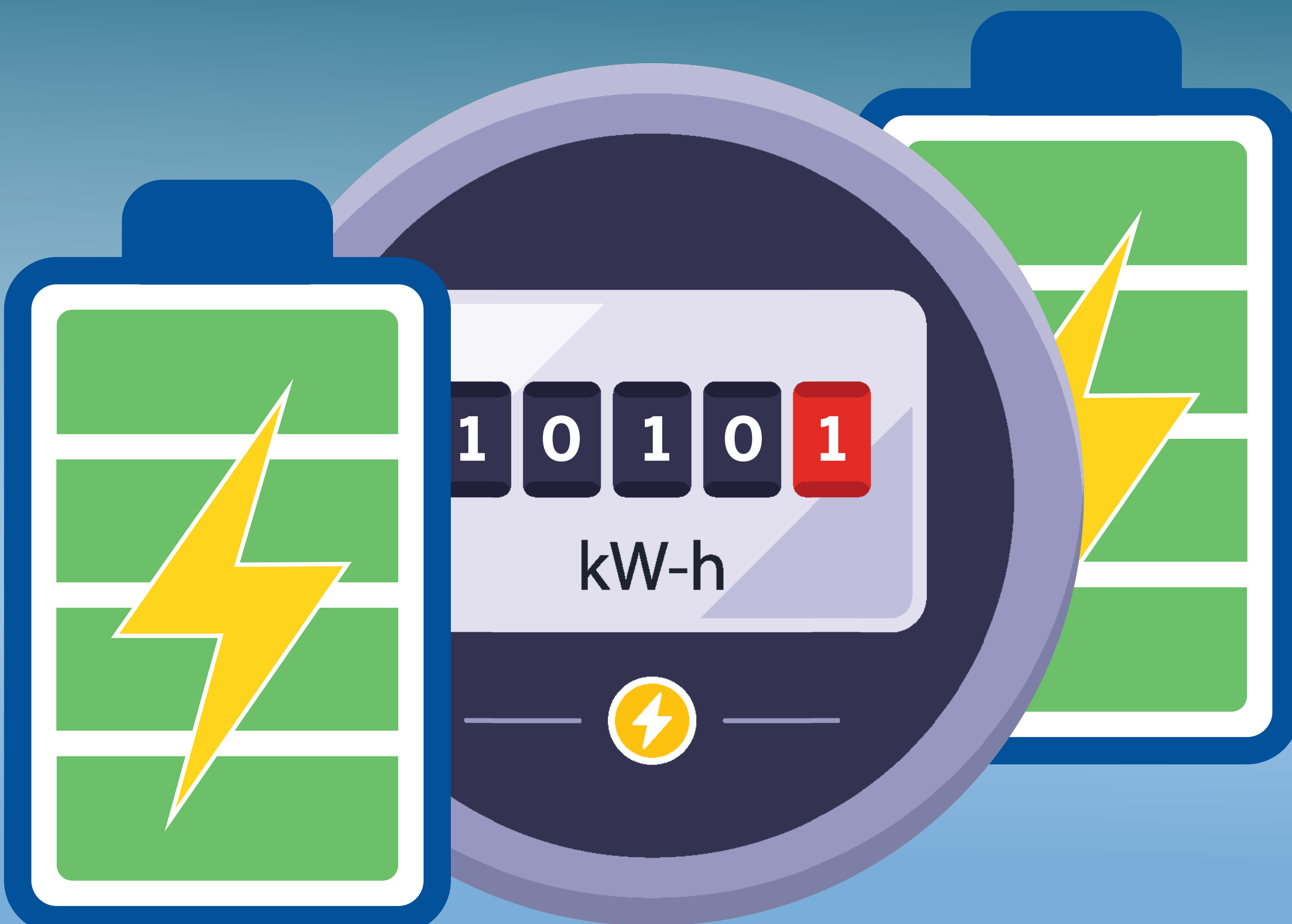
LOCATION, LOCATION, LOCATION

An economic comparison of large-scale batteries installed in front of vs. behind the meter in Massachusetts



SEPTEMBER 2025

Clean Energy Group

AMERICAN MICROGRID SOLUTIONS

About This Report

This report was prepared by American Microgrid Solutions, under contract to Clean Energy Group (CEG), for the Cape & Vineyard Electric Cooperative (CVEC) in the Commonwealth of Massachusetts. The purpose of the report was to provide information and analysis to CVEC that would help it decide what kind of large-scale battery system to support and which ownership model to pursue in its energy storage acquisition. The report presents an economic analysis that compares one utility-scale, front-of-the-meter (FTM) battery installation to five commercial-scale, behind-the-meter (BTM) batteries, of the same aggregate capital cost. The report also discusses important non-monetizable benefits of BTM energy storage that should be considered, and it provides a cost estimate for backup power—a "resilience premium" associated with BTM energy storage sited at municipal facilities to provide a community resilience benefit.

Acknowledgements

This report was funded with the generous support of the Barr Foundation. CEG wishes to thank Cape & Vineyard Electric Cooperative and the municipalities included in this study—Barnstable, Eastham, West Tisbury, Tisbury, Orleans, Martha's Vineyard and Yarmouth—for their help in putting together the data needed to conduct this analysis.

Disclaimer

This document is for informational purposes only. The authors make no warranties, expressed or implied, and assume no legal liability or responsibility for the accuracy, completeness, or usefulness of any information provided within this document. The views and opinions expressed herein do not necessarily state or reflect those of funders or any of the organizations and individuals that have offered comments as this document was being drafted. The authors alone are responsible for the contents of this report. Before acting on any information, you should consider the appropriateness of the information to your specific situation. The information contained within is subject to change. It is intended to serve as guidance and should not be used as a substitute for a thorough analysis of facts and the law. The document is not intended to provide legal or technical advice.

Cover Design: David Gerratt/NonprofitDesign.com

© 2025 Clean Energy Group

LOCATION, LOCATION, LOCATION

An economic comparison of large-scale batteries installed in front of vs. behind the meter in Massachusetts

Prepared by
American Microgrid Solutions
for Clean Energy Group

AUTHOR

NATE MILLS
AMERICAN MICROGRID SOLUTIONS

CONTRIBUTING EDITOR

TODD OLINSKY-PAUL
CLEAN ENERGY GROUP

SEPTEMBER 2025

CleanEnergyGroup

AMERICAN MICROGRID SOLUTIONS

Table of Contents

Executive Summary 5
1 Introduction 8
2 Methodology 10
2.1 Behind-the-Meter Site Selection 10
2.2 Behind-the-Meter Economic Analysis 11
2.3 Front-of-the-Meter Economic Analysis 13
3 Qualitative Assessment 14
3.1 Context: Benefits of Battery Storage 14
3.2 Behind-the-Meter Battery Considerations 14
3.3 Front-of-the-Meter Battery Considerations 16
4 Quantitative Assessment 18
4.1 Summary Matrix 18
4.2 Results comparison 19
4.3 Sensitivity Analysis 19
5 Conclusion 21
Appendix A Site Downselection Ranking 23
Appendix B Summary Performance for BTM Systems 24
Appendix C Eastham Town Hall 25
Appendix D Orleans DPW 28
Appendix E West Tisbury Library 31
Appendix F Yarmouth DPW 34
Appendix G Yarmouth Fire Station #3 37

Executive Summary

This report, commissioned by Clean Energy Group (CEG) for the Cape and Vineyard Electric Cooperative (CVEC) in Massachusetts, compares the costs and benefits of one utility-scale, front-of-the-meter (FTM) battery system versus five commercial-scale, behind-the-meter (BTM) batteries of the same aggregate cost. The purpose of this analysis was twofold: first, to provide useful information to CVEC to assist it and its constituent members in deciding between two possible ownership models for future energy storage procurement; and second, to provide the broader energy storage community with a cost/benefit comparison between FTM utility-scale and BTM commercial-scale batteries. In this analysis, the larger FTM battery is considered a community storage project, owned and operated by CVEC on behalf of its constituent municipalities. The municipalities would share in any net profit or cost savings realized over the operational life of the system.

Results show that the FTM system has a better economic profile, based on monetizable values (see Table ES-1, p.6). These results are notable because Massachusetts has some of the most supportive energy storage incentives and subsidy programs in the country for BTM batteries. In almost any other state, the BTM batteries would have had fewer revenue opportunities than those in this analysis.

However, this result does not take into account difficult-to-monetize values. In this case, host facility resilience (the ability to provide backup power to the host facility during a power outage) is the primary non-monetizable value for the BTM batteries. This means that the differential between net costs of the FTM system versus the BTM systems effectively establishes the cost of providing backup power to the facilities. In other words, this study establishes the added cost of host facility resilience for the systems being compared – the “resilience premium.”

Takeaways from this analysis include:

- The FTM battery system modeled in this study significantly outperformed the comparable BTM systems in economic metrics such as internal rate of return (IRR), net present value (NPV), and cash flow projections. This is notable because the study site is in Massachusetts, which offers incentives for BTM batteries that do not exist in most other states: the ConnectedSolutions performance incentive, the SMART solar+storage rebate, and the Clean Peak Energy Standard, which allows BTM systems to generate Clean Peak Energy Certificates. In states where significant BTM storage incentives do not exist, the FTM system is likely to “win” economically by an even greater margin.
- Commercial-scale BTM battery storage is the most expensive type of battery system at this time. This is because utility-scale FTM systems benefit from economies of scale, can execute lucrative tolling agreements with utilities, and can more easily access wholesale energy markets. At the other end of the size spectrum, residential and small commercial battery systems benefit from off-the-shelf, fully commercialized components that do not require custom engineering and design, and do not typically encounter costly interconnection barriers. Commercial-scale systems, which typically fall into the 60-200 kW range, often require custom engineering and design and may encounter interconnection barriers, but do not enjoy easy access to utility tolling agreements and

wholesale energy markets.[1] Furthermore, one of the most valuable benefits of commercial-scale storage—facility/community resilience—is a non-monetizable benefit.

