MASSACHUSETTS CLEAN ENERGY CENTER

Clean Energy and Resiliency (CLEAR) Program

Final Report

Concord Street Microgrid Feasibility Study

City of Framingham, MA

WILLDAN

April 30, 2021

Acknowledgment

Willdan Group successfully completed the City of Framingham Concord Street Microgrid Feasibility Study. This project is funded by the Massachusetts Clean Energy Center Clean Energy and Resilience (CLEAR) program. At Willdan, we believe Commonwealth communities' critical infrastructures can become the islands of resiliency. We committed to developing a clear roadmap for local government facilities and used the City of Framingham's critical infrastructures as an early adopter. This roadmap results from months of successful collaboration among community stakeholders, including the City of Framingham department, MassCEC team, Eversource, technology vendors, and Willdan group teams, including Willdan Smart Cities and Willdan Financial Services, Integral Analytics, and E3.

On behalf of the members of this project, Willdan would like to thank Ariel Horowitz, Senior Program Director, Rhys Webb, and Rees Sweeney-Taylor, Net Zero Grid Program Managers, Steve Casey, Eversource Energy, various City of Framingham departments led by Shawn Luz, City of Framingham Sustainability Coordinator for making this work possible. The many tasks of this work could not have been completed without the dedicated effort of Todd Isherwood, Project Manager; Dr. Wei Tian, Lead Engineer; Molly McKay, Managing Partner; and David Nissenson, Principal.

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Acronyms and Abbreviations

ACP	Alternative Compliance Payment
ADA	Americans with Disabilities Act
BOT	Build-Operate-Transfer
BRIC	Building Resilient Infrastructure and Communities
CSCRS	Concord Street Community Resiliency System
CIP	Capital Improvement Planning
CLEAR	Clean Energy and Resiliency
C&CB	Capability and Capacity Building
CWSRF	Clean Water State Revolving Fund
CPEC	Clean Peak Energy Credit
CPS	Clean Peak Standard
DER	Distributed Energy Resource
EEA	Energy and Environmental Affairs
ESA	Energy Service Agreement
ESPC	Energy Savings Performance Contract
FCM	Forward Capacity Market
FHA	Framingham Housing Authority
FMS	Fuller Middle School
FS5	Fire Station #5
GF	General Fund
ICAP	Installed Capacity Reduction
ICP	Installed Capacity Tag
IOU	Investor-Owned Utility
ITC	Investment Tax Credit
IRS	Internal Revenue Service
MassCEC	Massachusetts Clean Energy Center
FB	Farley Building (Represented by the Mass Bay Community College and Framingham Public Schools)
MACRS	Modified Accelerated Cost Recovery System
MCES	McCarthy Elementary School
MCTS	Microgrid Controller Technology Stack
MEMA	Massachusetts Emergency Management Agency (MEMA)
NG	Natural Gas
OWOW	Office of Wetlands, Oceans, and Watersheds
PACE	Property Assessed Clean Energy
PPA	Power Purchase Agreement
PPP	Public-Private Partnerships
RNS	Regional Network Services
SMART	Solar Massachusetts Renewable Target
SHMCAP	State Hazard Mitigation and Climate Adaptation Plan
SRF	State Revolving Funds

Executive Summary

The Massachusetts Clean Energy Center (MassCEC) is a state economic development agency dedicated to accelerating the growth of the clean energy sector across the Commonwealth to spur job creation, deliver statewide environmental benefits, and secure long-term economic growth for the people of Massachusetts. MassCEC works to increase the adoption of clean energy while driving down costs and delivering financial, environmental, and economic development benefits to energy users and utility customers across the state.

MassCEC's mission is to accelerate the clean energy and climate solution innovation that is critical to meeting the Commonwealth's climate goals, advancing Massachusetts' position as an international climate leader while growing the state's clean energy economy. Resilience refers to the ability of a system or its components to adapt to changing conditions and withstand and rapidly recover from disruptions, i.e., the ability to recover from a disturbance. The electrical and thermal infrastructure is vulnerable to many phenomena, such as hurricanes, earthquakes, drought, wildfire, flooding, extreme temperatures, etc. Some extreme weather events have become frequent and severe due to climate change.

MassCEC's Clean Energy and Resiliency ("CLEAR") Program[1] is focused on identifying community resiliency projects that reduce GHG emissions, integrate renewable energy sources, and provide energy resilience for critical facilities during outages. The program is a successor to the Community Microgrids Program, which funded fourteen (14) feasibility studies to identify scalable, broadly replicable microgrid business and ownership models to increase microgrid deployment and attract investment. DOE defines a microgrid as "a group of interconnected loads and distributed energy resources within clearly defined electrical boundaries that acts as a single controllable entity for the grid." [2]

This Massachusetts Clean Energy Center's Concord Street Resiliency Community Study evaluated the technical feasibility and commercial/financial opportunities for a municipal resiliency system at Concord Street in the City of Framingham.

The feasibility study evaluated renewable energy installations, in partnership with the public energy and natural gas utility, Eversource Energy, at the following properties ("stakeholders"):

- Fuller Middle School (FMS): FMS is a newly-constructed campus commissioned in the Fall of 2021 with planned backup generation and onsite solar PV with battery storage.

  FMS has one natural gas (NG) fueled backup generator with a capacity of 300 kW. FMS also has a PPA contracted for a solar PV (499.8 kW) system and battery (250 kW/496 kWh) project to be installed in the near future.
- Farley Building (FB): FB, which the Framingham Public School District owns, is a four-level, 112,000 square-foot facility situated adjacent to the new FMS. In addition to the Framingham Public School District staff, the FB currently houses a campus of the Mass Bay Community College. The building has a 45 kW generator that powers critical life safety systems such as emergency lighting.
- McCarthy Elementary School (MCES): MCES is a two-story, 94,936 square-foot facility across the street from the FB. It currently houses a significant portion of the Framingham School District's network hub.

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[1] https://www.masscec.com/clean-energy-and-resiliency-clear

[2] https://www.energy.gov/sites/prod/files/2016/06/f32/The%20US%20Department%20of%20Energy's%20Microgrid%20Initiative.pdf

MCES has a 100 kW onsite NG-fired backup generator to power emergency lighting, an elevator, and lift safety equipment.

- Fire Station #5 (FS5): FS5 is a 7,728 square-foot, two-story facility located at 520 Concord Street. FS5 has a 55-kW backup natural gas generator. The site also has 1,000 gallons of onsite fuel storage to support station vehicles and equipment.
- Framingham Housing Authority (FHA): FHA facilities selected for this study include three sections of housing, which contain approximately 314 units (120 units at section 667-5, 84 units at section 667-6, and 110 units at Section 28-2 on John J. Brady Drive), and 32 buildings (Rose Kennedy Lane and John J. Brady Drive). FHA includes federal and state housing that serves low-income, elderly, and disabled residents. FHA has a 30 kW diesel backup generator with 150 gallons of onsite fuel to backup the community room and an office during a grid outage.

The total existing generation capacity is 530 kW. The new distributed energy resource generation proposed in this study includes solar plus battery installations at all the stakeholders' locations.

The resiliency-focused community microgrid is proposed to interconnect with the Eversource Energy electrical distribution system to achieve the resiliency, environmental, and economic objectives of the MassCEC CLEAR Program.

The technical solution recommends a solar PV capacity of 1,693 kW and battery storage capacity in the range of 0.39 MW/1.56 MWh (for economic purposes) and 1.5 MW/6 MWh (for maximum resiliency purposes). A Combined Heat and Power (CHP) solution is not considered in this report since this CLEAR program is mainly focused on using clean energy to promote community resiliency.

The current annual energy costs and CO_2 emissions for the existing loads are calculated to be $1.58 million and 3,099 metric tons, respectively. This represents the baseline for the proposed microgrid solution. The proposed community microgrid would have a 28.6% annual energy cost saving and 13.7% annual CO_2 emissions saving compared with the base case. The annual CO_2 emission reduction compared to the base case is 426 metric tons.

The recommended course of action, given reasonable funding limit projections, is to pursue each of the components of the proposed microgrid separately and then eventually tie them together into a community microgrid if conditions warrant. Interconnection to the utility grid be an important step in the process. With the federal and state incentives, solar installation is suggested whenever it is available. If an attractive power purchase agreement (PPA) can be developed, then the solar-battery combined system installation will offer economic advantages and environmental benefits.

In order to utilize federal/state tax incentives such as the investment tax credit (ITC) on the proposed solar and battery storage installations, an owner must have a tax liability. The community microgrid could be owned jointly by the stakeholders (in a special-purpose vehicle), a third-party financier, or partly owned by the utility (battery storage). Since all the stakeholders are public or nonprofit entities, a third-party special-purpose entity or Power Purchase Agreement (PPA) owner will likely be developed to own and manage the microgrid. This report refers to the special-purpose entity as the Concord Street Community Resiliency System (CSCRS) owner. The microgrid participants will then develop and determine long-term agreements to purchase power from the microgrid owner/operator.

A financial feasibility analysis was conducted to evaluate the City of Framingham’s position in a PPA deal structure by measuring the respective capital inflows and outflows to both the City (Host) and the third-party PPA provider. The resulting capital inflows and outflows indicate strong financial positions for both the PPA provider and the City/Host.

The PPA provider's internal rate of return (assuming an all-cash deal) equates to 17.9 percent and a net present value of $2.64 million, calculated using a discount rate of 8.25%. The city's cash flow over the 20-year term is estimated at $1.9 million, generating a net present value of $1.36 million when discounted at a rate of 3.0 percent annually.[3]

Depending upon the availability of funding and the financial situation for the overall project, and for each of the stakeholders, Willdan recommends that the proposed resiliency-focused community microgrid proceed with small-scale pilot projects at each of the target locations/assets to test the technical and economic viability of the microgrid power that would be subsequently integrated into a community microgrid.

As shown in Figure 1, all the stakeholder locations are fed by the 13.8kV feeder. This configuration serves to reduce the complexity of community microgrid islanding and interconnection.

However, PPA-financed solar and battery are being installed on the FMS campus, creating an extra layer of uncertainty regarding the feasibility of including FMS as part of the proposed community microgrid. Further negotiations would be needed between the City and the potential CSCRS owner to fully evaluate the integration of the PPA-based DER resources required to improve the overall economics and resiliency of the system.

Due to the distance between FS5 and the other proposed facility locations, the system would need switches/breakers to isolate the connected loads between FS5 and FHA during the islanded mode, resulting in complicated control/operations and higher infrastructure upgrade costs. The overall upgrade cost could reach a range of $150,000-$300,000 depend on the complexity. It is recommended that FS5 run independently as an ancillary building microgrid, operating separately from the overall community microgrid and utilizing local distributed energy resources on the property.

Figure 1 is the final concept of the proposed community microgrid, which is the result of the detailed assessment of the existing system and consideration of the different stakeholders' needs, requirements, goals, and operational constraints. The applied methodology and strategy will be fully elaborated in the following sections.

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[3] The discount rate of 3.0 percent reflects the relatively lower cost of municipal capital from the perspective of the City of Framingham in comparison to private commercial rates.

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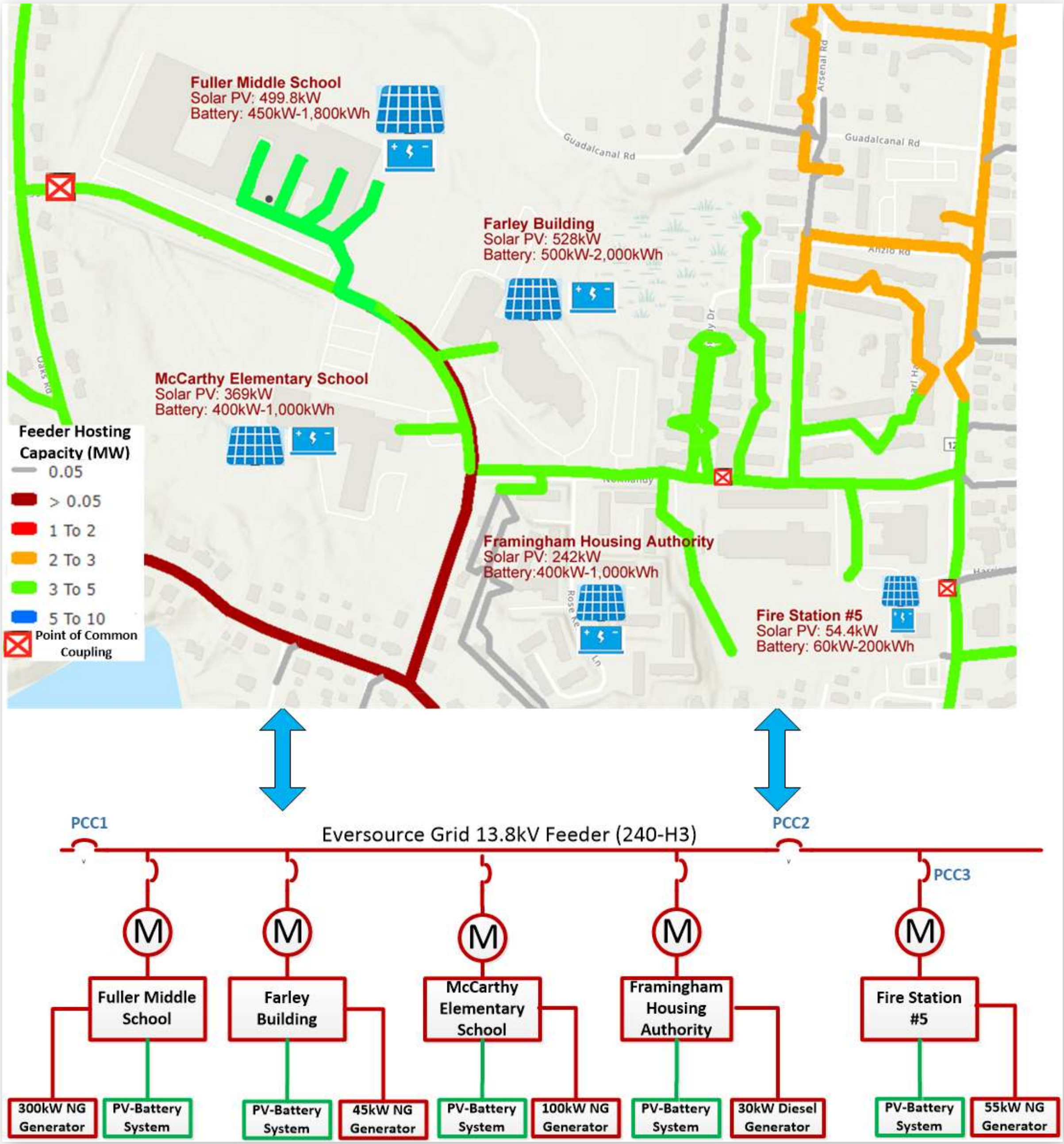
Figure 1. Concord Street Community Resiliency System Concept Configuration (Top chart shows the feeder map, hosting capacity, stakeholders' locations and suggested DERs; Lower Chart shows the simplified configuration)



1. Introduction

Framingham, Massachusetts, was incorporated as a town on June 25, 1700, then adopted a home rule charter and transitioned to a City on January 1, 2018. The branches of government include the executive (Mayor) and legislative (City Council). Also, an elected School Committee oversees the nine districts in Framingham.

The City of Framingham (the City) recognizes the escalating threat that climate change poses to its critical facilities and the greater community that it serves. Natural hazards have already resulted in emergency events such as utility outages, highlighting local infrastructure vulnerabilities. The current energy distribution system contributes to greenhouse gas emissions and leads to higher energy costs. In 2018, the City hosted a Community Resilience Building Workshop through the Municipal Vulnerability Preparedness Program that identified energy resiliency improvements as one of its most crucial priorities. The City has already taken steps towards addressing these climate threats by creating a Sustainability Committee and Internal Energy Working Group. The City also has an energy efficiency outreach program, participates in an energy demand-response program, and is developing municipal solar PV projects. The City is also currently working on updating its Multiple Hazard Mitigation Plan. The MassCEC CLEAR study hopes to provide another opportunity to address community energy resiliency.

The goal of this CLEAR study is to report on the site assessment, identify resiliency needs, develop preliminary technical design and configuration, assess the commercial and financial feasibility and perform the cost-benefit analysis for a community microgrid anchored at Concord Street in the City of Framingham. Willdan Energy Solutions (Willdan) is the lead technical consultant retained by MassCEC to perform the analysis and navigate the study team through the community microgrid evaluation. The CLEAR study team includes Willdan, FMS, FB, MCES, FS5, FHA, and Eversource Energy.

The primary goals of the study are to determine how a microgrid system at this grouped location could (1) increase the fuel diversity of municipal facilities to improve the resiliency of their critical infrastructure, (2) achieve greater integration of clean energy technologies to reduce greenhouse gas emissions, and (3) cut energy costs.

The MassCEC CLEAR study seeks to build on the resilience-focused energy planning programming started during MassCEC’s Community Microgrid Feasibility Studies. Identifying technical and

ECONOMIC BENEFITS OF RESILIENCY

Energy resiliency is achieved through the preparation, operation, and subsequent recovery from extreme weather and other prolonged adverse events that disrupt the provision of reliable power.

Businesses rely on a regular supply of energy and contingency measures in the event of a power failure. Causes of resiliency issues include power surges, weather, natural disasters, accidents, equipment failure, and human operational error.

Businesses with access to reliable energy are better insulated against energy price increases or fluctuations in supply. Resiliency planning enables businesses to avoid shutdowns of important processes that impact their delivery of goods or services.

While most power outages are short-term in nature, there is a clear trend in the increasing number of large-scale natural weather events that trigger broader, longer-term disruptions.

Critical public health and safety operations such as health care, senior centers, and emergency services particularly rely on resilient energy systems to protect their communities.

The study will create the body of data on costs and system designs needed to create resilient facilities. An additional goal is to provide a replicable pathway for customers to assist utilities in outage recovery events. The study may also identify barriers, therefore helping inform future energy-related policy decisions.

investment solutions will enable critical loads to "ride through" interruptions in grid service and save productivity losses.

Following the execution of the proposed work plan and scope of work, this final feasibility study report summarizes the findings from all tasks and is organized as follows:

- Section 2 presents the project initiation and site assessment (Task 1).
- Section 3 identifies the resiliency needs or requirements of each of the stakeholders (Task 2).
- Section 4 presents the preliminary technical design costs and configuration (Task 3).
- Section 5 discusses the commercial and financial feasibility assessment as well as the cost-benefit analysis (Task 4).

Section 6 summarizes the major findings and recommendations of the feasibility study (Task 5).

2. Project Initiation

2.1 Introduction

The proposed Concord Street Community Resiliency System incorporates municipal and community facilities and involves the Framingham Public Schools, Framingham Fire Department, FHA, and FB.

This section reviews and describes the existing site assets, including energy usage, generation resources, etc. that were applied in the proposed resiliency study. The assessment included a review of the existing documents such as the City's Municipal Vulnerability Plan (MVP) program, the Hazard Mitigation Plan, maps, and building layouts. Generation resource load information, energy demand uses and requirements, and preferred microgrid characteristics provided a baseline for this MassCEC CLEAR study.

