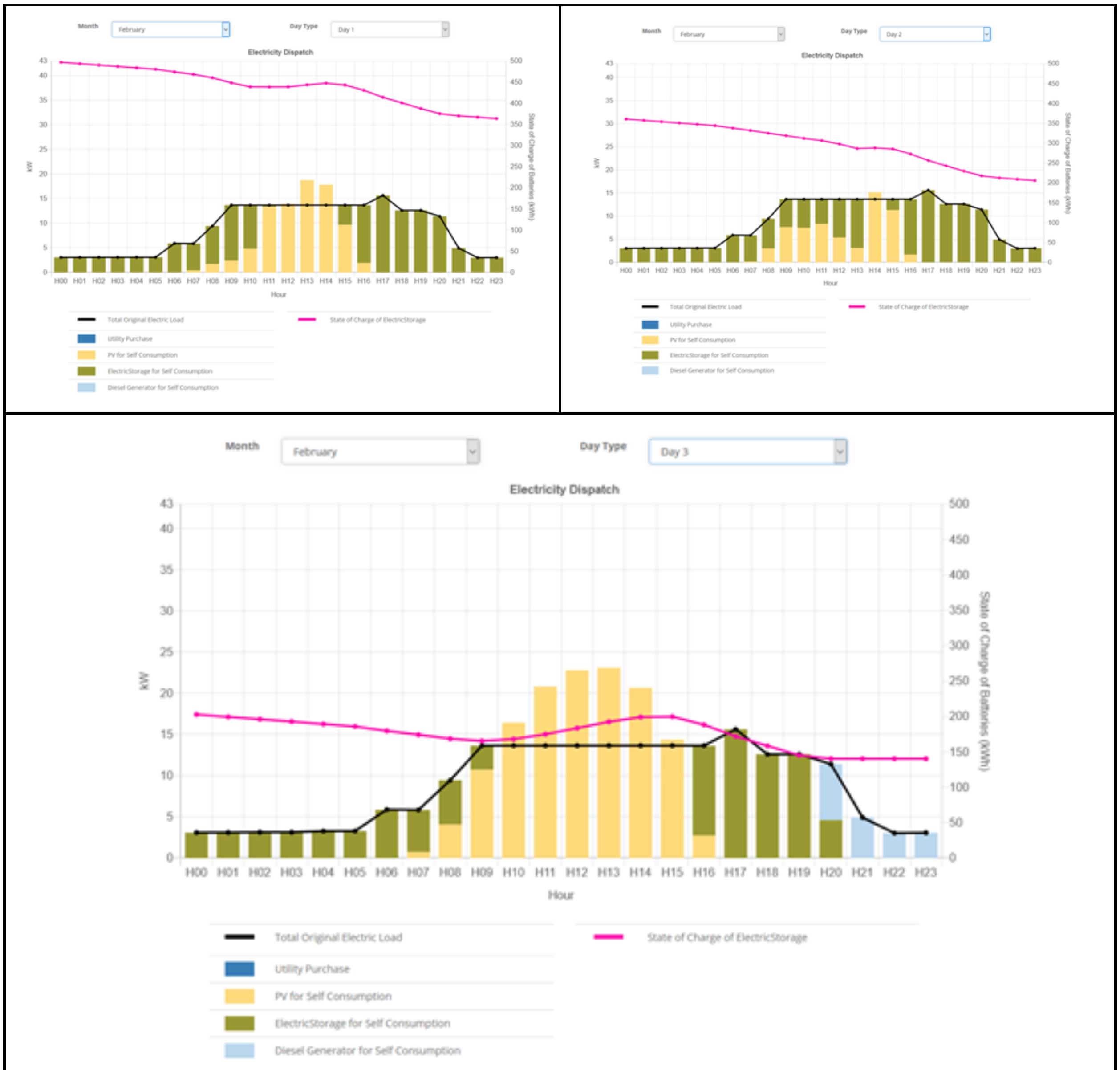


Figure A2: PSB outage scenario with 50% load (in each hour) and a forced 500 kWh battery. Left top figure represents the first outage day and it can be supplied completely with the battery (if some PV generation is available too). The right top figure represents the 2nd outage day and is also fully supplied with battery and PV power. Starting with the third day (bottom figure) the backup diesel generator needs to be used since the battery will be empty.