Table ES-1: Comparison of financial outcomes for the combined behind-the-meter systems and the single large-scale, front-of-the-meter system

	BTM (5-year incentives)	BTM (10-year incentives)	BTM (20-year incentives)	FTM (single large-scale battery)
Solar	567 kWh	567 kWh	567 kWh	--
Battery	490 kW/ 1,175kWh	490 kW/ 1,175 kWh	490 kW/ 1,175 kWh	2,000 kW/ 12,500 kWh
Financial Returns				
Capital Cost	$4,541,588	$4,541,588	$4,541,588	$4,541,588
ITC	$1,750,156	$1,750,156	$1,750,156	$1,816,635
Capital Cost after ITC	$2,791,432	$2,791,432	$2,791,432	$2,724,953
IRR	-2.2%	-1.2%	0.7%	4.4%
NPV @ 6%, 20 years	($1,407,458)	($1,241,188)	($1,045,895)	($371,671)
Revenue & Cash Flow - First Year				
Utility Savings/Income	$104,772	$104,772	$104,772	$264,000
Total Incentives	$84,278	$84,278	$84,278	$0
Total O&M Expenses	($27,047)	($27,047)	($27,047)	($66,631)
Replacement capex	$0	$0	$0	$0
Capital Cost after ITC	$0	$0	$0	$0
Cash flow	**$162,003**	**$162,003**	**$162,003**	**$197,369**
Revenue & Cash Flow - 20-year				
Revenue	$2,571,028	$2,571,028	$2,571,028	$6,553,642
Rebates & Incentives	$831,749	$1,111,238	$1,611,249	$1,816,635
Total O&M Expenses	($657,173)	($657,173)	($657,173)	($2,196,420)
Replacement capex	($432,759)	($432,759)	($432,759)	$0
Capital Cost after ITC	($2,791,432)	($2,791,432)	($2,791,432)	($2,724,953)
Cash flow	**($478,588)**	**($199,099)**	**$300,912**	**$1,632,269**

- Because resilience is the primary non-monetizable benefit of BTM systems, the differential in economic performance between the FTM and BTM systems is the effective cost of resilience.

[1] FERC Order No. 2222, which requires wholesale market operators to improve market access for distributed energy resources, has not yet been fully implemented in most parts of the country; and even if distributed BTM batteries are able to enter wholesale markets, interconnection barriers and hosting capacity limitations can restrict their ability to fully realize wholesale market revenues.

In this analysis, the "resilience premium" on the BTM systems averages $13,300 per site per year, or $66,500 annually for five sites, assuming state performance incentives continue at their present values for 20 years. This premium increases to $21,100 per site per year if state incentives continue for only five years.

- The FTM system economics rely heavily on the "tolling rate," which is set through a contract between the battery owner and the electric utility that acts as an off-taker of battery services. The assumed tolling rate of $11/kW-year is based on similar projects in Massachusetts; however, this level of compensation is entirely defined by the utility's needs at the location of battery interconnection and can only be determined through negotiation between the battery owner and the utility. To illustrate the importance of this variable, a reduction in tolling rate by 20 percent reduces the FTM system's 20-year cash flow by $1.3 million. In turn, this reduces the effective resilience premium paid by BTM sites, and the BTM systems and the FTM system would then have equivalent financial outcomes.
- The BTM systems' economics rely heavily on incentives and subsidies. If the current Massachusetts BTM incentive programs were to terminate at 10 years—halfway through the lifespan of the battery systems—the BTM systems would not break even by their expected end of life (at 20 years). Thus, while state incentive programs are currently necessary to support commercial-scale battery system economics, simply creating these programs is not enough; it is also critically important that incentives can be relied upon to remain in place over the lifespan of the project. If the future of state incentive programs were in question, this would affect the economics and therefore the financeability of the BTM systems. A phased implementation approach - installing the BTM systems one at a time, with Investment Tax Credit (ITC) savings and incentives from each project being rolled forward to help fund the next project - could help to reduce overall costs while managing the risk of future changes to subsidy and incentive programs.
- The inherent economic advantage of the one large-scale FTM system over the five commercial-scale BTM systems illustrates the economic potential of a FTM "community storage" or "community solar+storage" model, in which ratepayers are able to purchase shares in a large, optimally sited and operated storage or solar+storage project and then share in the economic benefits. This model could offer both economic and equity benefits. CEG will further develop this model in future publications.

It's important to understand that this type of economic analysis does not, and should not, determine which of the system types being compared is "better." It shows only which has superior economics based on currently monetizable values in Massachusetts. For example, the municipalities included in this study may well decide that the "resilience premium" is worth paying in exchange for the ability to provide a powered community shelter during grid outages.

Furthermore, economic analyses for both the FTM and BTM systems included in this analysis are subject to significant variations in locational value. Therefore, the values reported herein apply only to the specific systems being compared. While it is possible to draw some general conclusions from this study, the value of future projects should be determined through economic analysis specific to those projects.

Todd Olinsky-Paul
Senior Project Director, Clean Energy Group

1 Introduction

The objective of this assessment was to determine whether it would be more beneficial for the Cape and Vineyard Electric Cooperative (CVEC) to purchase, install, and operate a single large-scale, front-of-the-meter (FTM) battery for the benefit of its members, or to install and operate several smaller behind-the-meter (BTM) batteries of the same aggregate cost, distributed throughout the CVEC service territory at sites chosen to maximize economic and energy resilience benefits.

CVEC develops, manages, and/or owns renewable electric generation and storage facilities, and procures and/or sells long-term electric supply or other energy-related goods or services, promoting and supporting the development of renewable energy resources, improving the quality of service and reliability, and utilizing and encouraging conservation and other forms of energy efficiency. These activities are conducted on behalf of CVEC's municipal members and participants. CVEC has 25 municipal members: Aquinnah, Barnstable, Barnstable County, Bourne, Brewster, Chatham, Chilmark, Dennis, Dukes County, Eastham, Edgartown, Falmouth, Harwich, Oak Bluffs, Orleans, Marion, Mashpee, Nantucket, Provincetown, Sandwich, Tisbury, Truro, West Tisbury, Yarmouth, and the Cape Light Compact.

On behalf of Clean Energy Group (CEG), American Microgrid Solutions (AMS) analyzed five commercial-scale BTM solar+battery energy storage systems and compared the economics of these five systems in aggregate to a single, larger, utility-scale FTM battery.[2] In this analysis, the larger FTM battery is considered a community storage project, owned and operated by CVEC on behalf of its constituent municipalities.

The methodology involved evaluating both BTM and FTM energy storage systems through a structured analysis of site selection and financial feasibility. For BTM systems, the project team selected representative sites while excluding extreme outliers, considering variables such as building area, peak demand, and battery-to-solar ratios. Projects with data quality issues and small battery sizes were excluded to avoid distortion. Economic analysis incorporated variables such as power consumption, incentive programs, and installation costs, with assumptions about consistent load profiles and financing. For FTM systems, assumptions included a tolling arrangement with electric utility Eversource as the off-taker, no solar integration, and over-building to meet capacity guarantees. Both methodologies employed a 6% discount rate for net present value (NPV) and adhered to prevailing wage requirements, ensuring realistic financial projections. The FTM battery was sized such that the capital cost is equal to the sum of all BTM systems. This constraint was specifically to allow an apples-to-apples comparison of the economic outcomes given a certain amount of capital to invest. This comparative framework provided a robust basis for evaluating the performance and feasibility of both configurations. Taken together, this is the basis for the quantitative comparison of systems, which must be balanced against a qualitative evaluation of the pros and cons of each.

[2] Solar was not considered as part of the FTM system because it confers no clear economic benefit in the absence of a resilience function. In the case of a FTM utility-scale battery, investing a portion of the project budget in solar means reducing the capital investment in the battery, thereby reducing battery size and revenue potential. The loss of revenue from reduced battery capacity outweighs the loss of solar production revenues and solar incentives in the FTM case.

CVEC's decision to pursue either FTM or BTM energy storage systems hinges on balancing financial goals, project complexity, and the value of non-financial benefits. FTM systems are ideal when financial performance is the primary objective, as they are designed to deliver net-positive returns through mechanisms like utility tolling arrangements. However, these systems can face substantial challenges, including lengthy interconnection delays, environmental permitting, and public perception hurdles, which can complicate project timelines and introduce risks. Conversely, BTM systems offer faster implementation with fewer regulatory and logistical uncertainties, making them a practical choice for facilities prioritizing immediate deployment. Additionally, BTM systems provide unique benefits like resilience and sustainability, enabling backup power during outages and pairing seamlessly with solar to enhance environmental goals. The decision should ultimately consider both the reliability of FTM revenues and the multifaceted value BTM systems provide, particularly when resilience and sustainability are strategic priorities. Assigning a value to resilience may be difficult, but it is a key consideration in assessing the relative value of the two solutions.

2 Methodology

2.1 Behind-the-Meter Site Selection

AMS performed a preliminary assessment of the 12 proposed battery installation sites and presented the results for discussion with CVEC. The goal of downselection was to pick a set of sites that was representative of the whole suite and well-suited to further analysis.

The final selection of sites and their respective rankings are shown in Appendix A, with the boxed sites making the cut for further analysis. Note that the system component sizes displayed in Appendix A do not necessarily match the final solution for each BTM site because the design was refined in the final analysis.

2.1.1 Basis of Comparison

A ranked-sum approach to site selection with disqualifiers was used here. A representative set of sites will naturally exclude those sites that tend to be "extreme" in any of the considered attributes (e.g., very large or very small). By ranking the sites against each other for each attribute and summing the ranks, we can identify the "median" sites and exclude outliers. This selection method may include sites with individual outlier attributes, which is good because it maintains the existing variability among candidates. The following attributes were used for ranking:

- Building area
- Peak demand
- Annual consumption
- Ratio of battery size (in kilowatt hours [kWh]) to Solar Size (in kilowatt direct current [kWdc])
- Disqualifiers: two conditions were identified that indicated a poor candidate for this study (which does not mean that the projects should not be pursued).
    - Data quality issues: new construction sites or those without any bill data at all would require broader estimates of load profiles and economic returns. Modeling returns based on actual usage will yield higher-fidelity results than synthetic data, which tends to make buildings look uniform.
    - Very small battery size: for some sites, the required battery is small enough that it is effectively a residential battery that can be installed indoors. Residential systems have a fundamentally different capital and operational cost structure than an outdoor packaged commercial system, and inclusion of those types of batteries could make distributed batteries look unusually attractive relative to the FTM version. Alternatively, their small size and cost could make them irrelevant when combined with batteries from larger sites. Either way, they could distort the results of a BTM-FTM comparison.