2.2 Relevant Reports and Background Information

The technical team has received and reviewed the following reports/documents related to this resiliency study.

1. Town of Framingham Multiple Hazard Mitigation Plan (2017 Update)[4]
2. City of Framingham-Community Resilience Building Workshop Summary of Findings (May 2019)[5]
3. Town of Framingham Master Plan Part 2: Master Land Use Plan (September 2014)[6]
4. Concord Street Flood Map[7]
5. City of Framingham Municipal Energy Initiatives[8]
6. Framingham Public School Emergency Response Plan (February 2016)[9]

Flood, wind, fire, earthquake[10], winter storms/blizzards, and extreme temperatures are identified as the primary potential hazards that might impact the resilience of this area’s energy system.

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[4] https://www.framinghamma.gov/DocumentCenter/View/27116/FINAL-MHMP-Update-2017_04072017
[5] https://www.framinghamma.gov/DocumentCenter/View/35478/English_EEA_Report_Framingham
[6] https://www.framinghamma.gov/DocumentCenter/View/5236/Master-Plan-Update-Sept-2012?bidId=
[7] www.resilientma.org/map
[8] https://www.framinghamma.gov/2743/Municipal-Programs-Initiatives
[9] https://www.framingham.k12.ma.us/cms/lib/MA01907569/Centricity/Domain/68/Emergency%20Response%20Plan%20SY14-15%20revision.doc
[10] https://www.framinghamma.gov/DocumentCenter/View/27116/FINAL-MHMP-Update-2017_04072017

The data and information identified in this section will be integrated with the technical and financial solutions in later tasks.

2.3 Stakeholder Group Meeting

The technical team has conducted several stakeholder meetings, including meetings with the local electric utility provider (Eversource Energy) within the project period. The technical team met with the stakeholders two times during Task 1. The stakeholder meetings are summarized in Table 1.

Table 1. Meeting Summary

Meeting	Date	Participant	Topic
Stakeholder Meeting-01	07/21/2020	MassCEC, City of Framingham, FHA, Framingham Fire Department, Framingham Public School (FPS), FB, Willdan Group	Introduction meeting and kickoff
Stakeholder Meeting-02	09/24/2020	MassCEC, City of Framingham, FHA, FFP, FPS, Willdan Group	All stakeholder meeting
Stakeholder Meeting-03	10/29/2020	MassCEC, City of Framingham, FHA, FFP, FPS, FB, Willdan Group	RFI and resiliency survey review, and questions from the Framingham MVP Report
Stakeholder Meeting-04	03/10/2021	City of Framingham, Willdan Group	Financial stakeholders meeting
Stakeholder Meeting-05	04/20/2021-05/20/2021	MassCEC, FHA, City of Framingham, PWD, FFD, FPS, Willdan Group	Series of meetings for high-level overview of the potential solution
Stakeholder Meeting-06	08/03/2021	City of Framingham, Willdan Group	Second financial stakeholders meeting
Eversource-Willdan Meeting-01	11/10/2020	MassCEC, Eversource Energy, Willdan Group	RFI review and discussion
Eversource-Willdan Meeting-02	01/22/2021	Eversource Energy, Willdan Group	RFI review and discussion
Eversource-Willdan Meeting-03	05/19/2021	MassCEC, Eversource Energy, Willdan Group	Overview of resiliency expectations, planning and operation, and community microgrid configuration.
Eversource-Willdan Meeting-04	10/06/2021	MassCEC, Eversource Energy, Willdan Group	Review refined concept of the technical solution at Concord Street

2.4 Critical Asset Assessment

A summary of the stakeholders' information is listed in Table 2. Each stakeholder location and its existing generation assets are shown in Figure 2. The potential locations for new generation assets for each location are identified in Figure 3. The electricity usage percentage for each of the sites is shown in Figure 4.

Table 2. Stakeholder Summary

Stakeholder	Critical Facility[11]	Building Sq. Ft.	Annual Electricity Usage (kWh)	Backup Generation (kW)
FMS	Tier 2	137,100	919,478 (Estimated)	300
MCES	Tier 2	94,936	433,272	100
FB	Tier 2	112,000	1,254,480	45
FS5	Tier 1	7,728	81,659	55
FHA	Tier 2/1	806,250	4,960,415	30

The summary of annual energy usage and cost is presented in Table 3. The monthly use and cost for both natural gas and electricity are presented in Section 2. MCES, FB, and FHA have 5-min interval electricity load data. Only monthly bill data, including use and cost, are available for FS5. The energy usage and cost data for FMS are based on the best estimation from the City's design engineer.

Table 3. Energy Usage and Cost

Stakeholder	Annual Gas Usage (Therms)	Annual Gas Cost ($)	Annual Electricity Usage (kWh)	Annual Electricity Cost ($)	Hourly Electricity Load Data
FMS	26,459	19,572	919,477 (Estimated)	198,560	Not Available
MCES	35,376	31,045	433,272	105,117	Available
FB	20,397	6,266	1,245,480	245,437	Available
FS5	4,423	4,459	81,659	15,983	Not Available
FHA	201,129	71,815	4,960,415	888,245	Available

The technical team visited the five sites and toured the Concord Street study site's surrounding area on November 24, 2020. Todd Isherwood (Willdan) and Shawn Luz (City of Framingham) met with personnel from the City of Framingham's Fire Department, Public Schools, FB, and FHA (FHA). FHA, which contributes 65% of the total electricity consumption, is the largest electricity user of the group.

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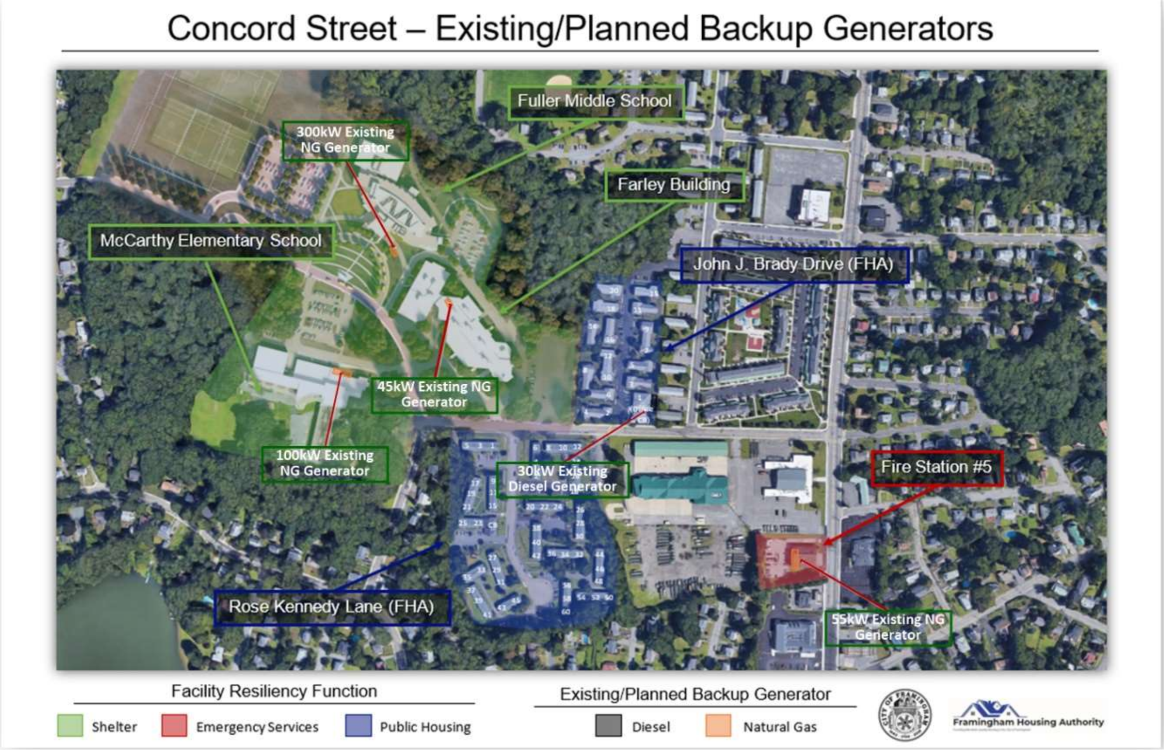
[11] Tier 2 assets are regionally and nationally significant critical infrastructure and key resources (CIKR); Tier 1 assets and systems are a subset of Tier 2 and are capable of causing the greatest adverse consequences, defined by the Homeland Infrastructure Threat and Risk Analysis Center (HITRAC), https://www.dhs.gov/xlibrary/assets/nipp_srtltt_guide.pdf

Figure 2. Concord Street Stakeholders & Existing Backup Generator Locations

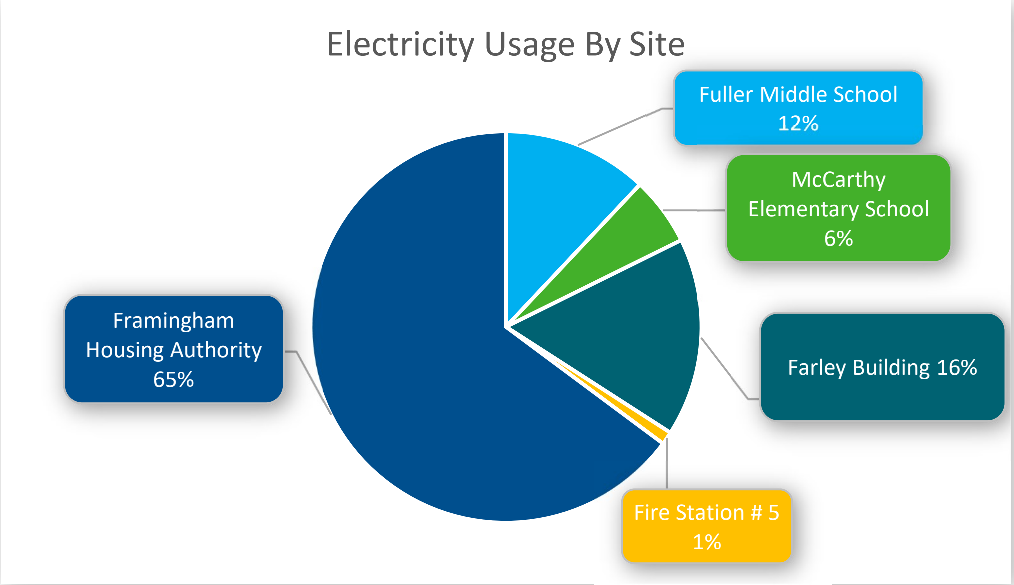


Source: City of Framingham, 2021

Figure 3. Potential Resiliency Solution

Source: City of Framingham, MA, 2021

Figure 4. Concord Street Stakeholders Electricity Usage Contribution Percentage



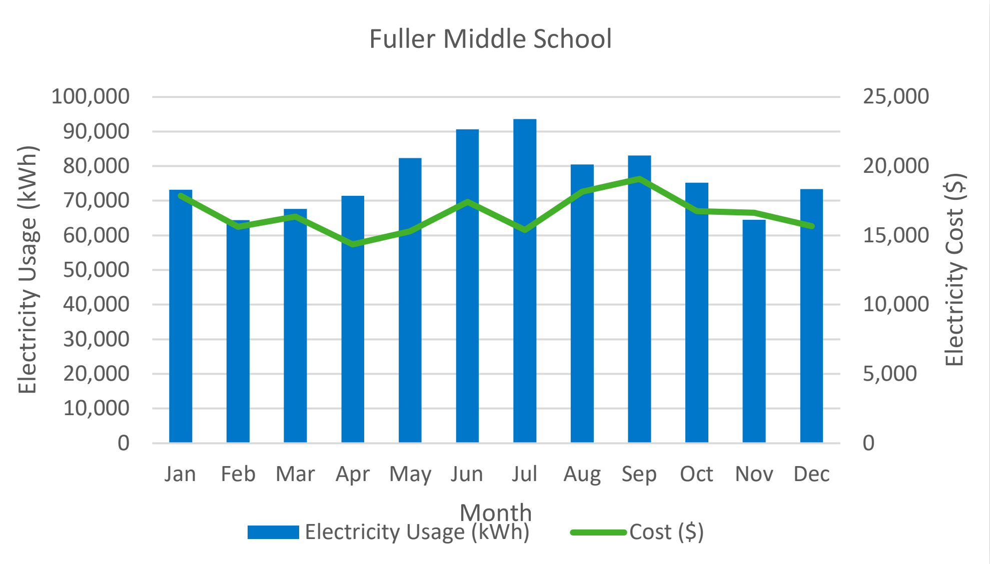
2.4.1 Fuller Middle School

FMS pictured in Figure 4, was under construction when visited in November 2020; construction was completed in the Fall of 2021 (the team did not visit this location). The existing school (observed in operation) was demolished after the new school (observed under construction) was commissioned.

The team's RFI answered most of the questions about the new site. All construction documents are in the team's possession.

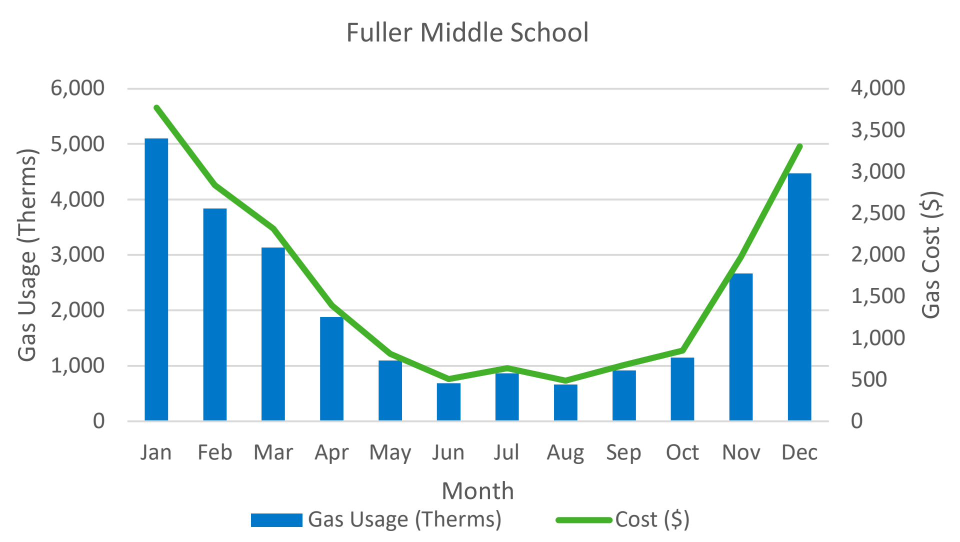
Figure 5. FMS (Opened as of September 2021)

Figure 6. FMS Monthly Electricity Usage and Cost (Estimated and Provided by Stakeholder)



All locations identified by the City for solar canopies in parking lots have potential. An additional potential solar PV area was identified on the new parking lot just west of the new school (where the old school currently is located); however, there are potential environmental challenges on this site that should be addressed before the solar installations. The estimated monthly electricity/gas usage and cost are shown in Figure 6 and Figure 7, respectively. The estimated monthly average electricity usage and cost are 76,623 kWh and $13,026, respectively. The monthly gas usage and cost are 2,205 therms and $1,631, respectively. The estimated average electricity demand is 105kW.

Figure 7. FMS Monthly Natural Gas Usage and Cost (Estimated and Provided by Stakeholder)



2.4.2 McCarthy Elementary School

Figure 8. MCES

As shown in **Figure 8**, MCES is a two-story, 94,936 square-foot facility across the street from FB. It currently houses a significant portion of the Framingham School District's network hub. The facility receives backup power from a 100 kW natural gas-fired generator.

The following site observations were compiled from a site walkthrough and conversations with Tim Rivers of the Framingham School Department.

- Two natural gas-fired boilers for heating are in a mechanical room below grade. They are vulnerable to rainwater flooding during severe storms.
- One gas-fired backup generator onsite serves the emergency lights, elevator, and life safety equipment.
- The building is not centrally cooled. Only two small direct expansion (DX) systems are used for the computer room. Two air-handling units are used for the gym only.
- The main computer room hosts a server farm that supports one-half of the public school's IT network. This room has split-system cooling that is backed up by the generator.
- The facility is not considered to be a shelter.
- The building management system uses American Energy Management (AEM) controls, which are the standard across the school's real estate portfolio, except for the FB, and can be accessed remotely (off-site).
- One pneumatic control exists on the boilers' mixing valve. One air compressor is on-site to serve the mixing valve control. All other controls are digital.
- The site lighting is LED, and building lights in the school have LEDs.
- All locations identified by the City for solar canopies in parking lots have potential. An additional area for solar PV has been identified on the school roofs; however, capital infrastructure improvements may be necessary to support the solar PV deployment.

- There is ample space for outdoor energy storage/battery locations.
- Combined heat and power is a potential option for this location.
- A sump pump is running continuously in the mechanical room to keep water out of the building.
- Recently added air purifiers during COVID-19 conditions may add load to the electrical system.

The monthly electricity/gas usage and costs are shown in Figure 9 and Figure 10, respectively. The monthly average electricity usage and cost are 36,106 kWh and $8,760, respectively. The average electricity demand is 49.5 kW. The monthly gas usage and cost are 2,948 therms and $2,587, respectively.

Figure 9. MCES Monthly Electricity Usage and Cost in 2019

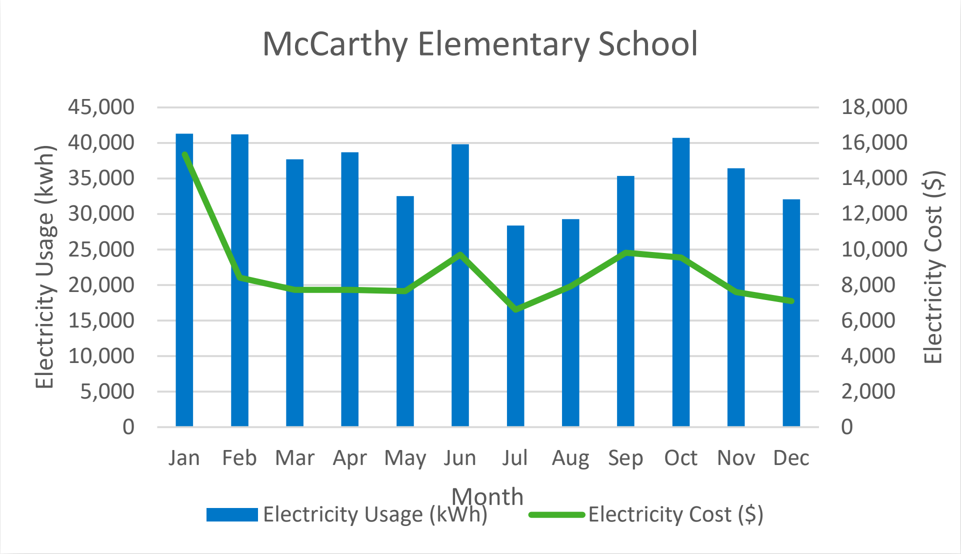
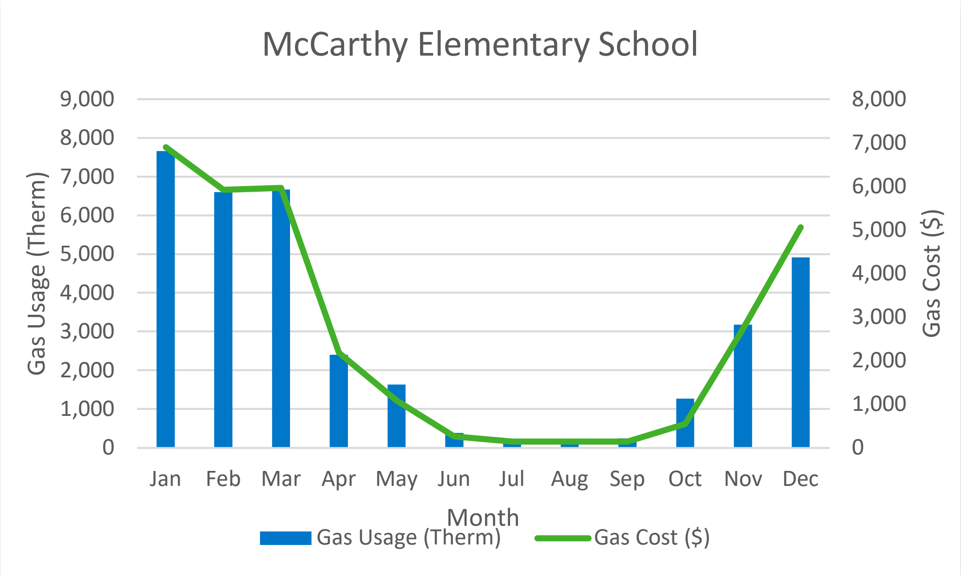


Figure 10. MCES Monthly Natural Gas Usage and Cost in 2019



2.4.3 Farley Building

The FB, shown in **Figure 11,** is owned by the Framingham Public School District. It is a four-level, 112,000 square-foot facility situated adjacent to the new FMS. It receives minimal backup power from a 45 kW natural gas-fired backup generator that powers emergency lighting.