Legend:
Green bars - battery output

Blue bars - diesel backup generation output
Yellow bars - PV generation
Black line - Critical electric load
Pink line: State of the charge of the battery

Results Library Resilience Case Full Load Coverage in the Event of an Outage

Change in total annual energy costs (including amortized investment costs), (%)	**-20 (savings compared to the as-is case)**
Utility cost reduction compared to baseline scenario (%)	52
CO2 Savings compared to baseline scenario (%)	52
Installed PV (kW)	50
Installed battery (kWh)	500
Upfront capital costs (k$)	538
SMART payments per year (k$)	9
ConnectedSolutions payments per year (k$)	22.5
Payback period (including SMART and ConnectedSolutions) (years)	**13**

Table A3: Library outage scenario with full load and a forced 500 kWh battery, detailed results

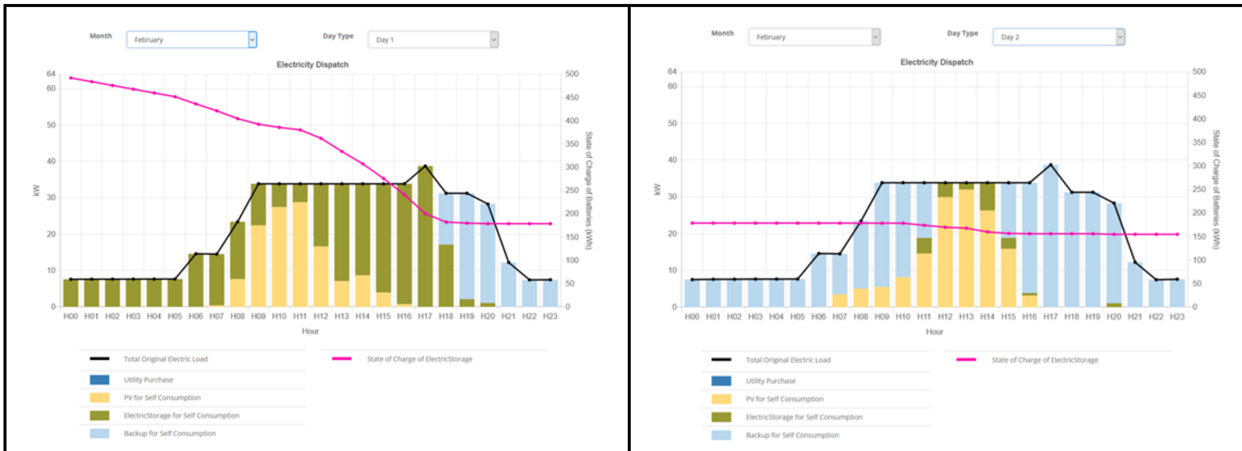


Figure A3: Library outage scenario with full load and a forced 500 kWh battery. Left figure represents the first outage day that can be almost supplied completely with the battery (if some PV generation is available). Starting with the end of the first day the backup generator needs to be used since the battery will be empty.

Legend:
Green bars - battery output
Blue bars - diesel backup generation output
Yellow bars - PV generation
Black line - full electric load
Pink line: State of the charge of the battery

Results Library Resilience Case with just Emergency Load Coverage in the Event of an Outage