2.1.2 Excluded Metrics

Some items were not considered at this stage as a basis for comparison:

- Solar size: this project is meant to compare battery selections, and the FTM battery does not have solar attached, making this attribute irrelevant for direct comparison.[3]

[3] Solar size refers to the capacity of the solar component of the BTM system. Note that although the solar capacity is not included in the comparison of battery capacity, solar revenues are included in the cash flow analysis.

- Battery size, both kW and kWh: because these are derivative of the usage data using them in the ranking would over-emphasize peak demand.
- Economic returns: capital expenses are a function of solar and battery size, and so are a direct result of utility bill data. Savings depends mainly on solar size and are one of the primary bases for comparison of results, and so are inappropriate for use in selecting the sites (to preclude cherry-picking).
- Load diversity: the type of loads in a particular building (i.e., the daily profile) can influence savings. The best metric we have for this is the "peak index", a ratio of maximum demand relative to the annual average. Batteries are somewhat better at capturing utility savings for sites with a high peak index, but demand prices are low enough in these rate schedules that it is unlikely to have a strong effect. Additionally, large buildings typically have an index close to 3, so the larger buildings dominate the overall economic returns. Taken together, load diversity is not expected to play a meaningful role in this analysis.

2.1.3 Subjective Valuation

Some sites have non-numerical attributes that tend to result in more successful project. CVEC knowledge of the site layout details, history of projects, overall data quality, and motivation of the hosts are all important inputs to selecting capital projects. Two projects were swapped based on these attributes in the final selection.

2.2 Behind-the-Meter Economic Analysis

Included in this analysis are 20-year financial proformas for each site and forecasted cumulative power costs for each scenario. Analysis of the five selected sites is based on the resources and assumptions detailed below.

2.2.1 Resources

AMS researched, was provided, or used proprietary knowledge of the following information pertinent to each site:

- Available economic incentives:
    - Market net metering credits for exported energy
    - Federal Investment Tax Credit (ITC)
    - Solar Massachusetts Renewable Target (SMART)[4] incentive
    - Direct sale of renewable energy credits
    - ConnectedSolutions[5] energy storage performance payments
    - Clean Peak[6] Energy Standard (CPES) certificates
- Each facility's power consumption needs, including:
    - Annual usage (critical to determining net metering thresholds)
    - Monthly usage (demonstrating seasonality of demand)

---

[4] The SMART program is a statewide incentive for solar development. For more information, see https://www.mass.gov/solar-massachusetts-renewable-target-smart.

[5] ConnectedSolutions is statewide demand response program in Massachusetts, in which a BTM battery owner is compensated for discharging the battery during times of peak utility demand. For more information, see https://www.cleanegroup.org/initiatives/energy-storage-policy-and-regulation/connectedsolutions.

[6] The Clean Peak Energy Standard is a statewide incentive program that provides funding for clean energy used to reduce seasonal peak demands. For more information, see https://www.mass.gov/clean-peak-energy-standard.

- Cost of installation
    - Cost of installed components
    - Ongoing costs post-installation, including operations and maintenance (O&M) and software costs

2.2.2 Assumptions

The following assumptions were made to make up for missing information or to generalize the analysis for broad applicability:

- Hourly usage is consistent with the U.S. Department of Energy's commercial reference building types for "small office" and "medium office" as applicable by building floor area. Based on the description of the building's operations, these reference buildings are the closest parallel available.
- No facility or utility upgrades were assumed to be required; if present, these could add to the installation cost of the system.
- ConnectedSolutions events and Clean Peak windows are coincident with building peak demand, such that demand charge management and participation in those incentive programs do not preclude each other.
- ConnectedSolutions is applicable for the first five years at each site. The program is renewed every three years, so the value of the incentive is dependent on how long it continues within the 20-year forecast window. Multiple potential outcomes are presented below.
- Prevailing wage will be paid by the municipalities for installation.
- Financing is structured as a cash transaction.
- ITC: the purchasing municipality will be eligible for Direct Pay, will capitalize the "energy community" adder,[7] if eligible, and will not capitalize the low-income adder,[8] even if eligible (due to capacity restrictions).[9]
- The discount rate for calculation of NPV is 6 percent.
- Solar was included as part of all BTM configurations and maximized existing roof area.[10]
- One site had solar already installed; the analysis presented here matched that solar installation but included its calculated installation cost in the overall economic analysis.
- Municipal entities in the CVEC portfolio are served under the Massachusetts Power Compact Agreement, in which no "capacity tag" savings are available from ISO-NE.

---

[7] The Energy Community Tax Credit Bonus affords an additional 10% in federal tax incentives for projects located in certain areas of the country. For more information, see https://energycommunities.gov/energy-community-tax-credit-bonus.

[8] The Clean Electricity Low-Income Communities Bonus Credit affords an additional 20 percent in federal tax incentives for projects that serve low-income communities. For more information, see https://www.irs.gov/credits-deductions/clean-electricity-low-income-communities-bonus-credit-amount-program.

[9] The low-income adder is not included in the analysis because there is no guarantee it can be captured. At the time of this analysis, the low-income adder was oversubscribed, meaning applicants were entered into a lottery to determine order of consideration.

[10] Solar+storage is the most common implementation of storage in BTM applications. Solar energy tends to be the primary driver of savings in BTM systems because it offsets energy use directly; without it, the battery would have an unusually slow payback and distort the intended comparison to FTM.

2.3 Front-of-the-Meter Economic Analysis

2.3.1 Resources

AMS researched, was provided, or used proprietary knowledge of the following information pertinent to each site:

- Available economic incentives
  - ITC
  - Market access
- Cost of Installation
  - Cost of installed components
  - Ongoing post-installation costs, including operations and maintenance (O&M) and software costs

2.3.2 Assumptions

The following assumptions were made to make up for missing information or to generalize the analysis for broad applicability:

- Eversource will be the off-taker and revenues will be from a tolling arrangement.
- The tolling arrangement will require a minimum 4-hour capacity guarantee. This guaranteed discharge time must be achieved in the lowest-capacity year considering normal battery degradation. We assume that occurs in Year 11, with battery augmentation occurring in Year 12. Alternatively, the system could be overbuilt at the beginning of system life such that Year 20 performance meets the capacity guarantee.
- The tolling rate is estimated based on previous successful Massachusetts projects.
- Prevailing wage will be paid by the municipalities for installation.
- Financing is structured as a cash transaction.
- ITC: the purchasing entity, either CVEC[11] or the municipality, will be eligible for Direct Pay, will capitalize the energy community adder if eligible, and will not capitalize the low-income adder even if eligible (due to capacity restrictions).
- The discount rate for calculation of NPV is 6 percent.
- Solar was not included as part of the FTM solution.[12]
- The battery will be sized such that the capital cost is equal to the sum of all BTM systems. This constraint is specifically to allow an apples-to-apples comparison of the economic outcomes given a certain amount of capital to invest.

---

[11] CVEC's operational model has typically been for a developer to own the asset, with CVEC reselling the energy from the developer to the municipal entity through an intergovernmental power sales agreement. This has no impact on the availability of tax incentives.

[12] For utility-scale solutions, solar does not clearly benefit the economics of the system. The solar energy would compete with other low-cost energy sources available to the off-taking utility during day, which sequesters capital (i.e., makes the battery smaller) for a feature the utility may not value. This is true even considering the revenue potentially available through SMART and other incentive programs. For large batteries used by the utility, the best use of capital is to maximize battery size and allow utility control of dispatch.

3 Qualitative Assessment

3.1 Context: Benefits of Battery Storage

Battery storage systems offer three main types of benefits to both grid operators and end users:

- **Savings and revenues**: Batteries can be used to optimize electricity use and can shift use from high to low demand periods, thereby saving money and earning revenue, for example through facility demand charge management, participation in utility demand response programs, or enrollment in regional capacity markets. Batteries can also reduce transmission and distribution costs by allowing deferral of costly grid upgrades. And batteries can provide valuable ancillary services to the grid, such as frequency regulation.
- **Energy security**: Batteries can enhance energy security by increasing the resilience and reliability of the electric grid. When properly configured, they can make the grid more able to respond to changing conditions and thus help to avoid blackouts while minimizing the need for costly and polluting peaker power plants. When the grid does go down, batteries can provide black-start services. For communities, batteries are an essential ingredient in microgrids, which can "island" and remain in operation when the surrounding grid goes down. This enables batteries to support essential emergency services during natural disasters.
- **Energy sustainability**: Batteries are key to enabling greater reliance on clean renewable generation, thereby reducing the need for fossil fuel generation. As such, they are an indispensable part of state and municipal decarbonization plans. Batteries also increase the capacity value, and thus the economic value, of variable renewable generation sources such as wind and solar. Human and environmental health are also important sustainability goals, and batteries can support these by enabling a reduction in both greenhouse gas and local pollutant emissions from fossil fuel combustion.

While many of these benefits of batteries are not currently monetizable in existing markets, Massachusetts offers several incentive programs that recognize and reward these benefits.

3.2 Behind-the-Meter Battery Considerations

3.2.1 Investment in Resilience

In many cases, installing a solar system without a battery has a rapid return on investment and, in some cases, a financed purchase agreement can save money outright from the beginning of a project. In this way, a solar installation can present as "free," or nearly so. This is not the case for battery storage. The cost of batteries has declined significantly over the past decade and is projected to fall even further in the next decade[13]; however, the soft costs of installation, such as siting and permitting, can exceed material costs, particularly for small commercial installations. While there are generous incentive programs and tax rebates available for battery installations, they rarely offset the capital cost completely. For most systems with a 20-year horizon, a battery results in a net cost to the facility relative to a solar-only solution, and for some it is a net cost relative to baseline spending. However, the battery also provides backup power during

[13] National Renewable Energy Laboratory. *Cost Projections for Utility-Scale Battery Storage: 2023 Update,* https://www.nrel.gov/docs/fy23osti/85332.pdf.

emergencies, which has a value that is normally not represented in forecast cash flows. In that way, installing a battery is an investment in resilience, similar to a generator but with more flexibility and no carbon emissions. While it is not "free," it may be quite valuable overall because of the resilience afforded to the site.