Figure 11. FB

The following site observations were compiled from a site walkthrough and conversations with Tim Rivers of the Framingham School Department and Andy Tobin from Mass Bay Community College.

- The primary use for this building is teaching and training in Health Sciences for Mass Bay Community College, as well as providing office spaces for the School Administration and Buildings and Grounds staff. Mass Bay Community College's nursing program is one of the top-rated nursing programs in the Commonwealth. The certificate programs for paramedics and EMTs are also provided at this location. The facility will also be the home of the Framingham Public Schools Welcome Center for parents and families.
- The cooling unit sizes vary and include various three-ton and twenty-ton roof-top units.
- The mechanical room has one gas-fired domestic water heater for bathroom sink use.
- One natural gas-fired backup generator provides power to emergency lights only.
- There is no diesel on this site.
- Electric baseboard heat is located at all building entries and in the library. Some inline duct electric resister coils supplement heating for the building.
- The building management system uses Carrier iView and automated logic.
- The site and building lights are of older vintages. Many T-12 Fluorescent lamps were observed.
- The parking locations identified by the City for solar canopies in parking lots have potential. An additional area for solar PV is on the school's roofs. However, it should be noted that capital infrastructure improvements may be necessary to support the solar PV deployment.
- There is plenty of space for outdoor energy storage/battery locations.
- The City of Framingham IT department has installed a new computer server farm at this location. They are not backed up on the generator.
- There is no potential for combined heat and power (CHP) (no water loop).
- This building is not sprinklered.

- This building is not a shelter location.

The monthly electricity/gas usage and cost are shown in Figure 12 and Figure 13, respectively. The building's average monthly electricity usage and cost are 104,540 kWh and $18,158, respectively. The average electricity demand is 143kW, and the peak demand is 368 kW. The monthly gas usage and cost are 1,700 therms and $522, respectively.

Figure 12. FB Monthly Electricity Usage and Cost in 2019

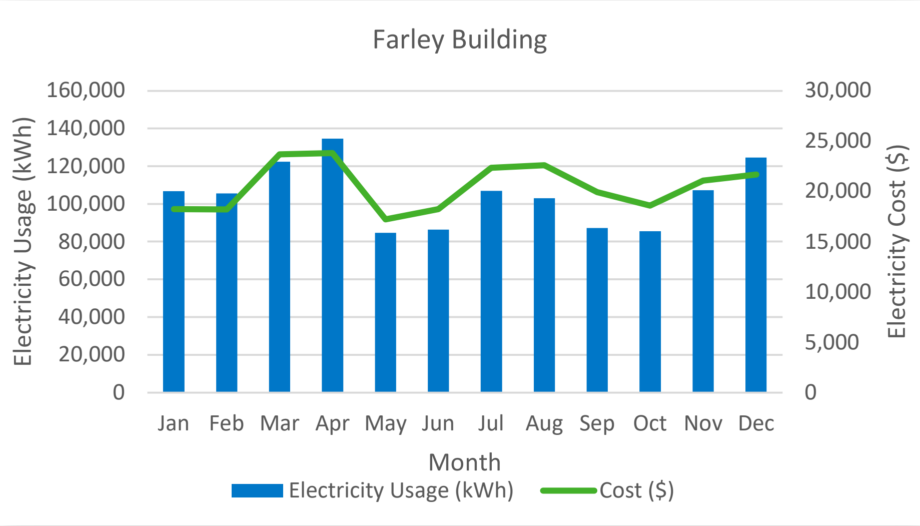
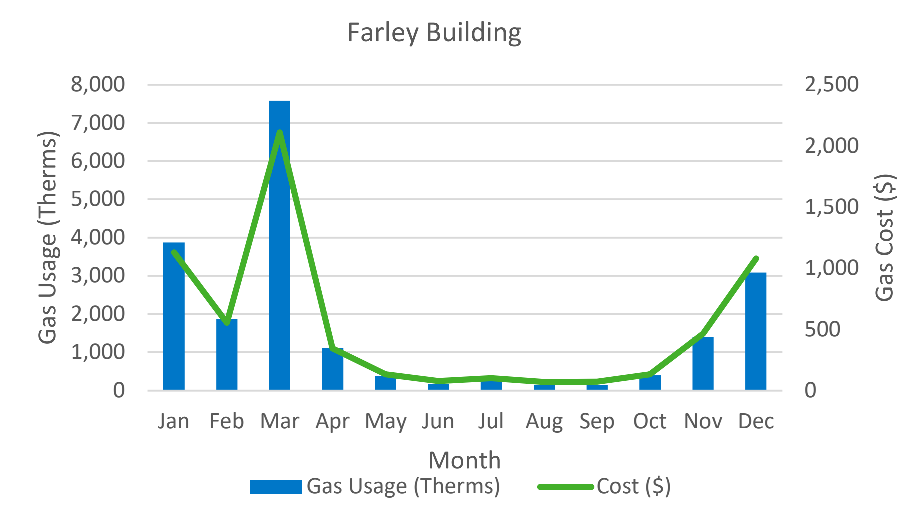


Figure 13. FB Monthly Natural Gas Usage and Cost in 2019[12]



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[12] Farley Building 2019 Gas Bills

2.4.4 Fire Station #5

Shown in **Figure 14**, FS5 is a 7,728-square-foot, two-story facility located at 520 Concord Street, bordering the Army National Guard facility and close to the FHA.

The following site observations were compiled from a site walkthrough and conversations with Dana Haagensen of the Framingham Fire Department.

- The primary purpose of this facility is emergency response.
- One natural gas-fired boiler for heating and a domestic water heater are in a mechanical room.
- Heat pumps provide cooling and supplemental heating for the majority of the facility.
- One natural gas-powered backup generator. The entire facility is backed up.
- This station has a diesel fuel storage tank on-site with a pumping station to fill vehicles and other equipment. The storage tank capacity is approximately 1,000 gallons.
- There are no automatic garage door closers. Open doors have contributed to high energy use to mitigate ambient air temperature entering the garage if the doors are not closed.
- This facility has residential uses, including sleeping quarters, men's and women's locker rooms and showers, and kitchen, laundry, gym, and lounge/entertainment areas.
- The building management system uses AEM Controls.
- The building was constructed in 1961.
- The roof and parking lot have the potential for solar PV (flat), if some trees were removed from the parking lot.
- Limited real estate may be available as an outdoor energy storage/battery location. The potential site is between the fire station and the adjacent Army National Guard parking lot.
- Recently added air purifiers during COVID-19 conditions may add load to the electrical system.

Figure 14. Framingham FS5

The monthly electricity/gas usage and cost are shown in Figure 15 and

Figure 16, respectively. Their average monthly electricity usage and cost are 7,346 kWh and $718, respectively. The average electricity demand is 10kW. The monthly gas usage and cost are 407 therms and $395, respectively.

Figure 15. FS5 Monthly Electricity Usage and Cost in 2019

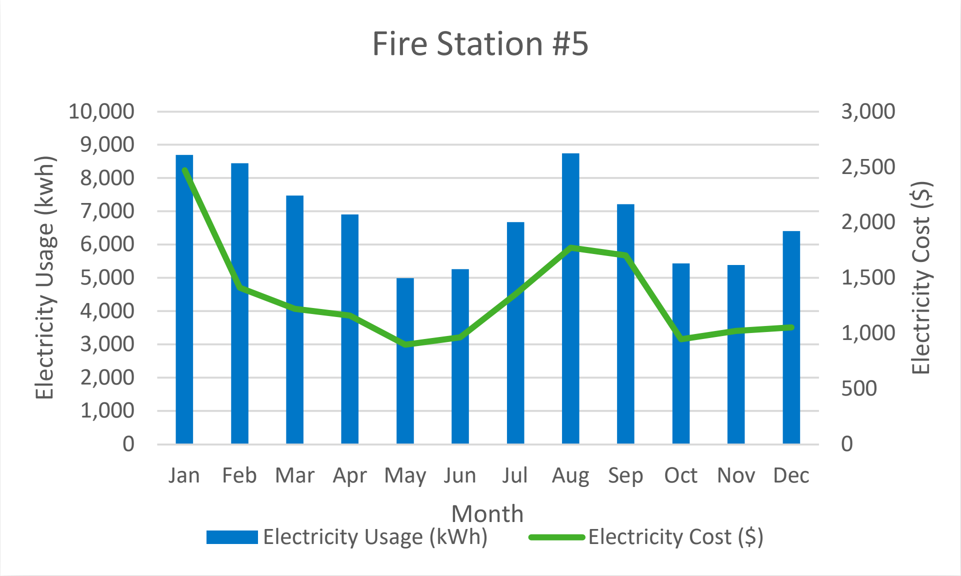
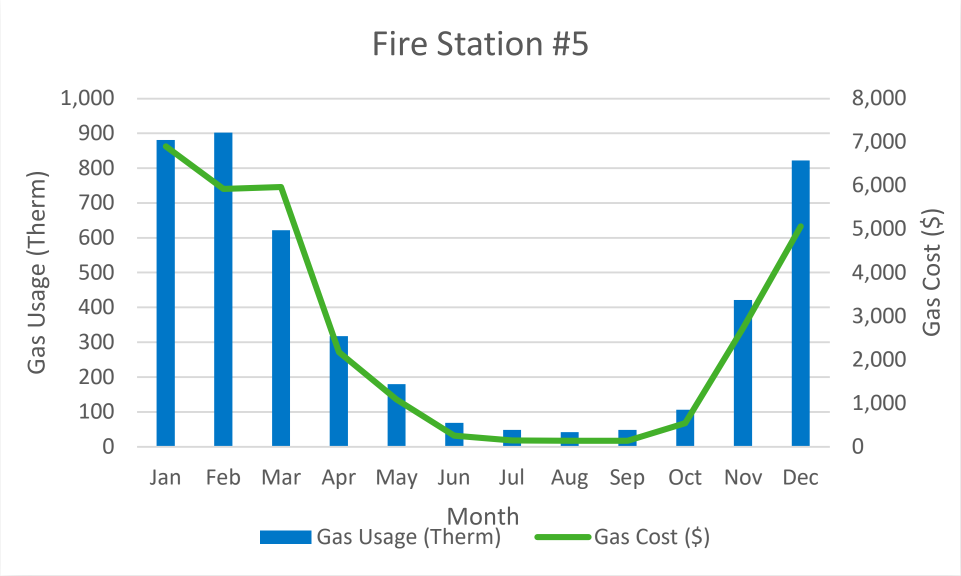


Figure 16. FS5Monthly Natural Gas Usage and Cost in 2019



2.4.5 Framingham Housing Authority

As shown in Figure 17, the FHA comprises two sections, which contain approximately 314 units (120 units at section 667-5 of Rose Kennedy Lane, 84 units at section 667-6 of Rose Kennedy Lane, and 110 units at Section 28-2 on John J. Brady Drive). The site includes federal and state housing that serves low-income, elderly, and disabled residents. One building on Brady Drive contains the neighborhood's community room and serves as the FHA's primary office. The average one-bedroom apartment is 550 square feet. The average two-bedroom apartment is 775 square feet.

Figure 17. FHA

The following site observations were compiled from a site walkthrough and conversations with Paul Landers, Kristin Davis, and Mike Fisher (electrician) of the FHA.

- The primary purpose of this site is residential use. The FHA staff offices and two community rooms are located at this site.
- The FHA controls over 11,000 units in its portfolio across the City of Framingham. This study includes 14 multi-unit buildings on John Brady Drive and 18 multi-unit buildings on Rose Kennedy Lane. Each 2-story multi-unit building typically consists of 12 dwellings.
- All the John Brady units provide electric baseboard heating and electric appliances. The two water heaters for the building are 85-gallon electric units.
- All the John Brady units can install through-the-window or the wall (cut-outs) plug-in air-cooling units.
- There is no natural gas connection at the John Brady site.
- The community room at John Brady Drive is heated with a forced hot-air distribution.
- The community room at John Brady Drive has two mini-chiller units to provide cooling.
- Each residential building and the John Brady Drive office building have various coin-operated clothes, washers, and dryers. Only the gas-fired units on Rose Kennedy have a gas-fired clothes dryer.
- The Brady Drive community room contains one diesel-powered backup generator. It has 150 gallons of diesel fuel to run for 48 hours. The FHA has a contract in place to refuel. The generator provides backup for the entire community room and offices.
- The community room at John Brady Drive serves as a warming and cooling shelter. It can hold half the residences located on John Brady Drive.
- There are 10 units on Rose Kennedy Lane heated with electric baseboard. They have electric appliances like the John Brady units. The two water heaters for the building are 85-gallon electric units.
- There are eight units on Rose Kennedy Lane heated with two natural gas-fired boilers per building. The two water heaters for the building are 85-gallon gas-fired units. The stovetops and ovens are gas-fired in these eight units.
- All Rose Kennedy Lane units can install through-the-window or the wall (cut-outs) plug-in air-cooling units.
- The community room at Rose Kennedy is not a shelter location.
- All the buildings’ cooling and heating controls are local.
- The south-facing roofs on all buildings have the potential for solar PV. FHA is not opposed to exploring the opportunity. Structural 2x6 trusses support the sloped roof.
- Limited real estate may be available as an outdoor energy storage/battery location.
- Residential parking canopies are not likely an option at these locations. A parking lot owned by the National Guard across the street from the John Brady Drive location has solar canopy potential but needs further investigation.

The monthly electricity/gas usage and cost are shown in Figure 18 and

Figure *19*, respectively. The monthly average electricity usage and cost are 413,368 kWh and $74,020. The average electricity demand is 413 kW, respectively. The monthly gas usage and cost are 16,761 therms and $5,985, respectively.

Figure 18. FHA Monthly Electricity Usage and Cost in 2019

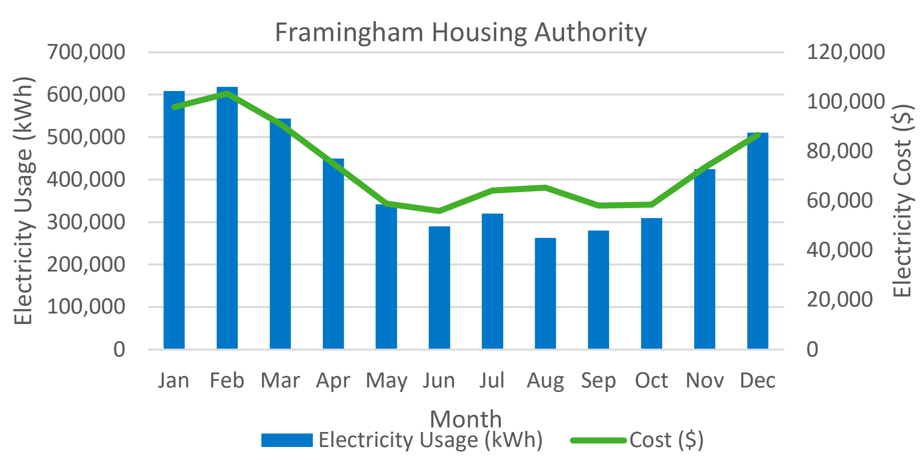
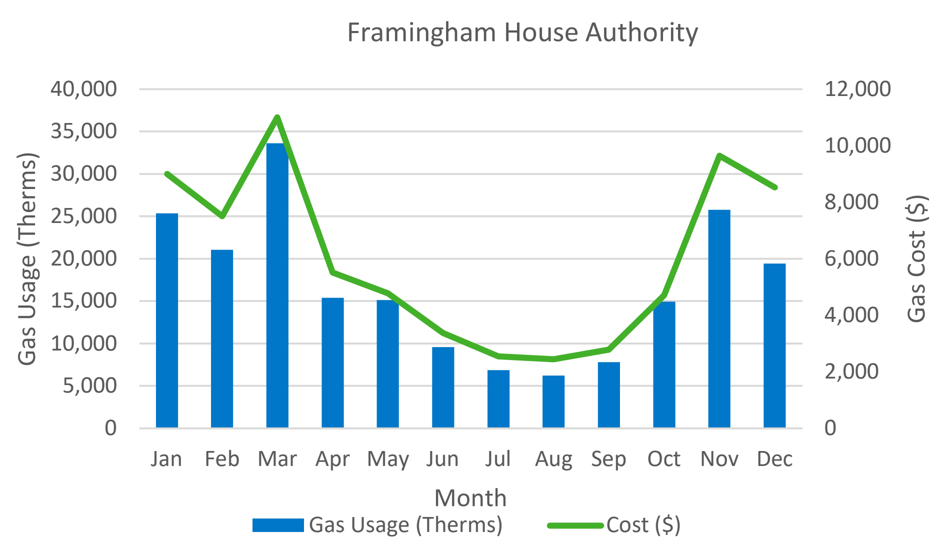


Figure 19. FHA Monthly Natural Gas Usage and Cost in 2019



2.5 Electrical and Thermal Infrastructure Resilience

At current condition, the resilience of the stakeholders is tied to the utility grid or existing emergency backup generators. For those critical facilities such as the fire and security systems (which already have an emergency backup battery/generator), the duration of running the emergency backup generator to serve the connected load would depend on the available amount of fuel in the tank or the available delivery service. Onsite fuel can generally last days up to one week.