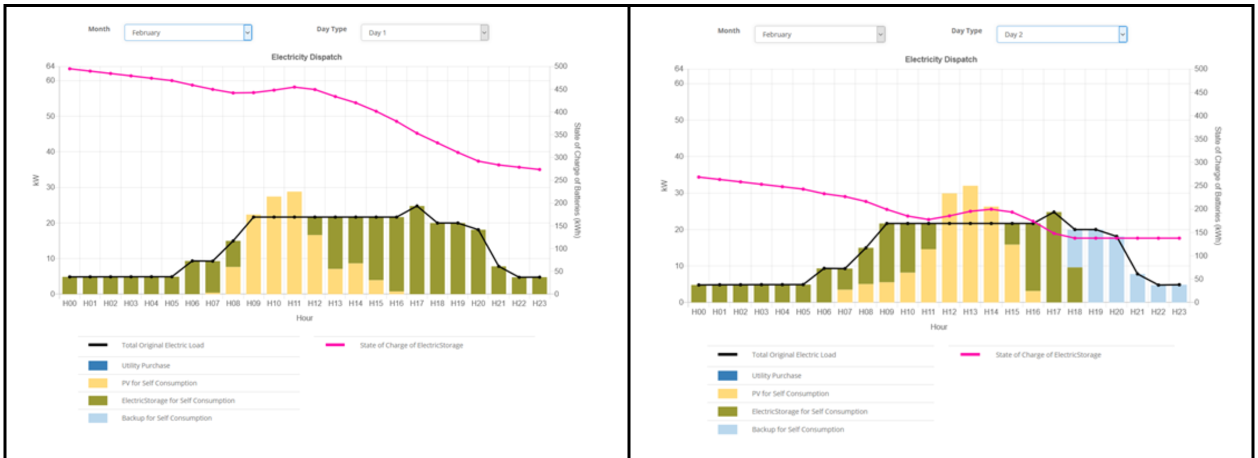


Figure A4: Library outage scenario with 64% load (in each hour) and a forced 500 kWh battery. Left figure represents the first outage day and it can be supplied completely with the battery (if some PV generation is available too). The right figure represents the 2nd outage day which is also almost fully supplied with battery and PV power.

Legend:
Green bars - battery output
Blue bars - backup generation output
Yellow bars - PV generation
Black line - Critical electric load
Pink line - State of the charge of the battery

Results FS1 Resilience Case Full Load Coverage in the Event of an Outage

Change in total annual energy costs (including amortized investment costs), (%)	**-67.4 (cost savings)**
Utility cost reduction compared to baseline scenario (%)	100
CO2 Savings compared to baseline scenario (%)	161
Installed PV (kW)	20
Installed battery (kWh)	25
Upfront capital costs (k$)	71
SMART payments per year (k$)	5.2
ConnectedSolutions payments per year (k$) - for 10 years due to the small PV	1.2
Payback period (including SMART and ConnectedSolutions) (years)	**3**

Table A4: FS1 outage scenario with full load and a forced 25 kWh battery, detailed results

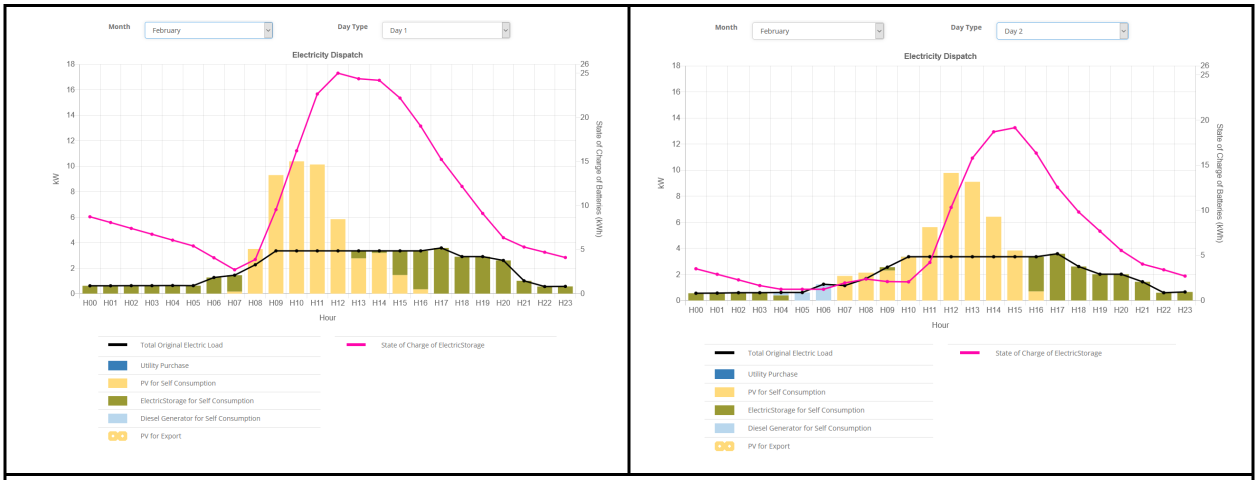


Figure A5: FS1 outage scenario with full load and a forced 25 kWh battery. Left figure represents the first outage day that can be supplied completely with the battery (if some PV generation is available). Starting with the second day the backup generator needs to be used very minimally.

Legend:
Green bars - battery output
Blue bars - diesel backup generation output
Yellow bars - PV generation
Black line - full electric load
Pink line: State of the charge of the battery