3.2.2 Infrastructure Constraints

Installing battery storage at municipal buildings can face several infrastructure-related constraints that impact feasibility. Space limitations are among the most common because systems large enough to support commercial operations are almost always pad-mounted cabinets or containers outside the facility. The physical size of the components with code-required setbacks from the building and public-facing exposures can quickly squeeze the potential locations for a battery and require a more expensive location or make the project infeasible. In addition, the balance-of-system components like inverters, combiner panels, and disconnects require significant space, and taken together this can be particularly challenging in older buildings or high-density areas where space is at a premium.

Electrical infrastructure compatibility is another critical consideration. Older buildings may have electrical systems that cannot support the integration of modern battery storage technologies without substantial upgrades. This can include rewiring or updating switchgear, which increases both costs and installation time. Even new buildings on old sections of the utility distribution system may prevent the installation or operation of a battery system that would otherwise be optimal. To address both types of limitations, a feasibility analysis is required to determine the best balance between site resources, goals, and constraints.

3.2.3 Predictability of Returns

The returns of a solar+storage system in Massachusetts are largely predictable due to the state's established utility rate schedules and a well-developed suite of incentive programs that make investment outcomes more reliable. Massachusetts has some of the highest electricity rates in the U.S.[14], which can be significantly mitigated by offsetting energy use through solar generation and using battery storage to avoid peak charges. Massachusetts utility providers, like National Grid and Eversource, offer time-of-use (TOU) rates that make it advantageous to deploy stored energy when grid prices are highest, providing a reliable financial framework for businesses calculating their energy cost savings.

State incentive programs further enhance these predictable returns. The incentives described in Section 2.2.1, offer a combination of up-front and long-term, performance-based incentives that pay battery owners based on published rates. This means that compared to a FTM battery, BTM batteries can develop a sense of overall returns more quickly and with limited utility interaction required.

3.2.4 Sustainability and Solar Pairing

As modeled in this study, most BTM battery installations are paired with storage because that provides the most economic installation and allows extended resilience during an outage. The inclusion of solar presents a straightforward way to calculate and advertise the enhanced sustainability posture of a facility or an organization.

---

[14] Energy Information Administration, Electric Power Monthly, see https://www.eia.gov/electricity/monthly/epm_table_grapher.php?t=epmt_5_6_a.

3.2.5 Phased Implementation

A significant advantage of using a fixed amount of capital for a series of BTM installations is that they can be phased in over time. The analysis presented here assumes that all systems are implemented at once, but in reality they can be done in series, and the first-year rebates and incentives from one project can be rolled forward into the next project, limiting the total capital that has to be assembled at one time. For example, the ITC rebates alone from the first three projects could pay for the fourth outright. The phasing can be extended further by installing solar and storage at different times. Overall, the phased BTM approach, although it delays full implementation for some years, confers a huge economic advantage, provides much more flexibility, and manages implementation risks over a longer period of time.

3.3 Front-of-the-Meter Battery Considerations

3.3.1 Interconnection Delay

Distributed energy resources (DERs), such as energy storage and solar+storage, can face significant delays in connecting with the electric grid. Interconnection is an essential step in allowing these systems to exchange energy with the grid, but there are challenges to predicting the timing of the utility's interconnection process. For each project, the servicing utility must assess the "hosting capacity" of local grids, determining if they can handle the additional load in both directions. If hosting capacity is inadequate, costly grid upgrades may be attributed to the FTM battery owner, which can render projects economically unfeasible.[15] Delays are further compounded by the interconnection approval process, resulting in wait times that can be years long. As of 2023, Massachusetts alone had $8 billion in proposed projects stalled in interconnection queues.[16] This situation has been more likely for FTM battery systems because they are typically much larger than their BTM counterparts and have no capability to manage loads "behind the meter" to limit reverse flow. The potential cost and timeline to achieve interconnection certainty make forecasting financial returns for FTM batteries challenging.

3.3.2 Environmental Concerns

The development of battery storage systems necessitates careful attention to environmental considerations with one of the primary concerns being site selection, particularly regarding proximity to sensitive areas such as wetlands and floodplains. Depending on the size of the project, Environmental Impact Assessments (EIAs) may be required and are critical in identifying potential ecological consequences during project development. These assessments evaluate factors such as wetlands, endangered species habitats, and air and water quality

---

[15] This impact may be somewhat mitigated by the MA utilities' process of "group study", in which multiple projects are collected for a single analysis, with the intent of spreading costs across projects more equitably. https://www.eversource.com/content/residential/about/doing-business-with-us/interconnections/massachusetts/distribution-group-studies. Furthermore, Massachusetts has recently advanced new cost allocation methods, that to some degree socialize the costs of distribution grid upgrades necessary to accommodate new DERs; and Massachusetts is also engaging in more proactive grid upgrades. https://www.mass.gov/news/dpu-approves-plans-to-modernize-electric-sector-to-accelerate-clean-energy-transition#:~:text=In%20the%20next%20proceeding%2C%20which,2035%20by%20September%2011%2C%202029.

[16] Clean Energy Group and Applied Economics Clinic. *The Interconnection Bottleneck: Why Most Energy Storage Projects Never Get Built.* 2023. https://www.cleanegroup.org/publication/the-interconnection-bottleneck-why-most-energy-storage-projects-never-get-built/

impacts. When required, a thorough EIA facilitates regulatory approval and promotes thoughtful environmental stewardship but can add significant time and cost to large FTM projects.

Furthermore, climate change poses additional challenges for battery system installations. As extreme weather events become more frequent, developers must assess risks associated with flooding and other natural disasters. Positioning projects outside of the 100-year floodplain[17] is essential for minimizing long-term risks, with expert guidance needed on whether even greater restriction is required.

3.3.3 Public Perception

Because battery installations are not especially loud or visually imposing, the primary public concern is likely to be fire risk. While battery fires are rare, they have occurred[18], and the setbacks required by zoning and code restrictions may not be sufficient to alleviate community objections. Employing advanced fire safety systems and regularly conducting safety drills with a well-trained installation team is expected to enhance safety protocols, but those measures are largely invisible to the public. Safety concerns raised by local community members could significantly delay or cancel a project.

3.3.4 Financial Structure

A relevant and executable financial strategy is crucial to FTM battery development, particularly when negotiating agreements with utility companies like Eversource. Project owners must assess potential revenue streams, such as capacity payments, energy arbitrage, and ancillary services if participating directly in the market, or have an understanding of how those revenue streams apply to the utility to contract directly with them as an off-taker. In the latter case, capacity guarantees can significantly impact financial models, as they may necessitate higher initial investments to ensure compliance with performance standards. When negotiating contracts, it is crucial to clarify terms related to maintenance responsibilities, penalties for underperformance, and conditions for future augmentations.

3.3.5 Financial Predictability

Financial predictability is vital for the long-term success of battery storage projects. Stakeholders must establish a clear understanding of capital and operational expenditures and be able to forecast potential revenues and expenses accurately. Given the significant upfront investment required for battery systems, companies often rely on consultants or developers with sophisticated financial models that incorporate anticipated cash flows over the project's lifespan.

Moreover, financial predictability can be influenced by market conditions and technological advancements. The rapid evolution of battery technology, coupled with fluctuations in commodity prices and the potential delays described above, can affect project costs and operational efficiency. Therefore, continuous market analysis and flexible financial strategies are essential to adapt to changing circumstances. The risk associated with financial uncertainty and the management strategies to mitigate it, is normally handled by large-scale developers due to the sophistication and financial stability required.

---

[17] Massachusetts Environmental Public Health Tracking, Flood Zone Mapping Tool, https://matracking.ehs.state.ma.us/planning_and_tools/flood-zones/flood-zones-tool.html.
[18] StorageWiki Database, BESS Failure Incident Database, https://storagewiki.epri.com/index.php/BESS_Failure_Incident_Database.

4 Quantitative Assessment

4.1 Summary Matrix

The financial and sustainability outcomes of the two approaches are shown in Table 1, with a single number representing the sum of all five BTM configurations compared to the single large FTM system.

Table 1: Comparison of financial outcomes for the combined behind-the-meter systems and the single large front-of-the-meter system

	BTM (5-year incentives)	**BTM (10-year incentives)**	**BTM (20-year incentives)**	**FTM (single large-scale battery)**
Solar	567 kWh	567 kWh	567 kWh	--
Battery	490 kW / 1,175 kWh	490 kW / 1,175 kWh	490 kW / 1,175 kWh	2,000 kW / 12,500 kWh
Financial Returns				
Capital Cost	$4,541,588	$4,541,588	$4,541,588	$4,541,588
ITC	$1,750,156	$1,750,156	$1,750,156	$1,816,635
Capital Cost after ITC	$2,791,432	$2,791,432	$2,791,432	$2,724,953
IRR	-2.2%	-1.2%	0.7%	4.4%
NPV @ 6%, 20 years	($1,407,458)	($1,241,188)	($1,045,895)	($371,671)
Simple Payback (years)	~24	~22	19	14
Revenue & Cash Flow - First Year				
Utility Savings/Income	$104,772	$104,772	$104,772	$264,000
Total Incentives	$84,278	$84,278	$84,278	$0
Total O&M Expenses	($27,047)	($27,047)	($27,047)	($66,631)
Replacement capex	$0	$0	$0	$0
Capital Cost after ITC	$0	$0	$0	$0
Cash flow	**$162,003**	**$162,003**	**$162,003**	**$197,369**
Revenue & Cash Flow - 20-year				
Revenue	$2,571,028	$2,571,028	$2,571,028	$6,553,642
Rebates & Incentives	$831,749	$1,111,238	$1,611,249	$1,816,635
Total O&M Expenses	($657,173)	($657,173)	($657,173)	($2,196,420)
Replacement capex	($432,759)	($432,759)	($432,759)	$0
Capital Cost after ITC	($2,791,432)	($2,791,432)	($2,791,432)	($2,724,953)
Cash flow	**($478,588)**	**($199,099)**	**$300,912**	**$1,632,269**

4.2 Results comparison

Economic analysis of the systems proceeded under the assumptions described in sections 2.2.2 and 2.3.2.