Snowstorms and peak loads in the winter season could cause damage or outages to the overhead system in the City of Framingham. Also, heat waves in summer could affect distribution line conductor sags and any equipment that needs to be cooled off, such as transformers, battery storage, etc. A wind gust could cause tower/pole and conductor faults due to trees falling. It would also be necessary to upgrade designs and focus more on emergency planning and restoration. For example, Hurricane Sandy occurred in 2012, which caused a widespread blackout of the power system in the eastern seaboard and left millions of homes in the dark for periods ranging from a couple of hours to a few weeks. Natural gas disruptions are less likely than electricity disruptions; however, it is relatively more difficult to recover from natural gas system failure-driven outages than those of electric systems because of the difficulty in locating and repairing the underground leakages, which would impact the fuel supply to the four natural gas backup generators (FMS, FS5, MCES and FB). The extreme weather would affect both individual equipment failure and system operations. The damage from such events can impose large costs on the distribution system as well as have a severe impact on the local economies.

A community microgrid would solve the constraints by providing additional capacity and resiliency to the Eversource electric system. The 13.8 kV feeder is overhead, and the majority of the existing distribution equipment within each stakeholder location is located on the ground and is highly sensitive to flooding. The equipment that needs to be upgraded will be evaluated when design specifications are created for the infrastructure upgrades, and special attention will be paid to flood risk and reliability in severe weather. Controls and communication will improve resilience not only during weather events but in advance by providing flags and warnings for preventative maintenance and minor malfunctions before they lead to larger events that can cause grid impacts.

2.6 Project Scope Definition

We believe that a community resilience plan requires implementing a holistic and integrated community analysis, including the cyber-physical infrastructure sector's vulnerability. However, considering the statement of work approved by MassCEC and the City of Framingham MVP information, we will focus on this community's energy infrastructure resilience. Additionally, we will evaluate different microgrid configuration options for the project facilities (Campus, Community, Utility-Owned/Operated).

3. Identify Needs

The goals of this section (Task 2) are to report identified needs for an energy resiliency solution utilizing a community microgrid. This task included reviewing relevant regulations, definitions, and assumptions. Furthermore, the data collection process and site assessment have been provided. The existing electrical distribution configuration and associated system metrics are outlined. Finally, the resilience indexes that have been created will help define the technical solution's preferred resiliency characteristics in the following section (Task 3).

3.1 Relevant Regulations, Definitions, and Assumptions

Framingham’s 2020 Strategic Plan has adopted the Commonwealth’s goal of achieving net zero emissions by 2050. The City's Sustainability Coordinator is closely monitoring the Commonwealth's 2050 Decarbonization Roadmap that includes achieving at least an 85% emissions reduction below 1990 levels. Supporting the City, the constituent-based Sustainability Committee will consider practical new programs and policies as well as public engagement and outreach activities that seek to address environmental, resource, and energy challenges. In coordination with feedback from the Sustainability Committee, City officials are seeking to develop a Climate Action Plan that will serve as a comprehensive and holistic blueprint to reduce greenhouse gas emissions and improve local resiliency.

Framingham has had a history of addressing energy and climate even before becoming a City. In December of 2013, Framingham received its Green Community designation from the Commonwealth of Massachusetts' Department of Energy Resources. The Green Communities Program provides municipalities with technical and financial support to cut municipal energy consumption by 20 percent over five years. Other criteria outlined in the Green Communities Act include greenhouse gas emissions reduction which contribute to addressing climate change. While the City has not achieved a 20% reduction of energy use over the five-year target from a 2011 baseline, this study for adopting community microgrids hopes to accelerate the pace toward that target. Community microgrids that utilize both renewable energy sources and energy storage dispatch have reduced the need for traditionally sourced public utility-supplied electricity and create efficiencies at many levels. As noted in Section 2, Framingham’s vulnerabilities to climate change are grounded in their Municipal Vulnerability Preparedness Program report.

In 2020, the City of Framingham held a Community Resilience Building (CRB) Workshop that identified improvements to energy resiliency as one of the City’s most critical priorities. CRB Workshop identified the following key action steps:

- Prioritize energy efficiency as a reliability asset to reduce vulnerability to extreme weather and other events
- Analyze opportunities for energy storage at municipal facilities

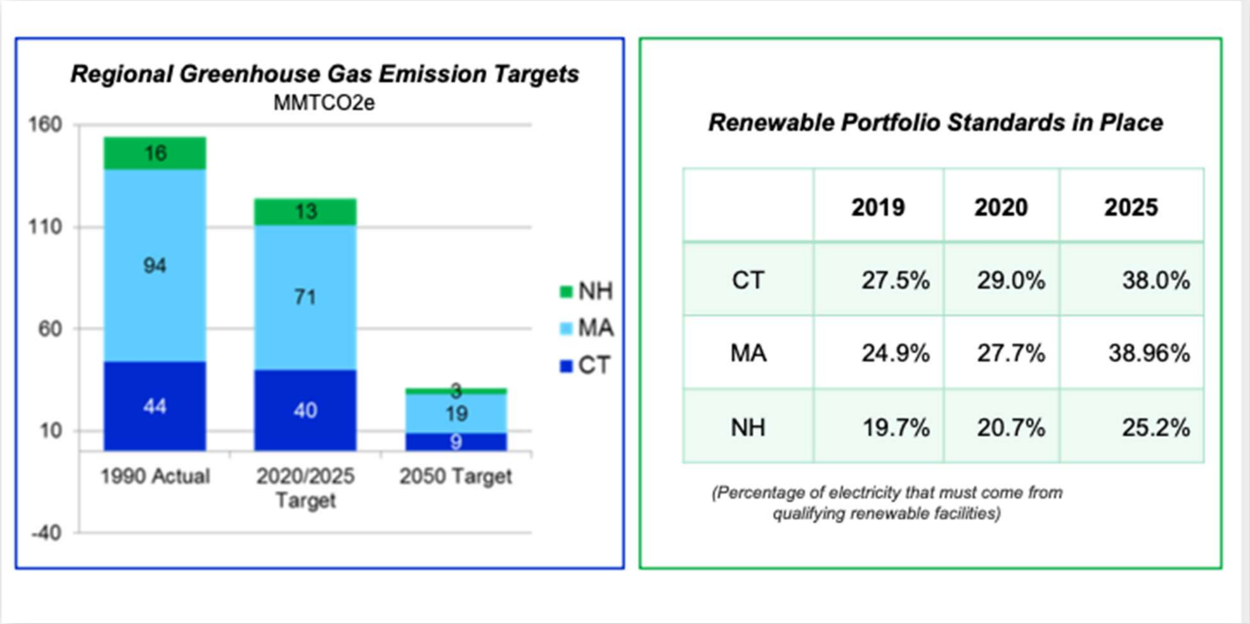
- Conduct a microgrid feasibility study to identify alternatives with minimal upfront capital outlays and no ongoing maintenance requirements.

A multi-faceted community energy resiliency project was proposed following the CRB workshop, prioritizing facilities that provide emergency shelter and response, critical wastewater infrastructure, and public housing assets for the community's vulnerable lower-income residents.

The City has leveraged several energy programs that provide energy incentives and savings. For example, the Green Communities Competitive Grant Program helped Framingham implement an Energy Savings Performance Contract (ESPC) for LED retrofits, HVAC system renovations, and equipment upgrades. MassSave energy efficiency programs administered by Eversource have been leveraged. The City will also use Eversource's net-meter provisions for solar PV installed at the new FMS. Infrastructure for electric vehicle charging stations is also being supported by Eversource. Finally, the City currently has a power purchase agreement (PPA) for almost 2 MW of solar located on the roof of a privately-owned shopping center in Framingham. It is assumed that these programs and associated procurements will help define the community microgrid as it was developed in Section 4 (Task 3) and 5 (Task 4) of this study.

As shown below[13], through the Renewable Portfolio Standard, Massachusetts will require that 38.96% of electricity must come from qualifying renewable facilities by 2025. Furthermore, the Regional Greenhouse Gas Emission Targets require 78% GHG emission reductions (Figure 20). Currently, Eversource grid emissions intensity in the City of Framingham is around 36%.

Figure 20. Greenhouse Gas Emission Target and Renewable Portfolio Standard



Renewable Portfolio Standards in Place

	2019	2020	2025
CT	27.5%	29.0%	38.0%
MA	24.9%	27.7%	38.96%
NH	19.7%	20.7%	25.2%

(Percentage of electricity that must come from qualifying renewable facilities)

The study will need to consider the barriers associated with developing a community-based microgrid. Currently, behind-the-meter generation and use are allowed in the regulatory environment. Some export of generation to Eversource's grid is allowed with approved precursory engineering studies. However, energy exchanges and financial transactions between different building owners in front of the meter are not allowed under current regulations. The City currently purchases its electricity from Eversource, an investor-owned utility. Eversource owns the franchise rights to deliver electric and natural gas energy in

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[13] Eversource Energy A Sustainable Investment Opportunity, November 2019

Framingham. The Commonwealth's Department of Public Utilities oversees safety concerns and rate-making policy for customer cost by Eversource. This study works toward solutions within the regulatory environment and potentially offers alternatives for front-of-meter technical solutions for future consideration.

3.2 Data Collection and Site Assessment

3.2.1 Existing Distributed Energy Resources (DERs)

The five stakeholders' locations, existing generation assets, and potential area for new distributed energy resources (DER) identified by the City have been presented in Section 2. The existing DER summary information for the five stakeholders is listed in Table 4.

Table 4. Stakeholder Existing DER Summary

Stakeholder	Backup Generation (kW)	Fuel Tank Capacity (Gallon)	Generator Detail
FMS	300	No onsite fuel storage	Natural gas-fired, under construction
MCES	100	No onsite fuel storage	Natural gas-fired, emergency lights, elevator, and life safety equipment
FB	45	No onsite fuel storage	Natural gas-fired, power emergency lighting
FS5	55	Natural Gas-powered backup generator. 1,000 gallons with pumping station to fill vehicles and other equipment	The entire facility is backed up
FHA	30	150 gallons for 48 hours' usage	Backup for a community room and office
Total	530	1,150 gallons	

3.2.2 The Building's Current Conditions and Upgrade Plans

FMS was under construction and was completed in the Fall of 2021. Solar canopies are going to be built in the parking lot area. The school has designed a solar-ready roof. The 499.8 kW potential solar with 250kW/496kWh battery combined system is at the interconnection study stage. The detailed condition of these five sites is presented in Section 1. There is no major upgrade plan at the remainder of the stakeholder locations as of the publication date of this this report.

3.3 System Data Collection

3.3.1 Distribution System (electric, water, communications)

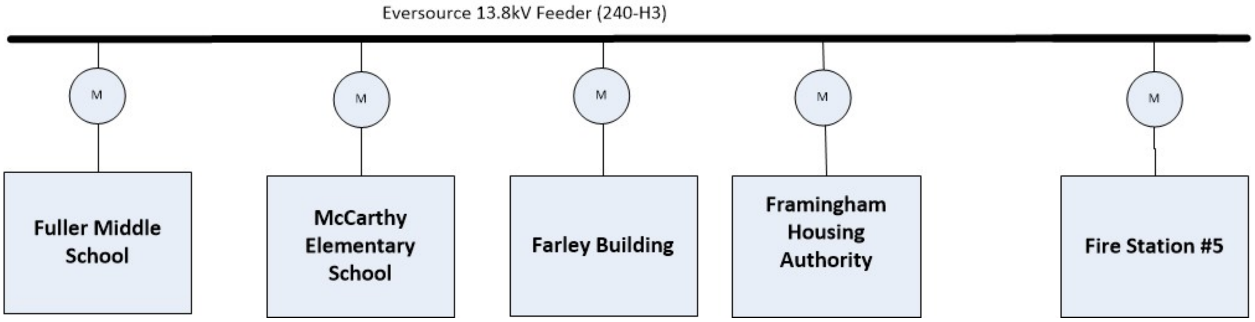
As shown in Figure 21, the old FMS is served by a 4.16 kV feeder (2409), and the other four stakeholders are served by the same 13.8kV feeder (240-H4). As confirmed by Eversource, the newly constructed FMS campus is served by the same 13.8 kV feeder as the other stakeholders, which would decrease the islanding and interconnection complexity. This 13.8 kV feeder is eligible to connect with DER or microgrid.

The historical reliability index for this feeder is CAIDI at 303 and SAIFI[14] at 0.228, respectively, smaller CAIDI and SAIFI index indicate that the customers experienced less outages with high reliable electricity supply.

With the information provided by Eversource regarding the gas delivery system in this project area, gas pipe sizes range from 2 inches to 6 inches. The gas delivery system has sufficient capacity for the installed services. The system is very reliable due to the underground design. Outages are minimized from weather or extreme conditions compared to above-ground utilities.

The water system, natural gas pipeline, and communication system information was not available and was not studied. The five stakeholders' interconnection configuration with the feeder is shown in Figure 21 for FMS, MCES, FB, FS5, and FHA (240-H3,13.8kV).

Figure 21. FMS (originally served by 2409, now served the 240-H3), MES, MBCC, FS5 and FHA (served by 240-H3,13.8kV)



3.3.2 Needs/Requirements During an Emergency

The information below was collected from the responses to the questionnaire sent to each of the stakeholders. The priority (or importance) of each stakeholder's resilience expectations is presented in Table 5.

Table 5. Priority (or importance) to the Stakeholder (1=highest priority, 5=lowest priority)

Stakeholder	Resiliency	Climate Goals	Economics	Operations	Community
FMS	4	3	1	2	5
MCES	4	3	1	2	5
FB	5	4	2	1	3
FS5	1	4	2	3	5
FHA	1	5	2	3	4

**Resiliency: Guarantees a better energy supply, in addition to the existing diesel generator*
**Climate Goals: Reduces Community GHG Emissions Portfolio*
**Economics: Rebates and incentives, unlocking energy services & benefits, minimize cost on development, procurement, and operation & maintenance energy assets*
**Operations: Maximizes the value of existing use/unused energy resources and staff*
**Community: Supports other stakeholders' critical operations & business continuity*

Fuller Middle School & McCarthy Elementary School

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[14] Customer Average Interruption Duration Index (CAIDI) and System Average Interruption Frequency Index (SAIFI) are a reliability index commonly used by electric power utilities. CAIDI gives the average outage duration that any given customer would experience. CAIDI can also be viewed as the average restoration time. SAIFI is the average number of interruptions that a customer would experience.

A campus/community microgrid is expected to improve the power supply's reliability and stability to avoid power fluctuations and outages. It is expected that a microgrid system based on solar PV and combined battery and storage would also help the schools to curtail their energy bills by reducing the energy cost and demand charge.

Farley Building

The backup natural gas generator only powers life-safety equipment and emergency lights. It is expected that the proposed community resiliency microgrid could power sewer injector pumps and lab areas during a grid power outage period.

Fire Station #5

Additional layers of resiliency to the Fire Department's energy supply are beneficial to keep operations running 24/7. Another benefit would be installing new replacement capital equipment as part of this project to reduce the department’s overall capital project costs.

Framingham Housing Authority

Power fluctuation and outages would negatively impact the sheltering requirements and the residents' safety and well-being.

3.4 Resilience Index

3.4.1 Critical Loads with Available Supply

FS5 is a "Tier 1" facility, and the others are "Tier 2" facilities. The resilience expectation for each of the stakeholders is presented in Table 6, based on information provided in the questionnaires. Approximate electrical loads of 70% at the FMS, MCES, and FHA are critical. All the loads of FS5 and the FB are critical loads.

Table 6. Resilience Expectation[15]

Stakeholder	Disruption Delay	Maximum Operation Degradation Level	Maximum Disruption Duration Tolerance	Recovery Response Time
FMS	Hours	30%	Hours	Minutes
MCES	5 seconds	30%	4 Hours	4 Hours
FB	Seconds	65%[16]	Minutes	Minutes to Hours
FS5	None	0%	None	None
FHA	Minutes	30%	Days	Hours

3.4.2 Service Delivery During an Interruption

The peak load, average load, and backup generation capacity of these sites are shown in Table 7. FMS and FS5 have enough backup generation capacity to cover their peak load if the backup generators can be online as designed. The three other stakeholders can only cover their critical loads, such as emergency

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[15] Stakeholder Resiliency Expectation Survey. Disruption delay: expectation of electrify service restoration time after grid outage. Maximum Operation Degradation Level: possible of percent of possible load curtailment. Maximum Disruption Duration Tolerance: the maximum limit of outage time, significant damage or loss could be caused if outage time surpass this limit. Recovery Response Time: Expected time of service to be restored.

[16] Calculated as the ratio between current backup generation capacity and averaged electricity load.

lights and security systems. The backup generators at the FMS, MCES, FB, and FS5 do not have onsite backup fuel. They depend on the natural gas delivery system.

Table 7. Load and Backup Generation Capacity

Stakeholder	Peak Load (kW)	Averaged Load (kW)	Backup Generation (kW)	Backup Fuel
FMS	304 (Estimated)	105	300	Depend on Natural Gas Delivery
MCES	162	56	100	Depend on Natural Gas Delivery
FB	368	143	45	Depend on Natural Gas Delivery
FS5	27	10	55	Depend on Natural Gas Delivery
FHA	917.2	566	30	150 Gallons for 48 hours’ usage

3.4.3 Recovering the Service After a Power Outage

The recovery procedures after a power outage were collected from each of the stakeholders and are discussed in this section.

Fuller Middle School, Farley Building & McCarthy Elementary School

Once power outages occur, the schools have to reschedule classes or school activities. A power failure usually ends up burning out the 3-phase motors. It can be a safety issue for people occupying the building to exit if emergency generators do not come online as designed. The building automation systems or individual equipment need to be physically reset to get the heating system running again during the winter months after the power outage.

Fire Station #5

The most significant factor in energy disruptions has been the impact of momentary loss and recovery of power on sensitive electronics/system controls. These brief power changes have wreaked havoc on modern systems with computer-based controls. Long-term power losses would be a concern because the department would need to relocate resources to another station, which would impact response times in the district of the outage.

Framingham Housing Authority

Part of the facility depends on electricity for heating. Power outages would negatively impact the sheltering requirements and the residents' safety and well-being, especially during wintertime.

A resiliency index weight table is defined to guide the simulation and analysis for different scenarios in later tasks, shown in Table 8.

Table 8. Resiliency Index

Islanding Days	Load Curtailment	Resiliency Weight
7	0-30%	100%-89.41%
6	0-30%	86.76%-76.18%
5	0-30%	73.53%-62.94%
4	0-30%	49.71%-73.53%
3	0-30%	47.06%-36.47%

2	0-30%	33.82%-23.24%
1	0-30%	20.59%-10%

Resiliency weight is defined on the following criteria:

- The maximum number of days that critical facility capacity is being responded to during the grid outage duration.
- The maximum level of a critical facility that can be served.
- The capability of serving critical facilities with no load curtailment for seven days (as the customer's requirement) is defined as 100% resiliency.

The customer would not experience any power disruption in this best resiliency scenario, i.e., 100% resiliency weight, in which 100% of load would be continually served for up to 7 days without interruptions or curtailments. Load curtailment is the disconnection of predetermined non-critical loads, such as non-emergency lighting, that can be programmed into building controllers for automated shut off in the event of an emergency. The capability of serving 70% critical facilities for one day is defined as 10% resiliency weight, i.e., the 70% customer's load could be continually served for one day at the 10% resiliency weight. The resiliency weight would be 20.59% if all the loads (100% of the loads or customers) were continually served for up to one day. The higher resiliency scenario would require more backup generation capacity, resulting in a large upfront investment cost. The resiliency index would be considered based on the resiliency expectation questionnaire or the current onsite backup fuel volume. Suppose the resiliency information not provided or available. In that case, the resiliency of 3 day (or 72 hours) supporting the expected critical load are generally applied.

4. Technical Solutions

The goal of the technical analysis (Task 3) is to propose a preliminary technical design and system configuration for the proposed community microgrid anchored at Concord Street in the City of Framingham, MA in accordance with the findings of the site assessment and characteristics identified in Section 3 (Task 2).

A preliminary assessment of the system was conducted, and multiple preliminary solutions were presented to key stakeholders at the microgrid team meeting. One solution was developed further into a technical design and system configuration based on stakeholder requirements and feasibility.

4.1 Proposed Microgrid Infrastructure and Operations

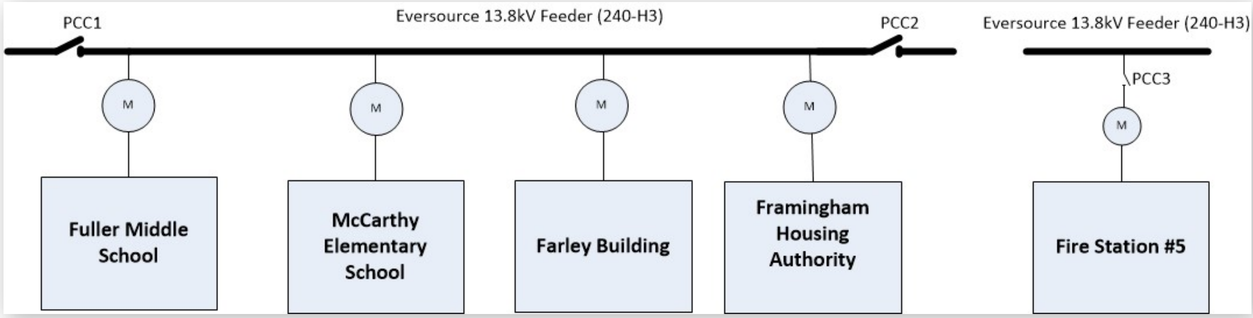
4.1.1 Microgrid Infrastructure and Equipment Layout

Figure 22. Concord Street Community Resiliency System Proposed DERs Layout

The layout of the proposed new distributed generation resources (DERs), such as solar PV and batteries, is shown in Figure 22. The backup generators shown in Table 7 are used mainly for emergency backup purposes and are not shown in this figure. A red label above the solar and battery icons identifies stakeholder solar and battery locations. CHP solution is not considered in this technical solution since this CLEAR program focuses on using clean energy to promote community resiliency. The CHP solution would need further study of the heating load pattern and electricity to heating load ratio. The Point of Common Coupling (PCC) or interconnection point with the utility is identified by a red rectangle with a cross inside. If the each of the stakeholders would run on building microgrid by them self, the PCC for each of the sites would be located at their main breaker or meter. The feeder in different colors represents the available feeder hosting capacity. The proposed community microgrid is a networked microgrid cluster. Each stakeholder location is designed as a microgrid and can run independently in islanded mode.

The simplified one-line diagram of the proposed microgrid is seen in Figure 23. The microgrid is fed from Eversource's 13.8kV distribution network. Depending on location, solar and batteries are connected to or isolated from various building loads. In this representative diagram, each stakeholder can run in islanded/grid-connected mode independently. During a power outage, FS5 would be running as an isolated building microgrid. The remaining four stakeholders would be connected through the optimally coordinated dispatch of loads and charging/discharging the battery and running as community microgrids.

Figure 23. Concord Street Community Resiliency System Simplified One-line Diagram



As shown in Figure 23, the old FMS campus was fed by the 4.16 kV feeder, while the newly constructed campus is connected to the adjacent 13.8 kV feeder, the same as the rest of the stakeholders, which reduces the community microgrid islanding and interconnection complexity. The PPA-contracted solar and battery storage would be installed on the FMS campus, which would add an extra layer of uncertainty to including FMS as part of the proposed community microgrid.

Further exploration would be needed among the City, PPA owner and potential CSCRS owner for integrating the PPA-based DER resources into the microgrid solution to improve the overall economics and resiliency. Within this report, the DER resources in FMS are included and evaluated as part of the technical and financial modeling.

Due to the distance between FS5 and other installation locations, the system would require switches/breakers to isolate the connected loads on feeder 240-H3 between FS5 and FHA during islanded if FS5 is integrated alongside the other stakeholder facilities, resulting in complicated control/operations and higher infrastructure upgrade costs. It is recommended that FS5 run independently as a building microgrid, separate from the overall community microgrid.

4.1.2 Existing and Planned Infrastructure

Based on the information provided by the City and stakeholders, a total of 530 kW diesel/natural gas backup generator has been or will be installed across the five sites. The existing/planned backup generation assets are summarized in Table 7.

The existing backup generators would only be running during islanded mode for extensive hours of self-supply. Hourly granular data are available for MCES, FB, and FHA as of the publication date of this report.

The proposed solar and batteries are seen in Table 9 and consist of solar and storage systems designed to maximize solar onsite, providing backup and fast response with the batteries. Both resiliency and economic-oriented solutions are studied. The proposed DERs would be able to work in both grid-connected and islanded modes. A DER optimization planning tool developed by Willdan is applied to find the optimal DER mix while satisfying stakeholders’ resiliency and economic expectation. The electricity tariff, hourly load shape, potential spaces for solar installation, historical weather data, etc., are considered in the model and simulation. In general, the resiliency-oriented solution would provide a 48-72 hours ride-through for the critical loads of each stakeholder during a grid outage, resulting in a high investment cost and a longer payback period. The economical solution results in a smaller battery recommendation, a lower investment cost, and a shorter payback time, which would be favored by a PPA contractor, as studied in the financial assessment (Section 5), while results in shorter time period of islanding capacity (1 hours for FHA, 10 hours for FS2 and 24 hours for FHS depending on clean energy only).

Table 9. Proposed DER by Facility Site

Location	Solar Capacity (kW)	Energy Storage (kW/kWh) (Resiliency)	Energy Storage (kW/kWh) (Economic)
FMS	499.8	450/1,800	50/200
MCES	528	500/2000	100/400
FB	369	250/1,000	125/500
FHA	242	250/1,000	100/400
FS5 (Isolated)	54.4	50/200	15/60
Total	1,693	1,500/6,000	390/1,560

Additional infrastructure, including electrical and thermal distribution, building and grid controls, and IT/telecommunications equipment, will be added to support the installation of the generation resources above, described in their respective sections of this report.

4.1.3 Microgrid Operation and Control

The proposed community microgrid will operate in grid-connected, islanded and partly islanded modes. The advanced controller used in this microgrid, along with the DERs proposed in this project, will support the microgrid to transfer seamlessly between the different modes. The generation resources located in different stakeholder locations would be optimally dispatched and controlled to provide economic benefits and better service to current customers on their path toward resilient and zero-emission communities. The proposed technical solution (including community microgrid and building microgrid) would improve both the power supply reliability and resiliency for current stakeholders and customers.

Under normal conditions, the Concord Street Community Resiliency System (CSCRS) would be operated in grid-connected mode to maximize the economic benefits for the customers or stakeholders. The CSCRS master controller will optimize energy purchases from the utility grid as well as generation and storage from the local DERs to minimize the total energy cost while maintaining the reliability and stability of the microgrid.

In emergency conditions such as utility grid outages, the proposed addition of solar and storage will allow the community microgrid to disconnect from the surrounding Eversource electrical distribution and transmission infrastructure and supply its own power for hours to days, based on the level of load curtailment. Within each of the stakeholder's locations, the solar generation and battery would optimally be dispatched for serving the critical loads first. With the proposed CSCRS, the operation hours of the existing backup diesel and natural gas generators could be significantly reduced, and reduced GHG emissions could result.

Additional loads would need to be curtailed during major storms or other extreme events when utility electric service is unavailable for long periods of time. In resiliency-focused solution, if no load is curtailed, the sites could be served by backup generators, solar, and batteries for around 5-7 days with sunshine or around 3-5 days for each of the stakeholder locations, respectively, when solar generation is not available. However, if non-critical loads are curtailed and the facilities focus on serving their critical resources such as lighting, police, fire, and alarm systems, administrative offices (for emergency coordination), and emergency shelters, the CSCRS could serve these critical facilities for weeks depend on the available fuel supply. This assumes a critical load at 1,268 kW of 2,284 kW peak load (Table 10) for an extended period of days to weeks, depending on the availability of diesel and natural gas delivery service for the backup units. In the case of no available fuel for backup generators, the proposed solar-battery system could support the critical loads for 8 hours to 3 days for each of the stakeholder locations, depending on its load and the available solar PV installation potential.

During a power outage, FS5 would be configured to be isolated from the grid and disconnected from the rest of the community microgrid and run independently as a building microgrid to avoid the complexity of isolating other connected loads other than those of the stakeholders. The proposed solar and battery in resiliency-focused solution could serve the load of FS5 (averaged load around 10 kW with peak at 27 kW) for weeks in normal conditions and could significantly reduce the operation hours of the onsite backup generator.

4.1.4 Interconnection with Utility Grid

The microgrid will be interconnected to the Eversource distribution grid at the interconnection point, labeled as PCC in Figure 1. In the proposed configuration, each of the stakeholder locations can be operated in islanded mode independently. Any interconnection application between 1-5 MW has the potential for a transmission review by the Independent System Operator, New England (ISO-NE), which may cause a longer interconnection process and approvement.

The local microgrid distribution grid and controls will be based on a combined solar-battery system with switches, reclosers, circuit breakers, and relays set up to prevent fault currents or back feeding from damaging the grid infrastructure or sensitive loads. Relays can be connected through a wired or wireless system to allow for fault isolation and automated reclosing and provide grid data to the Supervisory Control and Data Acquisition (SCADA) system or microgrid operator. Wired and wireless systems can back up and compensate each other to improve the overall resiliency in extreme conditions. Additionally, the frequency and harmonics of the grid will be monitored at critical points using phasor measurement units (PMUs) to maintain grid balance during island and resynchronization events.

Integrating DERs and novel topologies embedded in microgrids also pose great challenges to traditional protection schemes. Such challenges are mainly derived from the fact that the protection devices deployed in the present distribution systems are coordinated based on unidirectional downstream power flows, where the utility grid provides the fault current and protection devices are coordinated along the radial feeders to isolate faults. A hierarchical protection configuration strategy is proposed for the CSCRS protection that mainly contains four-level protection: load way, feeder way, microgrid way, and microgrid cluster level[17].

- Load-way protection: Digital relay with adaptive relay setting, responding to lower fault current in island mode, operates only in load-way faults.
- Feeder-way protection: Feeder-way protection has similar functions as load-way protection. The occurrence possibility of this backup is very low. Directional over-current relays are considered to be super high accuracy and reliability. Digital relay with adaptive relay setting. Operates in feeder faults, primary and backup permissive overreach transfer trip (POTT) schemes. Backup protection for load-way protection.
- Microgrid-level protection:

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[17] L Che, ME Khodayar, M Shahidehpour, "Adaptive Protection System for Microgrids: Protection practices of a functional microgrid system," IEEE Electrification magazine, 2014

  - In grid-connected mode: Unintentional islanded operation due to external fault or disturbance based on the signal from the master controller (MC), backup protection for the entire microgrid, intentional islanded operation based on the islanding command from the MC.
  - In islanded mode: Resynchronization initiated by a command from the MC.
- Microgrid cluster protection: Operates to isolate the faulted microgrid only when the load-way or feeder-way protections have failed within the cluster.

Each level is equipped with protection devices and the four levels are coordinated. The load-shedding and other control schemes can also be implemented on the load-way protection level, based on the under-/over-voltage and under-/over-frequency functions of these relays. The performance modes of microgrid protection are summarized as follows.

- Detect and isolate of faults both inside and outside of the microgrid
- Detect and isolate the faults inside the microgrid in both grid-connected and islanded mode
- Detect and immediately isolate the faults of the loads and DERs
- Prime protection and backup protection for protection device malfunction
- Compromise between selectivity and speed, depending on the level and seriousness of the faults. Those faults could cause serious damages or consequences are equipped and monitored by protection devices and action with high priority and fast response speed.

4.2 Load Characterization

4.2.1 Summary of the CSCRS Loads

The hourly granular electricity loads are available for MCES, FB and FHA. Only historical monthly usage and billing data are available for FS5. The electricity load for the newly constructed FMS was not available and was then estimated. The average, peak and critical loads of these stakeholders are collected through either an RFI or resiliency survey, and summarized in Table 10.

Table 10. CSCRS Average, Peak, and Critical Electrical Loads

Stakeholder	Critical Buildings/Loads	Average Load (kW)	Peak Load (kW)	Critical Load (kW)
FMS	Elevator, security lighting, fire panel, and the front lobby area including lighting, plugs, cooling and ventilation for that space.	105	345	190
MCES		49	211	116
FB		143	430	237
FS5	All loads, whole facility should be treated as critical load	10	27	27
FHA	Security lighting, fire panel	566	1,271	699
Total		873	2,284	1,268

4.2.2 Hourly Load Shapes of Each Stakeholder

Fuller Middle School

The estimated annual hourly electric load shape and peak day load shape of FMS are shown in Figure 24 and Figure 25, respectively. The average electricity load is 104 kW. Peak electricity load is around 345 kW in the summer, coinciding with the air conditioner usage. The load profile on a peak load day is shown in.

On average, FMS pays $0.17/kWh[18] for electricity usage, including the energy cost from the power supplier and the delivery charge from the utility. The monthly thermal load and cost are shown in Figure 7. FMS's annual electricity and heating loads are 919,477 kWh and 26,459 therms[19], respectively. The monthly energy usage, cost and demand for the year 2019 are shown in Table 11 and Figure 26.

Figure 24. FMS Hourly Electricity Load Profile (Estimated)

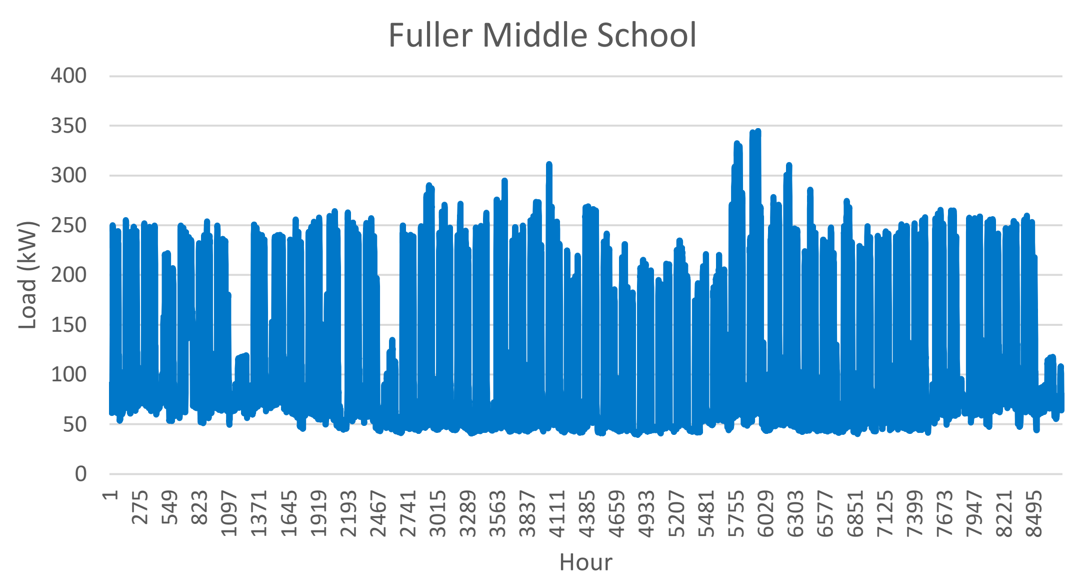
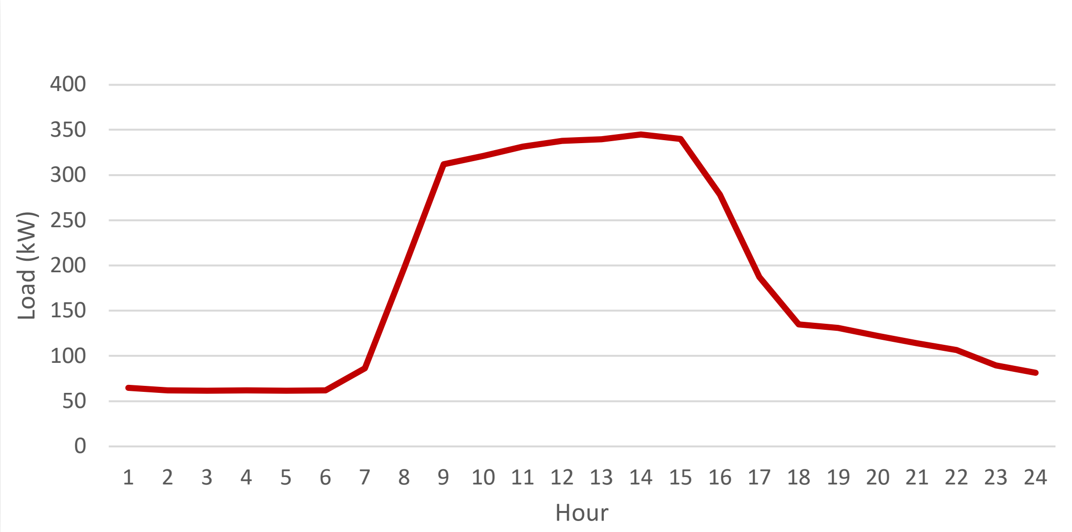


Figure 25. FMS Electricity Load Profile on a Peak Day



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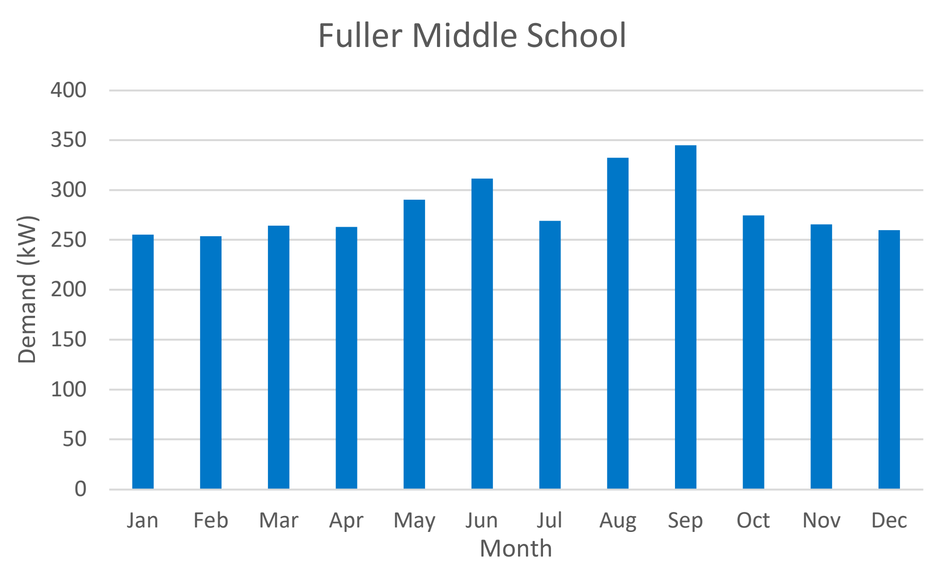
[18] Proposed Electric Load - Fuller.pdf

[19] Proposed Nat Gas Load - Fuller.pdf

Table 11. FMS Monthly Energy Usage and Cost (Estimated)

Month	Estimated					
	Electricity Usage (kWh)	Electricity Cost ($)	Gas Usage (Therm)	Gas Cost ($)	Averaged Electricity ($/kWh)	Averaged Gas Cost ($/Therm)
Jan	73,145	12,435	5,101	3,773	$0.17	0.74
Feb	64,395	10,947	3,836	2,838	$0.17	0.74
Mar	67,658	11,502	3,130	2,315	$0.17	0.74
Apr	71,453	12,147	1,882	1,392	$0.17	0.74
May	82,273	13,986	1,096	811	$0.17	0.74
Jun	90,607	15,403	688	509	$0.17	0.74
Jul	93,519	15,898	863	639	$0.17	0.74
Aug	80,420	13,671	662	489	$0.17	0.74
Sep	83,028	14,115	914	676	$0.17	0.74
Oct	75,190	12,782	1,149	850	$0.17	0.74
Nov	64,466	10,959	2,668	1,974	$0.17	0.74
Dec	73,324	12,465	4,470	3,306	$0.17	0.74

Figure 26. FMS Monthly Electricity Demand



McCarthy Elementary School

The hourly load shape for MCES is shown in **Figure 27**, with averaged electricity load demand at 38 kW. The hourly load shape in peak load data is shown in Figure 28. The annual electricity usage is 433,272 kWh and annual gas usage are 35,376 therms respectively[20] in year 2019.