- Capital cost matches in the two scenarios by design.
- ITC value is slightly higher for the FTM system because it fully captures the energy community adder, while one of the BTM sites (West Tisbury) does not.
- IRR, NPV, and 20-year cash flow are significantly higher for the FTM system. This is expected, as FTM systems are purely economic.
- The BTM system payback period is within the 20-year window as long as the state incentives exist for approximately 15 years.
- The annual income from the utility's tolling arrangement is significantly higher than the on-bill savings available to BTM systems.
- No incentives are available to the FTM system under the utility tolling arrangement, other than the ITC. (Note that the ITC value is not included in the first-year incentive total to illustrate the difference between BTM and FTM solutions; instead, it is captured in the "Capital Cost after ITC" value.)
- O&M expenses were calculated by different methods, but each totals approximately 25 percent of annual revenue in Year 1. This is a coincidence, as the O&M expectations for the two types of systems are different and the BTM combined result masks the variation in individual site O&M/savings ratios. Additionally, FTM O&M costs increase substantially in Year 6 because of changes in warranty and maintenance costs.
- There is no replacement CAPEX in the FTM scenario, as the battery capacity is increased at the beginning of system life to avoid augmentation. This is a plausible arrangement for large systems that are actively managed and monitored with high precision; the same is not necessarily true for smaller BTM systems.
- As shown in Figure 1 below, the FTM system consistently generates more revenue than the BTM systems. Because the FTM system offers no resilience, this is equivalent to a "resilience premium" on the BTM systems averaging $13,300 per site per year if the state incentives exist for 20 years. This premium is higher at $21,100 if the state incentives last only 5 years.

4.3 Sensitivity Analysis

Many variables in the analysis, such as utility escalation rate or discount rate, have similar effects on both configurations, and do not meaningfully change decision-making between the two scenarios. This section describes the variables that are most likely to alter the calculus of which configuration is preferred.

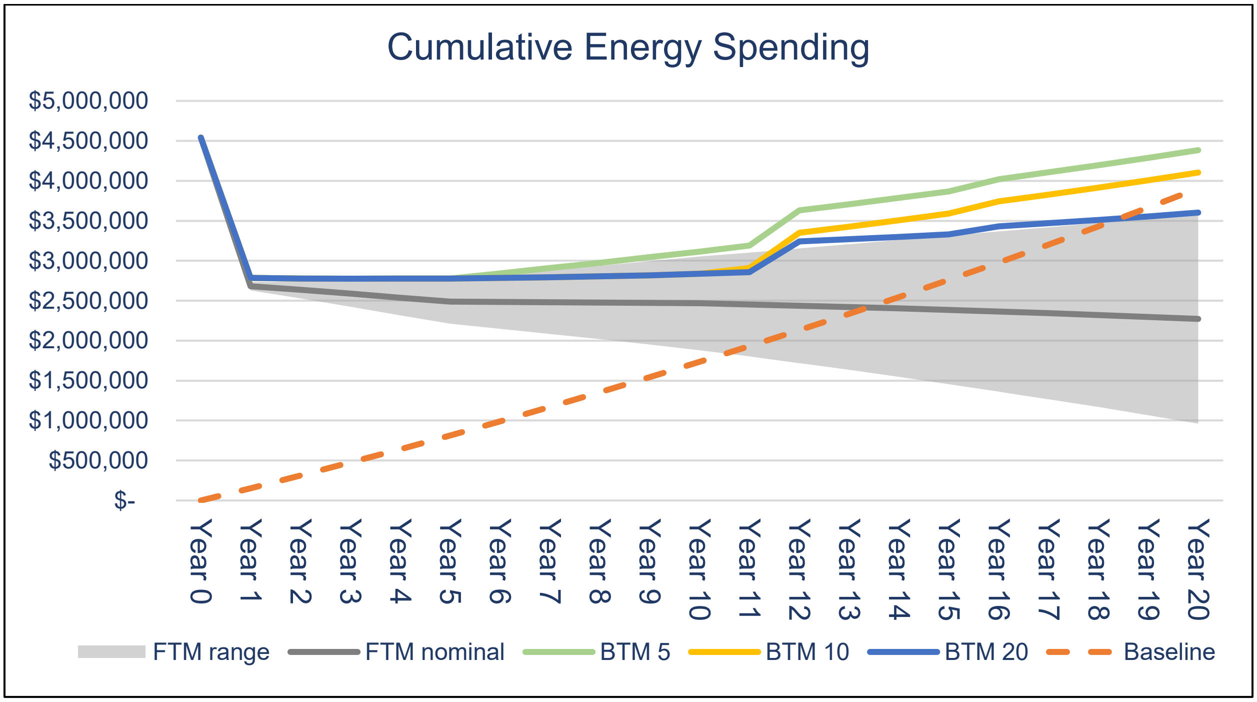
4.3.1 Tolling Rate

The FTM results presented in this analysis assume a tolling rate of $11 / kW-year. This level of compensation is entirely defined by the utility's needs at the location of battery interconnection and can only be determined through negotiation with the utility. While this number is predicted based on similar successful MA projects, the value of the battery at any given location may be lower. A reduction in tolling rate by 20 percent reduces the FTM 20-year cash flow by $1.3M. While it is still more lucrative than BTM overall, the results essentially match for the first 11 years and result in an effective resilience premium of $5,200 per site per year (less than one-third of the nominal calculation).

4.3.2 ConnectedSolutions and Clean Peak Duration

Because the ConnectedSolutions program is authorized every three years and all state incentives are subject to funding constraints, there is some uncertainty regarding how many years of incentives will be available for systems that are installed today. Multiple scenarios of incentive revenue (from only five years to permanent) are presented in Table 1. If the incentive programs were to continue indefinitely and if the expected tolling rate were reduced by 20 percent, the systems would have equivalent financial outcomes (see Figure 1, blue line and top of wide gray band).

Figure 1: Cumulative Energy Spending



Cumulative energy spending, accounting for baseline spending from existing buildings and the impact of each of the two system configurations. The FTM range (wide gray band) shows the impact of +/- 20% change in the tolling rate. Numbers following "BTM" indicate the number of years for which state incentives are applied.

5 Conclusion

For the purposes of this analysis, FTM battery storage systems are assumed to be driven purely by financial considerations, ensuring they are designed to generate a net-positive return. The economic feasibility of these systems hinges on negotiated agreements with utilities, such as tolling arrangements or payments for ancillary services, which guarantee revenue streams aligned with system capacity and performance. FTM systems are not typically configured to provide a resilience benefit, and therefore do not incur additional costs associated with this service; additionally, investment decision-making is more straightforward when all benefits are purely economic, meaning non-monetizable benefits such as energy resilience need not be considered.[19] By comparison, BTM systems serve both financial and community benefit roles, providing non-monetizable benefits such as community resilience, for which they pay a "resilience premium." Revenue for BTM commercial-scale battery systems relies on a combination of cost savings, such as demand charge management, and participation in incentive and subsidy programs, such as the Massachusetts SMART, ConnectedSolutions, and Clean Peak Energy Standard programs.

In the scenario studied, the utility-scale FTM system outperforms commercial-scale BTM systems in metrics such as IRR, NPV, and cash flow projections. This performance is primarily due to utility compensation mechanisms and the absence of replacement CAPEX, as FTM systems are built with greater precision in capacity planning and maintenance. A robust tolling rate can result in significantly higher annual income compared to on-bill savings for BTM systems.

However, the financial predictability of FTM systems can be influenced by the utility's specific requirements, such as hosting capacity and interconnection costs. Any misalignment in these variables or reductions in compensation rates can diminish overall cash flow. Even with these risks, FTM systems are likely to remain net-positive because they are inherently structured around optimizing financial returns, reflecting their role as grid-scale assets with broader economic benefits.

While FTM systems promise robust financial returns, they come with challenges that prolong project timelines and introduce uncertainties. Interconnection delays are among the most significant barriers, especially in congested regions like Massachusetts. Hosting capacity constraints often lead to extensive assessments and costly grid upgrades, which can render some projects unviable. Interconnection queues, which may stretch for years, further complicate project planning. Massachusetts has billions of dollars in proposed projects stalled due to interconnection bottlenecks, though we note that efforts are underway to improve the process.[20]

---

[19] Some FTM batteries do have a resilience aspect. This typically occurs when the utility has an additional need for resilience at certain facilities and land for the battery located nearby. In that case, the tolling arrangement may result in higher revenues because the utility is performing more than just economic functions in its control of battery discharge.

[20] Massachusetts Department of Public Utilities press release, 2024, "DPU Approves Plans to Modernize Electric Sector to Accelerate Clean Energy Transition," https://www.mass.gov/news/dpu-approves-plans-to-modernize-electric-sector-to-accelerate-clean-energy-transition.

Environmental concerns also add complexity. Large-scale FTM systems may require detailed EIA's, particularly if sited near sensitive areas such as wetlands or floodplains. While these assessments are essential for regulatory compliance and environmental stewardship, they extend development timelines and increase costs.

In addition, public perception issues, including fire safety concerns, can delay or derail FTM projects. Despite robust safety measures, local opposition can slow or halt a proposed project. Furthermore, securing financial agreements with utilities or directly participating in energy markets requires sophisticated modeling and negotiation, increasing the complexity and length of the development process. In contrast, BTM systems, being smaller and less exposed to such external factors, offer shorter timelines and more predictable implementation.

BTM systems also provide tangible benefits that FTM systems cannot replicate, particularly in providing on-site resilience. These systems can supply backup power to facilities during grid outages, a function analogous to generators but without carbon emissions. Although the BTM solutions may represent a net cost relative to FTM (or solar-only) projects, additional value lies in the resilience benefit they offer. The value of that resilience can be challenging for organizations to quantify, but a comparison to the FTM system suggests that the "resilience premium" is ~$13,300 per site per year under the assumptions stated here; if the FTM tolling rate were to be 20 percent lower, the resilience premium is nearly zero.

Infrastructure constraints can pose challenges, such as space limitations and compatibility with existing electrical systems, but careful site selection can address these. For example, sites with unused outdoor space or extra parking spaces make siting a battery significantly easier. Similarly, there are some electrical architectures that are more challenging to design due to limited commercial availability of solutions: high-power single-phase power supplies and low-power three-phase power supplies are two of these.[21]

Moreover, BTM systems allow for phased implementation, enabling businesses to spread costs and risks over time. This approach leverages rebates and incentives from earlier projects to fund subsequent installations, reducing upfront financial pressure. For example, if the BTM systems analyzed herein were installed in a phased series, ITC savings from the first three projects could pay for the fourth project outright. While this phased implementation strategy was not considered in this analysis, it is worthy of further consideration if timelines allow.

BTM systems, therefore, combine flexibility with resilience and sustainability benefits, making them a strategic choice for facilities seeking long-term energy independence.

As with many major capital projects, there is no obvious choice here between which use of funds is "better." The goals of any organization often include both sustainability and resilience benefits as well as the desire for positive economics. If the latter is not an explicit goal, it's also true that a better financial outcome could make funds available for additional projects that achieve non-economic goals. A strategic plan that includes all of these factors as well as the risk tolerance of the organization, from both schedule and financial perspectives, is necessary to find a balanced path forward.

[21] Residential service is typically single-phase, while three-phase service is more common for commercial facilities.

Appendix A
Site Downselection Ranking

	Barnstable	Eastham Police Station	Eastham Townhall	Eastham Transfer Station	MV Airport ARFF	MV Airport Water Treatment Plant	Orleans DPW	Orleans Old Composter	Tisbury Senior Center	W. Tisbury Library	Yarmouth DPW	Yarmouth Fire Station #3
Bldg Area (sqft)	2,000	5,978	7,238	40,320	18,900	3,700	45,000	7,300	5,056	13,500	37,680	11,302
Peak Demand (kW)	5	20	56	17	60	7	67	12	19	30	59	52
Annual Usage (kWh)	16,247	9,026	180,480	182,309	86,801	19,951	184,800	36,314	24,163	90,277	189,960	155,663
Utility	Eversource	Eversource	Eversource	Eversource	Eversource	Eversource	Eversource	Eversource	Eversource	Eversource	Eversource	Eversource
Rate Schedule	33	33	33	33	33	33	33	33	33	33	33	33
Solar (kWdc)	12	7	57	134	65	18	106	27	19	41	151	140
Battery (kW)	8	30	84	21.0	90	10	101	18	28	45	89	78
Battery (kWh)	19	72	202	61	216	24	241	44	68	108	212	187
Capital Cost	$247,565	$268,584	$556,683	$581,010	$595,208	$267,590	$725,825	$304,904	$301,773	$400,520	$789,712	$733,122
Y1 Utility Savings	$3,656	$3,818	$22,237	$30,550	$27,430	$4,264	$42,450	$6,498	$7,778	$13,912	$44,444	$38,497
IRR	-20%	--	-4%	6%	-2%	-16%	3%	-7%	-12%	-4%	5%	3%
NPV @6%, 20yrs	-$125,310	-$182,149	-$222,544	-$10,587	-$206,225	-$155,971	-$123,986	-$155,405	-$136,709	-$164,211	-$53,201	-$85,057
EUI (kWh/sqft/year)	8	2	25	5	5	5	4	5	5	7	5	14
Peak index	2.7	19.4	2.7	0.8	6.1	3.1	3.2	2.9	6.9	2.9	2.7	2.9
Battery-solar ratio (kWh/kWdc)	1.6	10.3	3.5	0.5	3.3	1.3	2.3	1.6	3.6	2.6	1.4	1.3
Data quality	Red	Yellow	Green	Green	Yellow	Red	Green	Red	Yellow	Green	Green	Green
Area rank	12	9	8	2	4	11	1	7	10	5	3	6
Demand rank	12	7	4	9	2	11	1	10	8	6	3	5
Usage rank	11	12	4	3	7	10	2	8	9	6	1	5
Battery-solar rank	8	1	3	12	4	11	6	7	2	5	9	10
Rank sum	43	29	19	26	17	43	10	32	29	22	16	26
Overall rank	11	8	4	6	3	11	1	10	8	5	2	6

Appendix B
Summary Performance for BTM Systems

	Eastham Town Hall	Orleans DPW	W. Tisbury Library	Yarmouth DPW	Yarmouth Fire #3
Solar	55.5 kW	156.2 kW	55 kW	160.5 kW	140.2 kW (existing)
Battery	90 kW / 246 kWh	125 kW / 220 kWh	90 kW / 246 kWh	125 kW / 330 kWh	60 kW / 123 kWh
Financial					
Capital Cost	$609,322	$1,013,344	$606,913	$1,137,944	$739,932
Capital Cost after Y1 Incentives	$365,593	$608,006	$424,839	$682,767	$443,959
Y1 Net Savings	$31,702	$59,581	$33,846	$40,368	$27,502
NPV @6%, 20 years	($169,599)	($55,461)	($195,125)	($420,731)	($222,452)
Sustainability					
Renewable Generation (kWh)	64,858	193,891	74,153	199,229	159,829
Usage offset by renewables	36%	101%	53%	100%	103%
Carbon Offset (metric tons)	46	137	52	141	113
Resilience					
Resilient Load Support	13 hours typical 4 hours minimum	30 hours typical 4 hours minimum	24 hours typical 4 hours minimum	42 hours typical 6 hours minimum	72 hours typical 8 hours minimum

Appendix C
Eastham Town Hall

Solar

Capacity	56 kW
Production (Y1)	64,858 kWh
% of annual electric usage	36%
ESA Rate* (20-year rate) (Utility rate is $0.237 / kWh)	$0.086 / kWh
Turnkey Installation Cost	$3.64 / W ($202,230)
Operations and Maintenance (O&M)	$1,055 / year
Inverter replacement, year 16 (Note: panel lifespan is 25 years)	$6,600
Operating Incentives	SREC modeled at $40
Notes	• *An alternative to self-purchasing the solar installation, an Energy Service Agreement can finance the project, with a rate escalating at 2% / year. • All designs are preliminary and conceptual • Capacity of roof to host solar must be verified • All references to solar installation size reflect kW_{pDC} unless otherwise noted

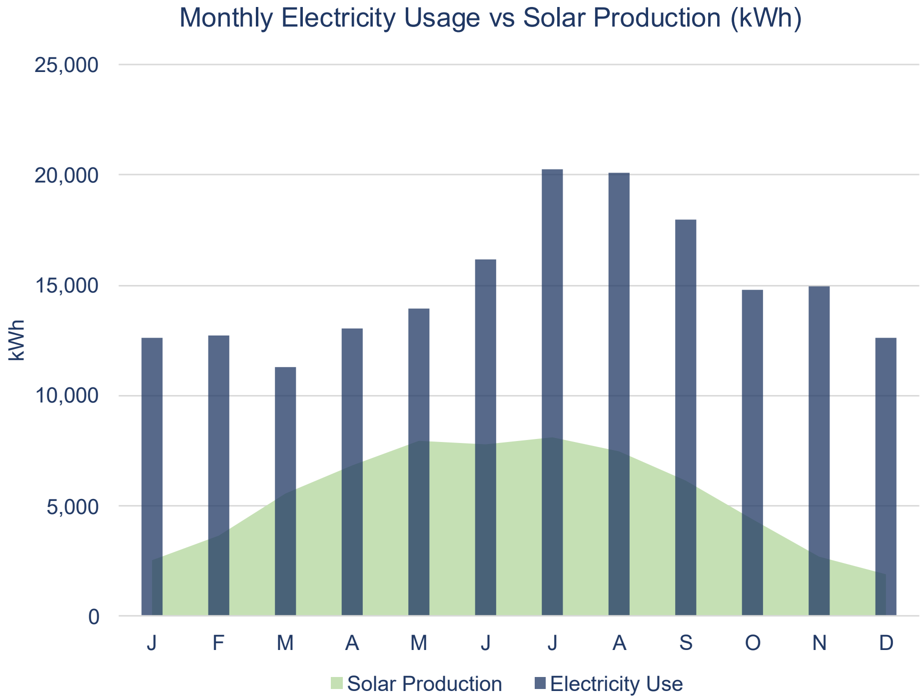
Proposed rooftop solar layout, image shown in North-up orientation. Panels are set to use the most productive roof space to the maximum extent possible.

Storage

Power	90 kW
Energy	246 kWh
Turnkey Installation Cost	$1,655 / kWh ($407,092)
O&M (software, maintenance)	$3,984 / year
Inverter/Module Replacement, year 12	$73,710
Operating Incentives	Connected Solutions and Clean Peak
Location	Outside enclosure
Chemistry	Lithium-ion battery
Applications	✓ Peak shaving ✓ Resilience ✓ Demand Response Participation ✓ Time-of-Use Management
Notes	• All designs are preliminary and conceptual

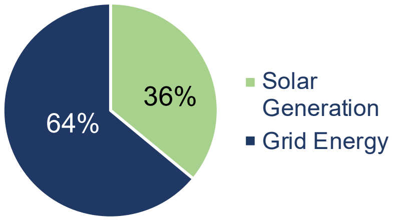
The battery module cabinet with its associated inverter is the height of a large refrigerator and has a footprint of a parking space. Clearances of 3-4 feet in front and on the inverter side cabinets are typically required for installation and maintenance. *(Note: this analysis is vendor-agnostic, and the example shown is meant to be representative, not a product recommendation).*

Sustainability Performance



Offsets 114,000 vehicle miles driven annually

Equivalent to carbon sequestered by 54 acres of forest every year



Appendix D
Orleans DPW

Solar

Capacity	156 kW
Production (Y1)	193,891 kWh
% of annual electric usage	101%
ESA Rate* (20-year rate) (Utility rate is $0.237 / kWh)	$0.120 / kWh
Turnkey Installation Cost	$3.24 / W ($505,872)
Operations and Maintenance (O&M)	$1,781 / year
Inverter replacement, year 16 (Note: panel lifespan is 25 years)	$18,744
Operating Incentives	SREC modeled at $40
Notes	• *An alternative to self-purchasing the solar installation, an Energy Service Agreement can finance the project, with a rate escalating at 2% / year. • All designs are preliminary and conceptual • Capacity of roof to host solar must be verified • All references to solar installation size reflect kW_{pDC} unless otherwise noted