Figure 27. MCES Hourly Electricity Load Profile (2020)[21]

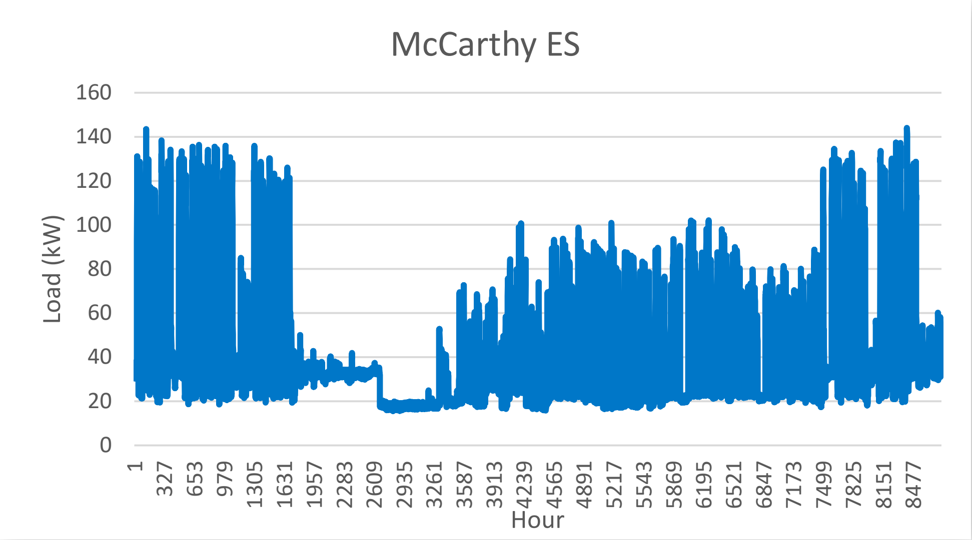
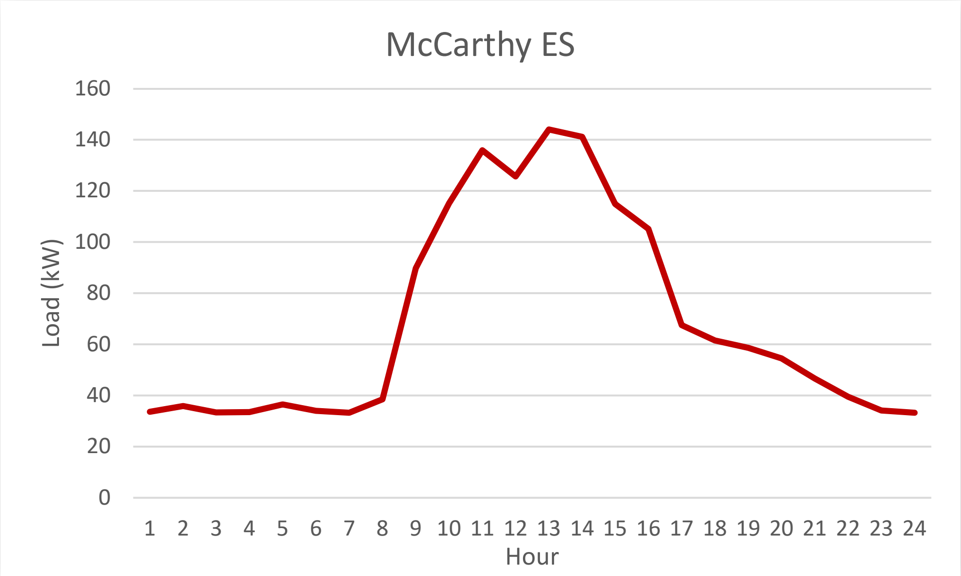


Figure 28. MCES Hourly Electricity Load Profile in Peak Load Data (2020)



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[20] MassCEC CLEAR Program Energy Data (3-3-22).xlsx

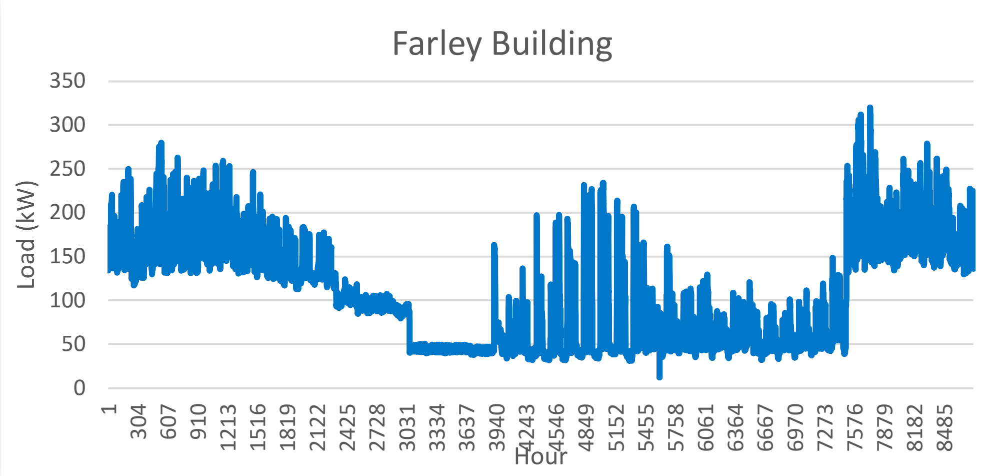
[21] Eversource_McCarthy School.csv, granular data from 09/01/2019 to 11/08/2020 is provided, 2020's data is applied here.

Table 12. MCES Monthly Energy Usage and Cost (2019)

Month	MCES					
	Electricity Usage (kWh)	Electricity Cost ($)	Gas Usage (Therm)	Gas Cost ($)	Averaged Electricity ($/kWh)	Averaged Gas Cost ($/Therm)
Jan	41,280	15,348	7,661	6,902	0.37	0.90
Feb	41,184	8,406	6,602	5,919	0.20	0.90
Mar	37,680	7,715	6,665	5,962	0.20	0.89
Apr	38,664	7,729	2,403	2,175	0.20	0.91
May	32,520	7,646	1,633	1,082	0.24	0.66
Jun	39,792	9,700	382	257	0.24	0.67
Jul	28,344	6,617	215	144	0.23	0.67
Aug	29,256	7,915	219	142	0.27	0.65
Sep	35,328	9,811	241	142	0.28	0.59
Oct	40,728	9,534	1,265	544	0.23	0.43
Nov	36,432	7,605	3,176	2,718	0.21	0.86
Dec	32,064	7,092	4,914	5,058	0.22	1.03

Farley Building

Figure 29. *FB Annual Hourly Load Profile (2020)*[22]



The FB annual hourly load profile is shown in **Figure 29**, with a peak load of 320kW and average demand of 107 kW. The annual electricity usage is estimated at 942,910 kWh. The hourly load profile on a peak load day is shown in **Figure 30**.

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[22] Eversource-MassBay-Farley.csv, granular data from 10/01/2019 to 11/10/2020 is provided

Figure 30. FB Hourly Load Profile in Peak Load Day

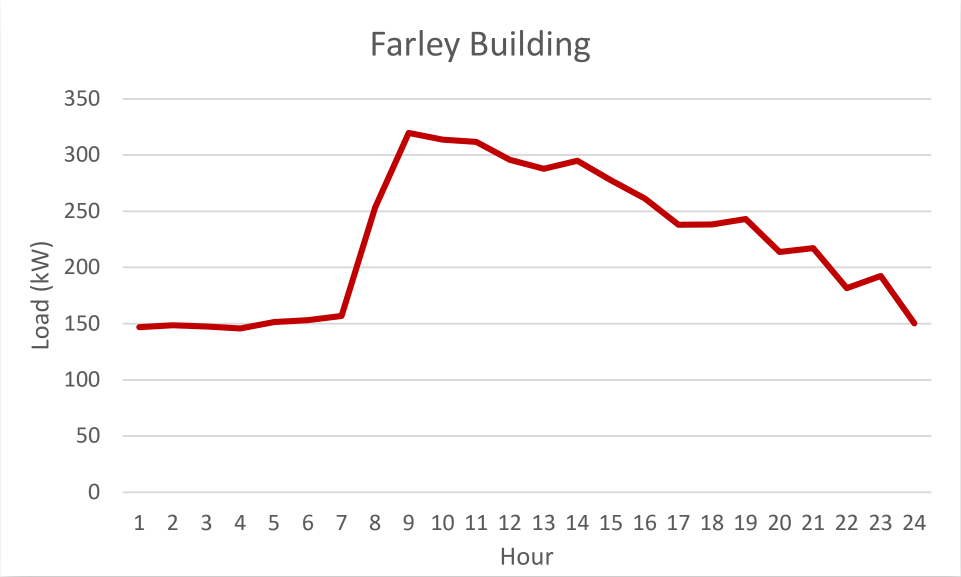


Table 13. FB Monthly Energy Usage and Cost (2019)

Month	FB					
	Electricity Usage (kWh)	Electricity Cost ($)	Gas Usage (Therm)	Gas Cost ($)	Averaged Electricity ($/kWh)	Averaged Gas Cost ($/Therm)
Jan	106,800	18,218	3,873	1,129	0.17	0.29
Feb	105,480	18,189	1,869	554	0.17	0.30
Mar	122,280	23,668	7,579	2,109	0.19	0.28
Apr	134520	23,817	1,110	343	0.18	0.31
May	84,600	17,213	381	132	0.20	0.35
Jun	86,400	18,212	162	77.66	0.21	0.48
Jul	106,920	22,340	260	100.46	0.21	0.39
Aug	102,960	22,573	138	72.09	0.22	0.52
Sep	87,240	19,907	139	72.32	0.23	0.52
Oct	85,560	18,590	400	133	0.22	0.33
Nov	107,160	21,062	1,399	466	0.20	0.33
Dec	124,560	21,650	3,087	1,078	0.17	0.35

FS5

The estimated hourly load shape for FS5 is shown in **Figure 31**, with an average electricity load demand 10 kW. The hourly data for peak load data is shown in **Figure 32**. The annual electricity usage is 88,154 kWh, and the annual gas usage is 4,881 therms.

Figure 31. FS5 Hourly Electricity Load Profile (Estimated)

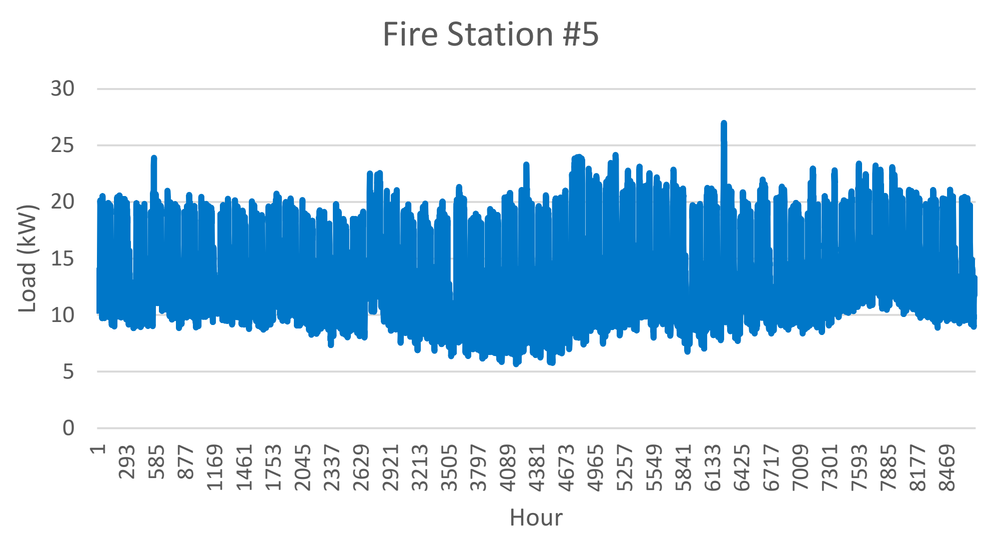


Figure 32. FS5 Hourly Electricity Load Profile in Peak Load Day (Estimated)

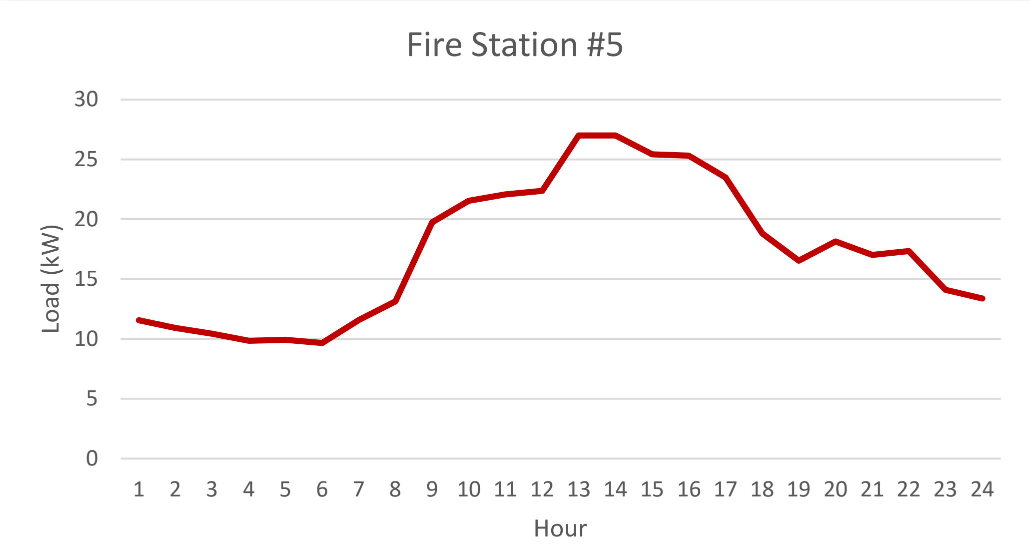


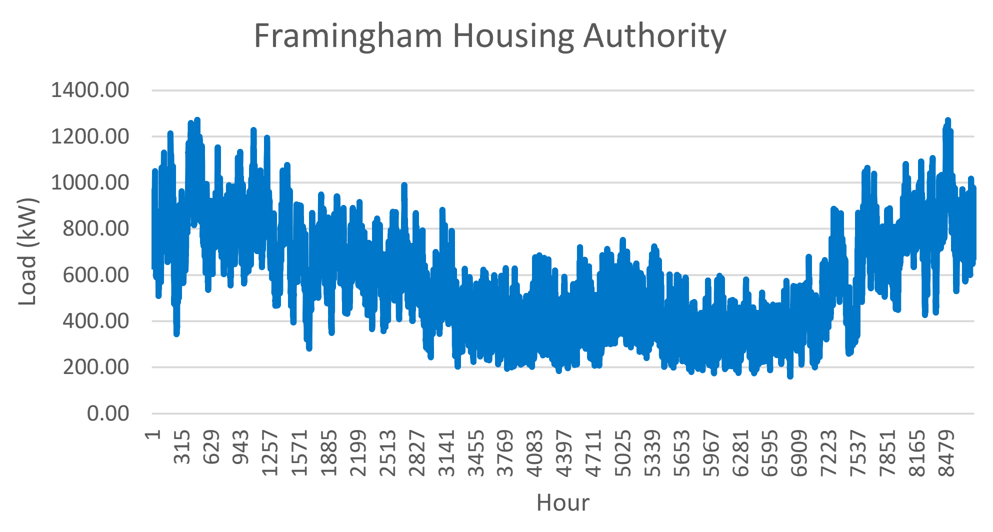
Table 14. FS5 Monthly Energy Usage and Cost (2019)

Month	FS5					
	Electricity Usage (kWh)	Electricity Cost ($)	Gas Usage (Therm)	Gas Cost ($)	Averaged Electricity ($/kWh)	Averaged Gas Cost ($/Therm)
Jan	8,693	2,473	878	881	0.28	1.00
Feb	8,450	1,413	906	902	0.17	1.00
Mar	7,477	1,221	621	622	0.16	1.00
Apr	6,908	1,161	308	318	0.17	1.03
May	4,993	900	205	180	0.18	0.88
Jun	5,263	965	69	69	0.18	1.00

Jul	6,680	1,355	$45	$48	0.20	1.07
Aug	8,747	1,772	37	42	0.20	1.14
Sep	7,219	1,702	50	48	0.24	0.96
Oct	5,435	947	158	106	0.17	0.67
Nov	5,390	1,021	427	421	0.19	0.99
Dec	6,404	1,053	719	822	0.16	1.14

Framingham Housing Authority

Figure 33. FHA Annual Hourly Load Profile (2020)



The FHA annual hourly load profile is shown in **Figure 33**, with a peak load of 1,272 kW and average demand of 565 kW. The annual electricity usage is estimated at 4,941,093 kWh. The hourly load profile on a peak load day is shown in **Figure 34**.