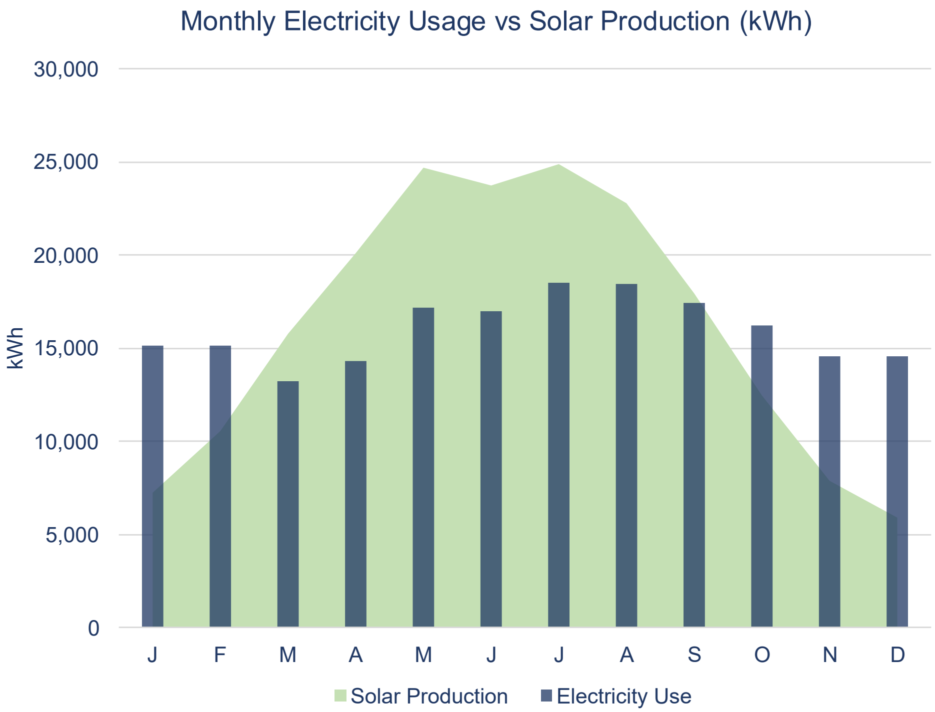
Proposed rooftop solar layout, image shown in North-up orientation. Panels are set to use the most productive roof space to the maximum extent possible.

Storage

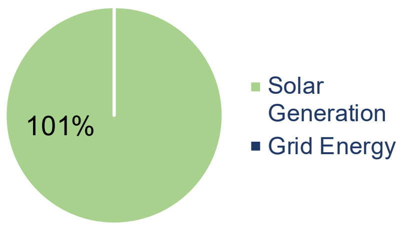
Power	125 kW
Energy	220 kWh
Turnkey Installation Cost	$2,359 / kWh ($518,910)
O&M (software, maintenance)	$3,880 / year
Inverter/Module Replacement, year 12	$76,825
Operating Incentives	Connected Solutions and Clean Peak
Location	Outside enclosure
Chemistry	Lithium-ion battery
Applications	✓ Peak shaving ✓ Resilience ✓ Demand Response Participation ✓ Time-of-Use Management
Notes	• All designs are preliminary and conceptual

The battery module cabinet with its associated inverter is the height of a large refrigerator and has a footprint of a parking space. Clearances of 3-4 feet in front and on the inverter side cabinets are typically required for installation and maintenance. *(Note: this analysis is vendor-agnostic, and the example shown is meant to be representative, not a product recommendation).*

Sustainability Performance



Offsets 341,000 vehicle miles driven annually



Equivalent to carbon sequestered by 163 acres of forest every year

Appendix E
West Tisbury Library[22]

Solar

Capacity	55 kW
Production (Y1)	74,153 kWh
% of annual electric usage	53%
ESA Rate* (20-year rate) (Utility rate is $0.238 / kWh)	$0.096 / kWh
Turnkey Installation Cost	$3.65 / W ($199,281)
Operations and Maintenance (O&M)	$1,048 / year
Inverter replacement, year 16 (Note: panel lifespan is 25 years)	$6,571
Operating Incentives	SREC modeled at $40
Notes	• *An alternative to self-purchasing the solar installation, an Energy Service Agreement can finance the project, with a rate escalating at 2% / year. • All designs are preliminary and conceptual • Capacity of roof to host solar must be verified • All references to solar installation size reflect kW_{pDC} unless otherwise noted

Proposed rooftop solar layout, image shown in North-up orientation. Panels are set to use the most productive roof space to the maximum extent possible.

AMERICAN MICROGRID SOLUTIONS

West Tisbury Library – Feasibility Analysis – 2024
1042 State Rd., Vineyard Haven, MA 02568

4

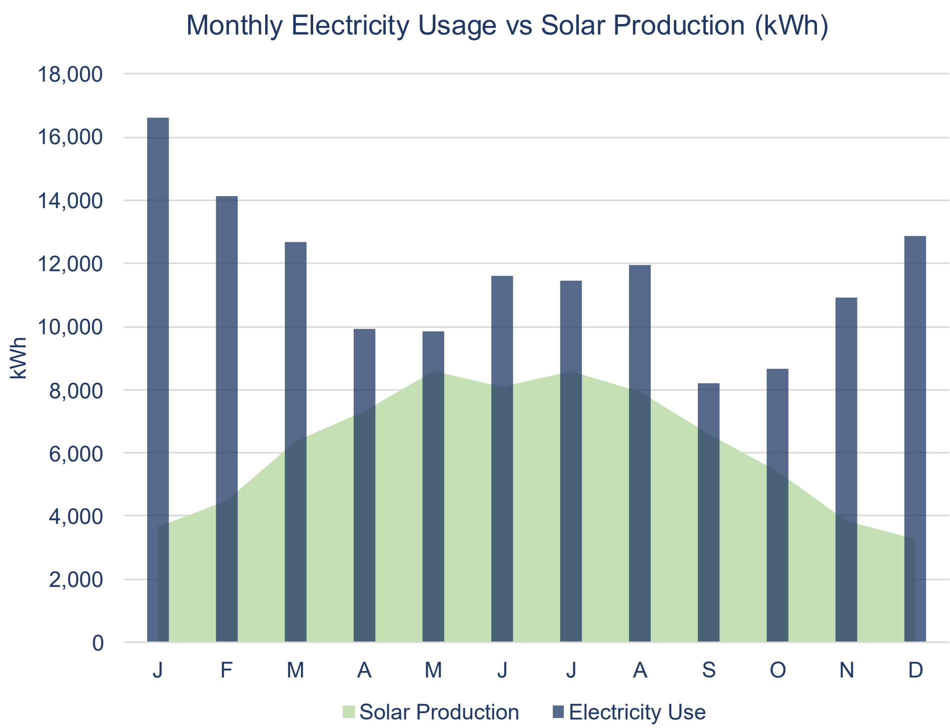
[22] This project was subsequently awarded and constructed with a different design.

Storage

Design	Resilient Power
Power	90 kW
Energy	246 kWh
Turnkey Installation Cost	$1,655 / kWh ($407,092)
O&M (software, maintenance)	$3,984 / year
Inverter/Module Replacement, year 12	$73,710
Operating Incentives	Connected Solutions and Clean Peak
Location	Outside enclosure
Chemistry	Lithium-ion battery
Applications	✓ Peak shaving ✓ Resilience ✓ Demand Response Participation ✓ Time-of-Use Management
Notes	• All designs are preliminary and conceptual

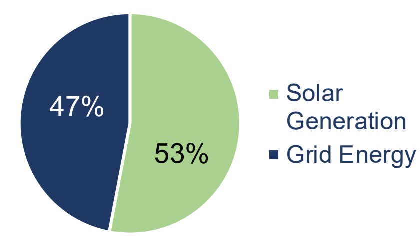
The battery module cabinet with its associated inverter is the height of a large refrigerator and has a footprint of a parking space. Clearances of 3-4 feet in front and on the inverter side cabinets are typically required for installation and maintenance. *(Note: this analysis is vendor-agnostic, and the example shown is meant to be representative, not a product recommendation).*

Sustainability Performance



Offsets 130,000 vehicle miles driven annually

Equivalent to carbon sequestered by 62 acres of forest every year



Appendix F
Yarmouth DPW

Solar

Capacity	361 kW
Production (Y1)	199,229 kWh
% of annual electric usage	100%
ESA Rate* (20-year flat rate) (Utility rate is $0.235 / kWh)	$0.113 / kWh
Turnkey Installation Cost	$3.23 / W ($518,091)
Operations and Maintenance (O&M)	$1,803 / year
Inverter replacement, year 16 (Note: panel lifespan is 25 years)	$19,260
Operating Incentives	SREC modeled at $40
Notes	• *An alternative to self-purchasing the solar installation, an Energy Service Agreement can finance the project, with a rate escalating at 2% / year. • All designs are preliminary and conceptual • Capacity of roof to host solar must be verified • All references to solar installation size reflect kW_{pDC} unless otherwise noted

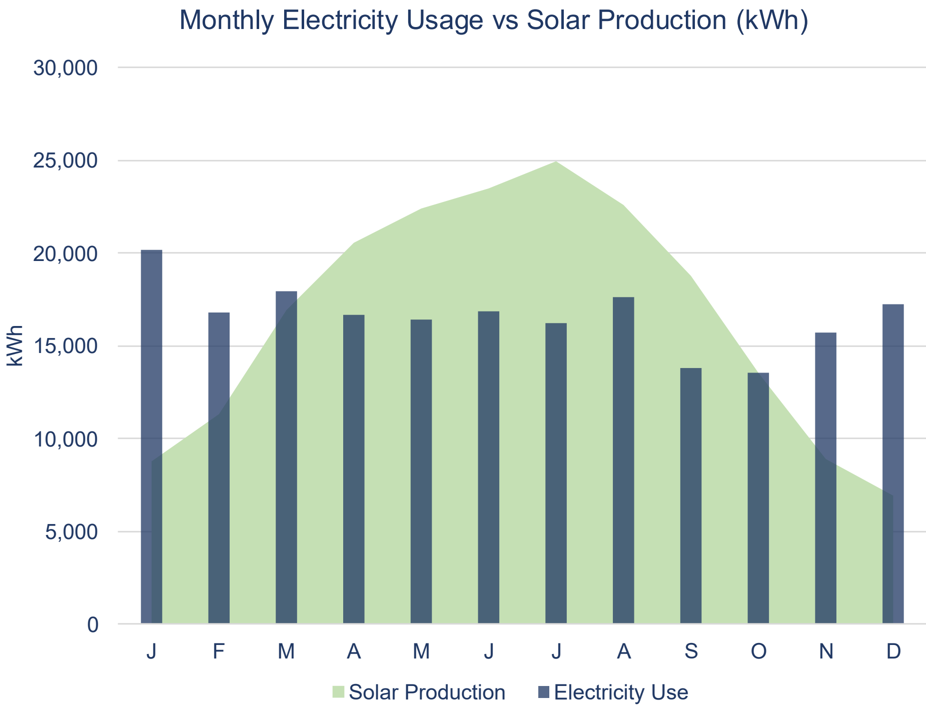
Proposed rooftop solar layout, image shown in North-up orientation. Panels are set to use the most productive roof space to the maximum extent possible.