Figure 34. FHA Hourly Load Profile in Peak Load Day

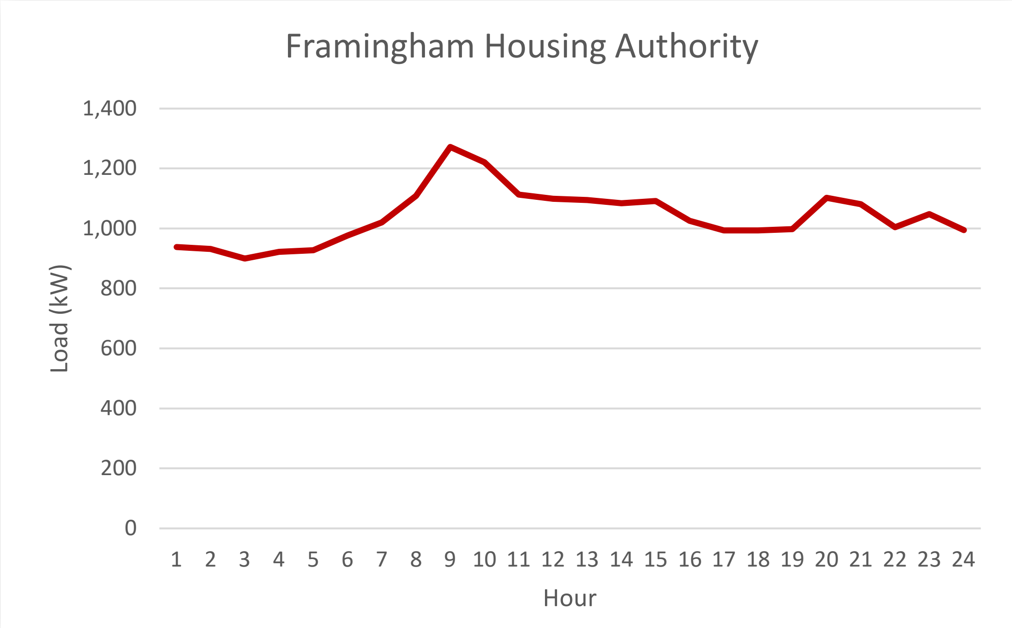


Table 15. FHA Monthly Energy Usage and Cost (2019)

Month	FHA

	Electricity Usage (kWh)	Electricity Cost ($)	Gas Usage (Therm)	Gas Cost ($)	Averaged Electricity ($/kWh)	Averaged Gas Cost ($/Therm)
Jan	608,634	97,866	25,335	9,000	$0.16	0.36
Feb	618,489	103,334	21,050	7,508	$0.17	0.36
Mar	543,640	91,005	33,626	11,007	$0.17	0.33
Apr	449,915	75,005	15,404	5,513	$0.17	0.36
May	341,956	58,905	15,116	4,779	$0.17	0.32
Jun	290,182	55,992	9,573	3,367	$0.19	0.35
Jul	319,753	64,178	6,851	2,546	$0.20	0.37
Aug	263,056	65,358	6,202	2,444	$0.25	0.39
Sep	280,021	58,078	7,816	2,779	$0.21	0.36
Oct	309,534	58,508	14,944	4,703	$0.19	0.31
Nov	424,435	73,400	25,772	9,646	$0.17	0.37
Dec	510,800	86,616	19,440	8,523	$0.17	0.44

4.2.3 Load Aggregation for CSCRS Simulation

The hourly load profile for all stakeholders is shown in **Figure 35**. The aggregated hourly load profile based on the current load data for CSCRS is shown in **Figure 36**. For the analysis of CSCRS, the average peak load considered was 1,820 kW, and the annual average load was 824 kW. Compared with the sum of peak load (2,284kW) shown in **Table 10**, the aggregated smaller non-coincident of individual building peak load demand would be able to provide the benefit by allowing different building's energy assets to be shared through a community microgrid. FS5 is studied independently due to the interconnection complexity.

Figure *35*. Averaged Hourly Electrical Load Profile in CSCRS

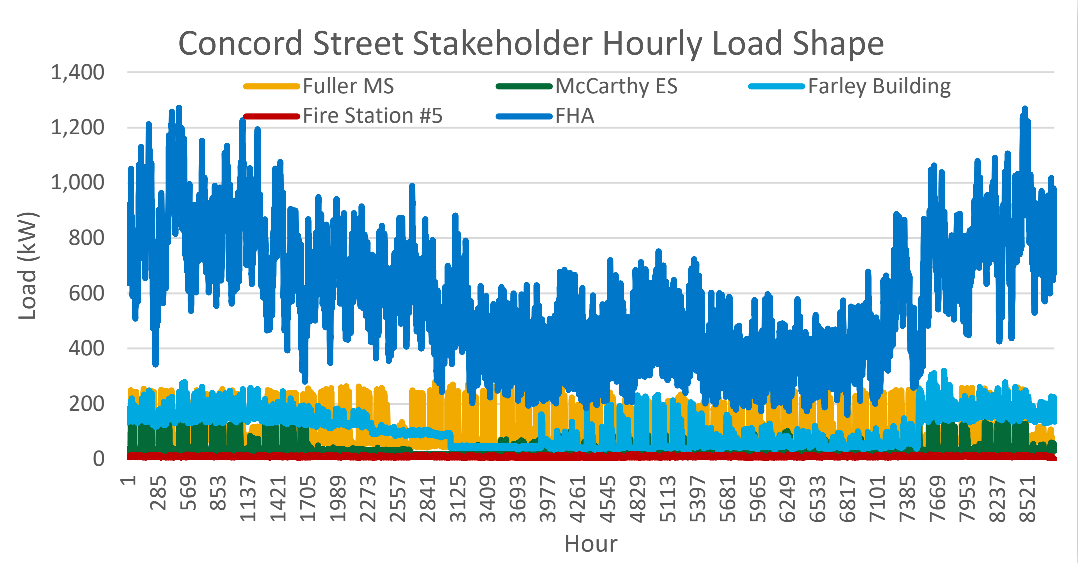
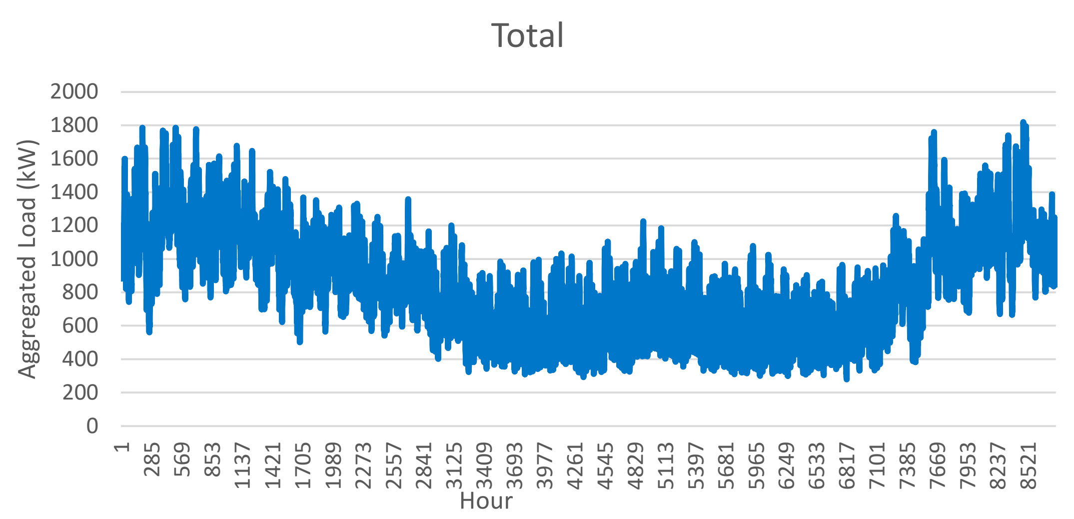


Figure 36. Aggregated Averaged Hourly Electrical Load Profile in CSCRS



4.3 Distributed Energy Resources Characterization

4.3.1 Description of Microgrid DERs

It is assumed that the stakeholder would pay a fixed electricity rate of $0.09593/kWh based on the contract through CSCRS based on the City's prior electricity supply contract. Transmission and distribution charges are paid to Eversource for electric delivery and the rates and charges are different, based on the service level of the accounts. The demand charge is different for different seasons; i.e., summer peak season and winter off-peak season. The detailed demand charges, energy costs, and gas prices used in the modeling are summarized in Table 16 for the DER-CAM simulation.

Table 16. Price Parameter Used in Simulation

Month	Electricity Energy Price ($/kWh)[23]	Demand Charge ($/kW-Month)	Gas Price ($/Therm)
Jan	0.13947	20.4	0.9
Feb	0.13972	20.4	0.9
Mar	0.12887	20.4	0.9
Apr	0.12633	20.4	0.9
May	0.11847	20.4	0.9
Jun	0.1116	29.62	0.9
Jul	0.1116	29.62	0.9
Aug	0.1116	29.62	0.9
Sep	0.1116	29.62	0.9
Oct	0.13947	20.4	0.9
Nov	0.13972	20.4	0.9
Dec	0.12887	20.4	0.9

Two scenarios were simulated with the aggregated hourly load profile and costs in this section. The preliminary cost-benefit analysis is summarized in Table 17. In Table 17, the incentives for solar and battery storage installation, such as federal tax credits, smart solar, energy efficiency rebate/incentive programs, etc., are not considered in this Task report, but will be studied in the next section (Task 4 Financial Solutions). The Resiliency scenario was selected and presented as the primary solution in this report, based on stakeholder feedback.

Table 17. CSCRS Preliminary Configuration and Cost Analysis Summary

	Base	Resiliency	Economic
Technical Data			
Solar Capacity (kW)	-	1,693	1,693
Battery Capacity (kW/kWh)	-	1500/6000	390/1560
CO_2 Emission (metric ton)	3,099	2,673	2,693
CO_2 Reduction (metric ton)	-	426	406
Solar Generation (kWh)	-	1,991,738	1,991,738
Battery Charged by Solar (%)	0%	91%	100%
Current Annual Load (kWh)	7,649,304		

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[23] Including the contract energy supply rate $0.09593/kWh and the kWh charge in Eversource delivery service (Distribution, Transition, Revenue Decoupling, Distributed Solar Charge, Renewable Energy, and Energy Efficiency)

Load Offset by Solar (%)	0%	26%	26%
Preliminary Economic Data			
Annual Electric Costs ($)	1,449,956	997,608	1,081,186
Annual Fuel Costs ($)	133,157	133,157	133,157
Annual Energy Cost ($)	1,583,113	1,130,765	1,214,343
Annual Energy Cost Saving ($)	-	452,348	368,770
Investment Cost (Battery) ($)	-	3,750,000	975,000
Investment Cost (Solar) ($)	-	5,502,900	5,502,900
Infrastructure Cost ($)		120,000	72,000
Total Investment Cost ($)	-	9,372,900	6,549,900
Project Administration Cost ($)	-	2,343,225	758,038
Total Project Cost ($)	-	11,716,125	8,187,375

The preliminary cost analysis for each stakeholder is presented in Table 18 through Table 23. The capacity value of battery storage has a big impact on the payback year since a battery energy storage system (BESS) is mainly for reliability improvement benefits. BESS reduced the demand charge cost but did not generate significant revenue, based on the demand charge assumption (averaged at $7.83/kW-month).

Table 18. CSCRS Preliminary Cost Analysis (FMS)

FMS	Base	Resiliency	Economic
Technical Data			
Solar Capacity (kW)	-	500	500
Battery Capacity (kW/kWh)	-	450/1800	50/200
CO_2 Emission (metric ton)	327	212	215
CO_2 Reduction (metric ton)	-	116	113
Solar Generation (kWh)	-	553,936	553,936
Battery Charged by Solar (%)	0%	84%	100%
Current Annual Load (kWh)	919,478		
Load Offset by Solar (%)	0%	60%	60%
Preliminary Economic Data			
Annual Electric Costs ($)	198,560	72,087	102,195
Annual Fuel Costs ($)	19,572	19,572	19,572
Annual Energy Cost ($)	218,132	91,659	121,767
Annual Energy Cost Saving ($)	-	1,125,000	125,000
Investment Cost (Battery) ($)	-	1,624,350	1,624,350
Investment Cost (Solar) ($)		20,000	20,000
Infrastructure Cost ($)	-	2,769,350	1,769,350
Total Investment Cost ($)	-	692,338	442,338
Project Administration Cost ($)	-	3,461,688	2,211,688
Total Project Cost ($)	-	1,125,000	125,000

Table 19. CSCRS Preliminary Cost Analysis (MCES)

MCES	Base	Resiliency	Economic
Technical Data			
Solar Capacity (kW)	0	369	369
Battery Capacity (kW/kWh)	0	250/1000	400
CO_2 Emission (metric ton)	287	204	205
CO_2 Reduction (metric ton)	-	83	82
Solar Generation (kWh)	0.0	404,286.0	404,286.0
Battery Charged by Solar (%)		100%	100%
Current Annual Load (kWh)	433,272		
Load Offset by Solar (%)	0%	93%	93%
Preliminary Economic Data			
Annual Electric Costs ($)	105,117	25,205	30,324
Annual Fuel Costs ($)	31,045	31,045	31,045
Annual Energy Cost ($)	136,162	56,250	61,369
Annual Energy Cost Saving ($)	0	79,912	74,793
Investment Cost (Battery) ($)	0	625,000	250,000
Investment Cost (Solar) ($)	0	1,199,250	1,199,250
Infrastructure Cost ($)	0	30,000	20,000
Total Investment Cost ($)	0	1,854,250	1,469,250
Project Administration Cost ($)	0	463,563	367,313
Total Project Cost ($)	0	2,317,813	1,836,563

Table 20. CSCRS Preliminary Cost Analysis (FB)

FB	Base	Resiliency	Economic
Technical Data			
Solar Capacity (kW)	0	528	528
Battery Capacity (kW/kWh)	0	500/2000	500
CO_2 Emission (metric ton)	367	225	227
CO_2 Reduction (metric ton)	-	142	139
Solar Generation (kWh)	0.0	684,556.6	684,556.6
Battery Charged by Solar (%)		100%	100%
Current Annual Load (kWh)	1,254,480		
Load Offset by Solar (%)	0%	55%	55%
Preliminary Economic Data			
Annual Electric Costs ($)	245,437	105,384	117,592
Annual Fuel Costs ($)	6,266	6,266	6,266
Annual Energy Cost ($)	251,703	111,650	123,858
Annual Energy Cost Saving ($)	0	140,053	127,845
Investment Cost (Battery) ($)	0	1,250,000	312,500
Investment Cost (Solar) ($)	0	1,716,000	1,716,000
Infrastructure Cost ($)	0	30,000	20,000

Total Investment Cost ($)	0	2,996,000	2,048,500
Project Administration Cost ($)	0	749,000	512,125
Total Project Cost ($)	0	3,745,000	2,560,625

Table 21. CSCRS Preliminary Cost Analysis (FS5)

FS5	Base	Resiliency	Economic
Technical Data			
Solar Capacity (kW)	-	54.4	54.4
Battery Capacity (kW/kWh)	-	50/200	15/60
CO_2 Emission (metric ton)	41.4	27.0	27.0
CO_2 Reduction (metric ton)	-	14.4	14.4
Solar Generation (kWh)	0.0	70,637	70,637
Battery Charged by Solar (%)	0%	97%	100%
Current Annual Load (kWh)	81,659		
Load Offset by Solar (%)	0%	87%	87%
Preliminary Economic Data			
Annual Electric Costs ($)	15,983	4,664	5,253
Annual Fuel Costs ($)	4,459	4,459	4,459
Annual Energy Cost ($)	20,442	9,123	9,712
Annual Energy Cost Saving ($)	0	11,319	10,730
Investment Cost (Battery) ($)	0	125,000	37,500
Investment Cost (Solar) ($)	0	176,800	176,800
Infrastructure Cost ($)	0	10,000	10,000
Total Investment Cost ($)	0	311,800	224,300
Project Administration Cost ($)	0	77,950	56,075
Total Project Cost ($)	0	389,750	280,375

Table 22. CSCRS Preliminary Cost Analysis (FHA)

FHA	Base	Resiliency	Economic
Technical Data			
Solar Capacity (kW)	-	242	242
Battery Capacity (kW/kWh)	-	250/1000	100/400
CO_2 Emission (metric ton)	2,076	2,005	2,019
CO_2 Reduction (metric ton)	-	71	57
Solar Generation (kWh)	0.0	278,322.2	278,322.2
Battery Charged by Solar (%)		76%	100%
Current Annual Load (kWh)	4,960,415		
Load Offset by Solar (%)	0%	6%	6%
Preliminary Economic Data			
Annual Electric Costs ($)	888,245	790,270	825,821
Annual Fuel Costs ($)	71,815	71,815	71,815
Annual Energy Cost ($)	960,060	862,085	897,636
Annual Energy Cost Saving ($)	0	97,975	62,424
Investment Cost (Battery) ($)	-	625,000	250,000
Investment Cost (Solar) ($)	-	786,500	786,500
Infrastructure Cost ($)		30,000	20,000
Total Investment Cost ($)	-	1,441,500	1,056,500
Project Administration Cost ($)	-	360,375	264,125
Total Project Cost ($)	-	1,801,875	1,320,625

The primary generation source for the proposed community microgrid (CSCRS) capacity would include the roof-top solar and solar canopy in the parking lot, with a total capacity of up to 1,693 kW, and battery storage, with a total capacity of up to 610 kW/2,440 kWh. Battery storage would be charged by solar generation during the daytime and discharged for supplying load during the night or charged during off-peak periods and discharged during high-demand cost periods under a time of use or real-time pricing rate.

Locations and space available for solar are shown in **Figure 37** through **Figure 41**, matching the totals in **Table 9**. In this report, all the potential space for solar is proposed to maximize the benefits considering the onsite load level. Adequate space was identified for battery installations during the site visits conducted during Task 2. Larger batteries (over 500-1,000 kWh) are exterior located inside NEMA-rated enclosures with integrated temperature control and fire protection.