Storage

Power	125 kW
Energy	330 kWh
Turnkey Installation Cost	$1,878 / kWh ($619,853)
O&M (software, maintenance)	$4,320 / year
Inverter/Module Replacement, year 12	$99,925
Operating Incentives	Connected Solutions and Clean Peak
Location	Outside enclosure
Chemistry	Lithium-ion battery
Applications	✓ Peak shaving ✓ Resilience ✓ Demand Response Participation ✓ Time-of-Use Management
Notes	• All designs are preliminary and conceptual

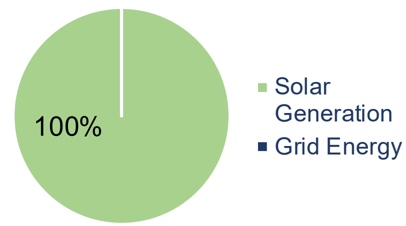
The battery module cabinet with its associated inverter is the height of a large refrigerator and has a footprint of a parking space. Clearances of 3-4 feet in front and on the inverter side cabinets are typically required for installation and maintenance. *(Note: this analysis is vendor-agnostic, and the example shown is meant to be representative, not a product recommendation).*

Sustainability Performance



Offsets 350,000 vehicle miles driven annually

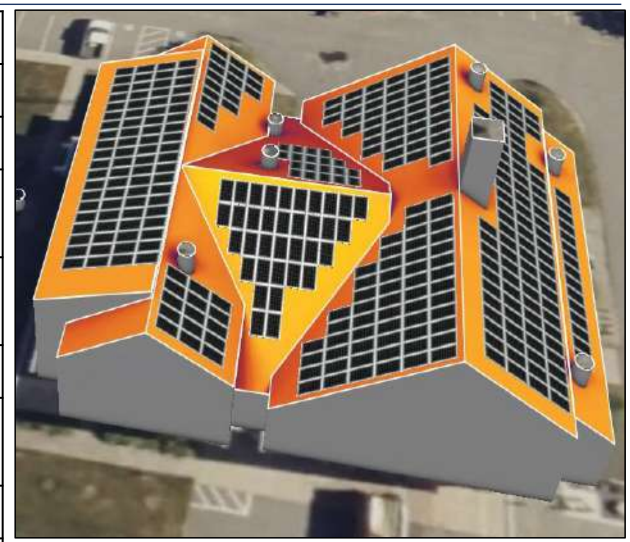
Equivalent to carbon sequestered by 167 acres of forest every year



Appendix G
Yarmouth Fire Station #3

Solar

Capacity	140 kW
Production (Y1)	159,829 kWh
% of annual electric usage	103%
ESA Rate* (20-year rate) (Utility rate is $0.235 / kWh)	$0.158 / kWh
Turnkey Installation Cost	$3.28 / W ($459,987)
Operations and Maintenance (O&M)	$1,701 / year
Inverter replacement, year 16 (Note: panel lifespan is 25 years)	$16,824
Operating Incentives	SREC modeled at $40
Notes	• *An alternative to self-purchasing the solar installation, an Energy Service Agreement can finance the project, with a rate escalating at 2% / year. • All designs are preliminary and conceptual • Capacity of roof to host solar must be verified • All references to solar installation size reflect kW_{pDC} unless otherwise noted



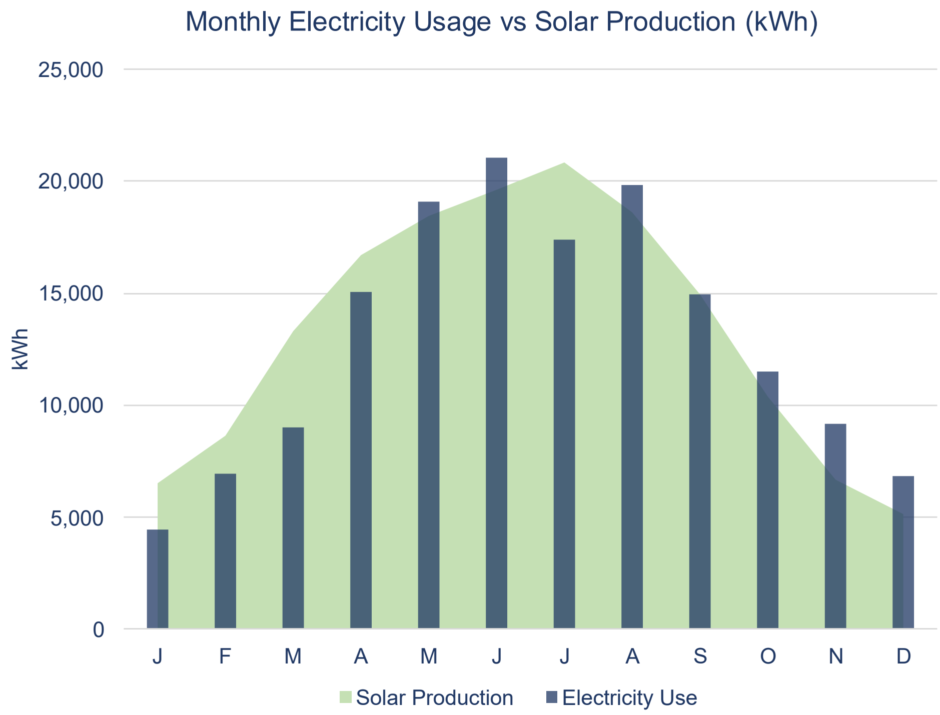
Proposed rooftop solar layout, image shown in North-up orientation. Panels are set to use the most productive roof space to the maximum extent possible.

Storage

Power	60 kW
Energy	123 kWh
Turnkey Installation Cost	$2,276 / kWh ($279,945)
O&M (software, maintenance)	$3,492 / year
Inverter/Module Replacement, year 12	$40,530
Operating Incentives	Connected Solutions
Location	Outside enclosure
Chemistry	Lithium-ion battery
Applications	✓ Peak shaving ✓ Resilience ✓ Demand Response Participation ✓ Time-of-Use Management
Notes	• All designs are preliminary and conceptual

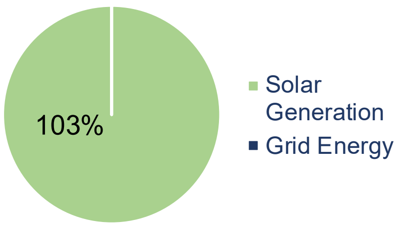
The battery module cabinet with its associated inverter is the height of a large refrigerator and has a footprint of a parking space. Clearances of 3-4 feet in front and on the inverter side cabinets are typically required for installation and maintenance. *(Note: this analysis is vendor-agnostic, and the example shown is meant to be representative, not a product recommendation).*

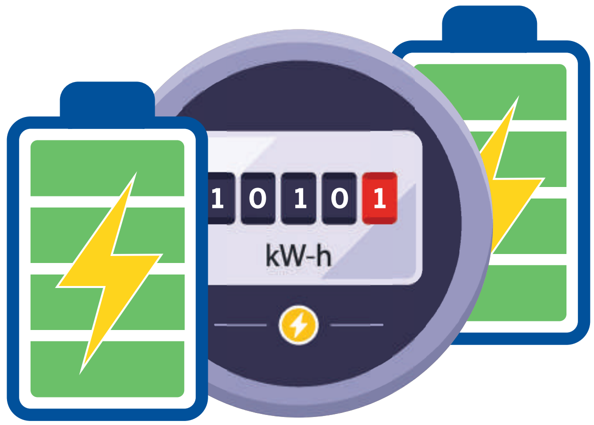
Sustainability Performance



Offsets 281,000 vehicle miles driven annually

Equivalent to carbon sequestered by 134 acres of forest every year





LOCATION, LOCATION, LOCATION

An economic comparison of large-scale batteries installed in front of vs. behind the meter in Massachusetts

AMERICAN MICROGRID SOLUTIONS

American Microgrid Solutions (AMS) is an award-winning microgrid development firm that delivers onsite power generation and storage systems for mission-critical facilities. AMS analyzes, designs, finances, and installs systems that reduce costs, strengthen resilience, and enhance sustainability. These systems integrate solar, batteries, conventional generation, and advanced control systems. The mission of AMS is to strengthen communities by developing and operating solutions that enhance savings, security, and sustainability. This mission is achieved using proprietary tools and processes that make it easy for understaffed facilities with limited budgets to install energy tools to make the communities they serve more resilient. Learn more at www.americanmicrogridsolutions.com.

CleanEnergyGroup

Clean Energy Group (CEG) is a national nonprofit organization working on innovative technical, economic, and policy solutions to accelerate the equitable deployment of clean energy technologies. By serving as a trusted partner for communities, advocates, and policymakers working at the forefront of the energy transition, CEG bridges critical gaps in the clean energy space through expert technical assistance, responsive guidance, and independent analysis. CEG collaborates with stakeholders across the country on the development of state, regional and federal policies that will support the equitable scale-up of energy storage. Learn more about Clean Energy Group's energy storage policy work at www.cleanegroup.org/initiatives/energy-storage-policy-and-regulation.

Clean Energy Group | 50 State Street, Suite 1 • Montpelier, VT 05602
802.223.2554 | www.cleanegroup.org | info@cleanegroup.org

© 2025 CLEAN ENERGY GROUP