Figure 37. *FMS (499.8 kW, provided by City)*

Figure 38. *MCES (369 kW)*

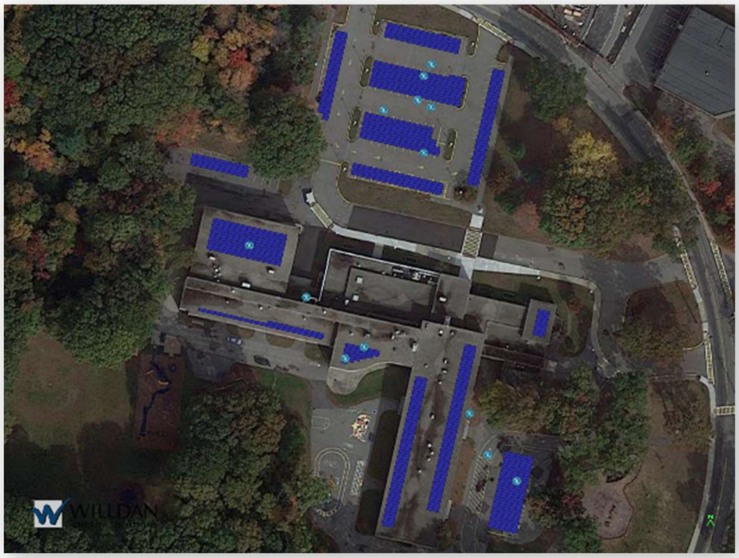
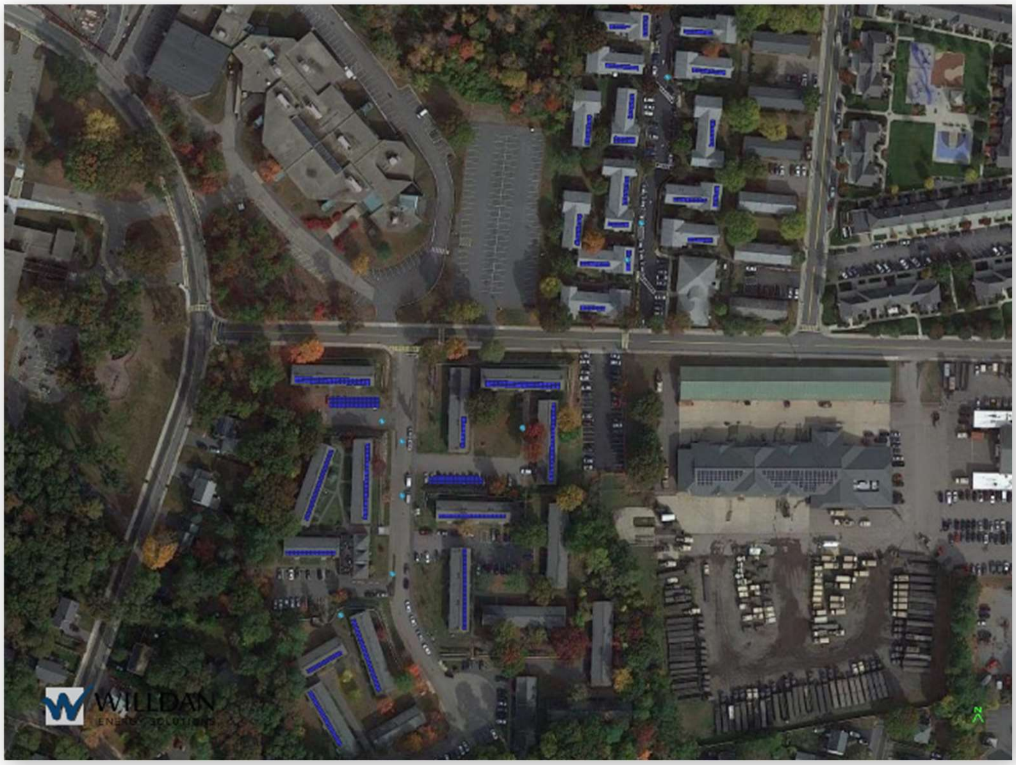


Figure 39. FB Solar PV Potential (528 kW)

Figure 40. FS5 Solar PV Potential (52.8 kW)

Figure 41. Framingham Housing Authority Solar PV Potential (242 kW)



4.3.2 Ability of DERs to Serve Load and Provide Resilience

During normal operating conditions, i.e., grid-connected mode, the microgrid generation resources would operate in parallel to the grid. The load would be continuously met through an approximately 26% annual offset of local distributed generation with the remaining electricity purchased from the utility.

DER assets will be installed considering flood and storm risks and rated accordingly. Modern solar panel rooftop racking is highly resistant to weather conditions and can be rated for 120 mph winds and greater. Switchgear and other electrical infrastructure will be raised above flood levels to prevent equipment malfunction due to the effects of climate change. Traditional generation and battery equipment will be installed indoors or in weather-rated containers.

The CSCRS controller would coordinate and dispatch the charge activity of battery storage and dispatch the energy generated by DERs located at different locations.

4.3.3 Fuel Sources for Fossil Fuel DERs

Eversource Energy is the current natural gas supplier for the CSCRS project area. If diesel supply is disrupted, the microgrid critical loads will continue to be electrically served by solar and storage for a period of 6-72 hours vary for stakeholders, with solar generation recharging the batteries during the day for continuous operation. With reconfiguration and authorization by each of the DER owners, the connected stakeholders are capable of sharing their generation resources among each other in community microgrid mode for optimizing the usage of the existing backup generation resources to support the critical loads.

4.3.4 DER Capabilities

The microgrid controller enables the DERs to respond quickly to energy needs, change ramp direction on demand, sustain up/down ramping for extended periods, start/stop multiple times a day, respond for defined periods of time on request, start with a short notice from zero or low-electricity operating level, and forecast operating capability through economic dispatch and real-time management of DERs such as solar and battery storage. This includes maintaining voltage and frequency in grid-following mode and utilizing battery and solar inverters to ride through islanding and resynchronization events. This will be done according to IEEE 2030.7 standards, following the IEEE 2030.8 guidelines.

4.4 Electrical and Thermal Infrastructure Characterization

Eversource owns and operates the distribution system within the community to serve all CSCRS stakeholders. Eversource Energy owns and operates the gas network to serve the natural gas customers. Whenever possible, the existing overhead/underground distribution cables will be used to connect the different microgrid stakeholders.

4.4.1 Simplified Electrical and Thermal Infrastructure Diagram

The conceptual simplified infrastructure diagram is presented in Figure 1. The connected substation and feeder for each stakeholder are summarized in Table 23. The five stakeholders are fed by the same feeders.

Table 23. Summary of Distribution System (Substation, Feeder and Capacity)

Stakeholder	Study Area	Substation	Voltage (kV)	Feeder	Capacity
FMS	Concord Street	STA-240	13.8	240-H3	4 MW left[24]
MCES			13.8	240-H3	
FB			13.8	240-H3	
FS5			13.8	240-H3	
FHA			13.8	240-H3	

4.4.2 CSCRS Meter Consolidation

The physical interconnection of the microgrid to the Eversource distribution system involves the physical consolidation of the site's meters into one master meter.

Physically consolidating each of the sites (except FS5) to a single meter allows for a true microgrid, where solar generation from one building can be shared with other buildings and with each of the stakeholders. It can also lower monthly fees due to reduced meter charges and energy/demand prices at a higher service level. These benefits may come with the significant capital, time, and effort expenditure required for the civil engineering and construction costs. Wherever possible, underground submersible switchgear and vaults will be used to improve distribution resilience and minimize the visual impact on the community. Depending on the ability to use the existing distribution equipment and conduit (of which limited information is available as of the publication date of this report), the sophistication of the

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[24] Framingham Request for Information 1.13.2021 – Confidential stamp.pdf

switchgear, and communications to support the relays and circuit breakers for this system could cost between $500,000 and upwards of $3,000,000[25].

FMS, MCES, and FS5 belong to the City and are currently with the same third-party power supplier (Public Power & Utility). The FHA is a quasi-state agency that operates independent of the City[26], and is associated with a different third-party power supplier (Direct Energy Business, LLC). FB is supplied by Constellation Newenergy, Inc. As confirmed with Eversource, it may be challenging and difficult to aggregate the loads under different owners and electricity tariffs.

4.5 Microgrid and Building Controls Characterization

The CSCRS will demonstrate several technological advancements and breakthroughs that will help the stakeholders achieve their energy goals. The critical breakthrough is the proposed development methodology that synchronously considers both system planning (LoadSEER) and simulated operation (IDROP and OPAL-RT), resulting in maximum efficiency and responsiveness in developing a microgrid configuration with an optimal mix of DERs, cyber-secure communication, real-time controllability and visibility, and islanding capability. The proposed methodology supports a high penetration of intermittent renewable energy resources by introducing a controllable and flexible load at the microgrid level.

4.5.1 Microgrid Controls Diagram

Most existing controller solutions use proprietary data architectures that limit interoperability with other platforms and systems, decreasing their applicability and replicability. The Microgrid Controller Technology Stack (MCTS) shown in

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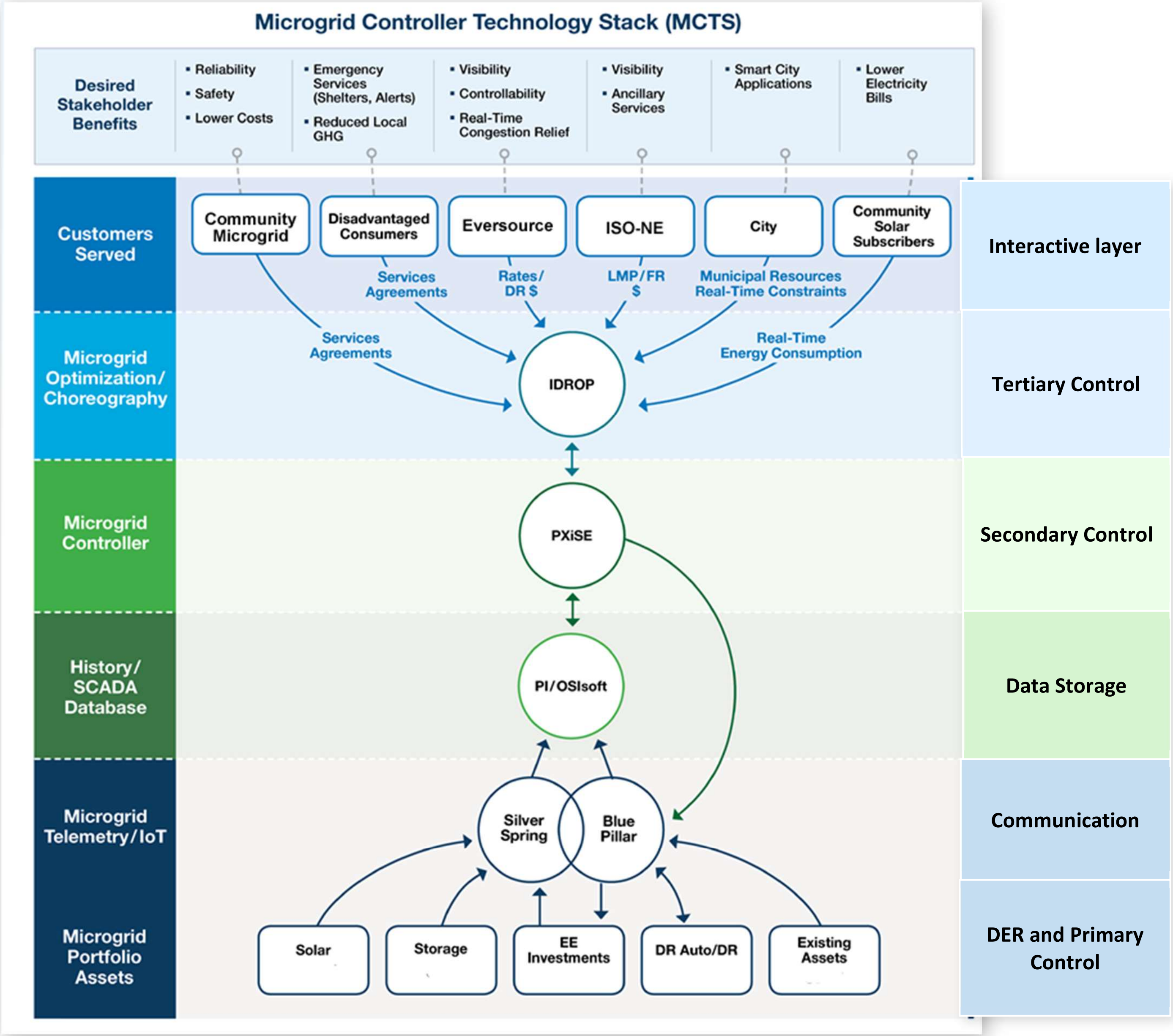
[25] Rough estimation based on the discussion with Eversource Energy. Possible for multiple meters belonged ti same customer. Big challenges for multiple meters belonged to different customers under current regulation.

[26] https://framinghamhousingauthority.org/

Figure 42 does not use proprietary architectures, replacing the current technology with utility-approved, cyber-secure components already deployed in utility-scale applications but leveraged to account for, and adjust to, real-world data inputs, which produces the optimal DER mix. LoadSEER is used in PG&E's load forecasting and planning, IDROP is used in SCE's utility-scale DER fleet management, PXiSE is used in SDG&E's Borrego Springs Microgrid, and PI System is used as the vast majority of major Investor-Owned Utilities (IOUs) historian and SCADA databases. MCTS will advance these current technologies by showing how they are able to address a current issue in microgrid implementation.

Figure 42. CSCRS Master Controller Technology Stack (MCTS)



In microgrids, the primary control offers a localized control in real time, which is essentially designed to realize load sharing among parallel-connected DERs with no need for providing communication channels between DERs.

The secondary control is disabled in grid-connected mode since the voltage is maintained by the utility grid. In islanded mode, the secondary control would eliminate voltage deviations without adjusting the dispatch of parallel DERs. Once a voltage deviation is detected, the secondary control would generate a voltage compensation signal to uplift the droop curve and restore the rated voltage without changing the DER dispatch.

The economic and optimal operation of microgrids necessitates an upper-level tertiary control. The master controller is the most important microgrid element, which is responsible for tertiary control. The master controller obtains data from the generation and load entities through supervisory control and data acquisition (SCADA).

Willdan takes utility-approved applications (LoadSEER, IDROP, OPAL-RT, PXiSE, and OSIsoft PI system) and combines them into two technology stacks—planning and operations—to allow a continuous feedback loop that maximizes efficiency and responsiveness to real-world conditions in an optimized microgrid configuration.

This configuration will reliably serve stakeholders while satisfying Eversource's requirements by using proven technologies in planning technology stack to analyze and optimally size and site DERs in the CSCRS. This innovation will address a significant barrier for microgrid implementation, that is the disconnection between planning and real-time operation, by analyzing a constant stream of simulated and actual data that can be used to plan and course-correct the operation of the microgrid.

The MCTS enables the WPMRS to respond quickly to energy needs, change ramp direction on demand, sustain up/down ramping for extended periods, start/stop multiple times a day, and provide optimal dispatch and forecast operating capability through the economic dispatch and real-time management of DERs such as solar and battery storage, and the dispatchable load demands.

The MCTS shown in

Figure 42 enables the integration and interoperability of different systems and components—including real-time communication with the electric grid, ISO New England energy market and BEBs on the road—using a standard interface and cyber-secure communications protocol. The CSCRS will follow the IEEE 2030.8 guidelines for simplifying communication and integration between different equipment and device. The microgrid controller's open architecture allows the integration of different system components and supports interoperability through cyber-secure, standard interfaces and communications, increasing the project's replicability and scalability, which will help in adopting new information, power and energy technologies in the CSCRS in the future. The MCTS shown in

Figure 42 unlocks the full economic value of DERs by factoring in real-time grid conditions (power flow, network constraints) and stakeholder requirements (peak-shaving, power quality, energy costs). Its platform of capabilities can manage additional public works services, increasing the commercial viability of the controller.

MCTS includes a series of software packages that could be deployed either onsite or hosted in the cloud. If hosted onsite, the MCTS server could be installed in any indoor environment with uninterruptible power supply (UPS) such as a battery container or an existing electrical room. One standard 42U server rack (H: 78 inches, W: 23.6 inches, D: 40 inches) would accommodate all the necessary servers, power supply and display equipment, with spare space for future upgrades.

4.5.2 Microgrid Services and Benefits

CSCRS would provide extra layer resiliency benefit in addition to the existing backup generators, 48-72 hours of backup and islanding capacity using proposed clean solution vary by sites. CSCRS would also provide benefits and values including, but not limited to, microgrid services in grid-connected (ancillary services, power quality services, quality of services, intermittency alleviation, reliability improvement to sensitive loads such as security systems) and islanded mode (black-start and resiliency), non-energy related and societal benefits such as workforce training, emerging technologies evaluation testbeds, and other smart grid services.

CSCRS will help stakeholders evaluate the actual benefits of the project and may inform future state policy considerations. OSIsoft's PI Historian database will be used to store data; perform event tracking of tests, outages, and equipment usage; monitor operations; analyze performance; and evaluate costs/benefits in real time or over a period of months or years.

CSCRS will demonstrate how using advanced data analytics in a community microgrid contributes to Integrated Resource Planning, specifically to deferring generation, transmission, and distribution upgrade costs, which are passed on to ratepayers as cost reductions. CSCRS also will demonstrate how integrated DER controls can respond to load-following and ramping needs at the local grid and system levels. For the project stakeholders, this will lower bills, provide more reliable energy services, and lead to a cleaner environment. The proposed project specifically will benefit stakeholders with greater reliability, lower costs, and increased safety, as described below.

4.5.2.1 Improved Reliability

a. CSCRS is designed to incorporate high DER penetration. Under this design, even if a few DERs fail, the rest of the DERs within the system will remain operational, ensuring microgrid stability and reliability.

b. The CSCRS MCTS will provide ISO-NE and Eversource with DER visibility, supporting daily operations and providing their customers with higher reliability.

c. The proposed control package has islanding capability, so it can continue to function in the event of an electric grid disruption, increasing grid stability and power quality.

d. The CSCRS uses renewable sources of generation, decreasing dependency on natural-gas-powered peak plants, which are subject to supply disruptions.

4.5.2.2 Potential Energy and Cost Savings

a. CSCRS's inclusion of energy efficiency and renewable generation lowers power procurement, generation, utility, and microgrid stakeholder costs, and can defer peak power plant, transmission, and distribution infrastructure upgrade costs. On a broader scale, lowering these costs could help result in future decreases in Eversource's ratepayer costs.

b. The CSCRS MCTS will provide efficient real-time operational schemes that allow microgrid operators to monitor and manage the microgrid assets more economically and efficiently.

c. The CSCRS will consider Eversource's interconnection requirements, reducing overall engineering efforts for both the utility and the community microgrid developer.

d. The CSCRS MCTS provides the utility with visibility, which enables more efficient operation (e.g., grid-level DER dispatch) and grid services (e.g., ramp up/down, support more storage, less intermittency and generation curtailment).

e. Optimally dispatching load demand with the battery storage dispatch and solar PV generation across the three locations would result in demand charge savings, energy savings and maximized utilization of solar generation and load demand response.

4.5.2.3 Safety

a. This proposed project will lower the running hours of backup natural gas generators and reduce natural gas use, which minimizes stress on the current aging natural gas infrastructure.

b. The CSCRS lowers the base load and provides peak shaving through the MCTS.

c. The CSCRS provides an alternate energy source, decreasing the impact of potential incidents, such as gas leaks.

d. The proposed system will provide power to CSCRS-designated emergency shelters during prolonged grid disruptions caused by natural disasters (e.g., winter storms, fires, heat waves, and floods).

e. The visibility provided by the microgrid controller increases safety for maintenance workers investigating system faults by showing the shortest path to correct the fault.

f. Locally generated power through DERs reduces the level of power flow necessary on campus distribution infrastructure, decreasing electrocution risks to electrical workers and for public safety issues such as exploding transformers.

4.5.3 Load Management and Resilience

The community microgrid has the capability of supplying power to critical facilities from battery storage and local DERs to improve the energy resilience of critical facilities. In cases of extreme weather events, if one building's microgrid fails due to less generation, the loads can be served by the generation resources located at another stakeholder's territory. With the proposed solar PV and battery storage in each of the sites, the energy consumption and demand could be managed effectively. More reliable and resilient power service could be achieved by dispatching DER assets and load in all stakeholder locations.

4.6 Information Technology (IT)/Telecommunications Infrastructure Characterization

Any modern utility or system operator relies heavily on their communication infrastructure to monitor and control their grid assets. For a microgrid master controller and microgrid operators, this architecture enables real-time control, the rapid digestion of critical grid information, and historical data for analysis and reporting. As part of a feasible microgrid, the assessment and upgrade of the equipment and protocols used in the microgrid area will be performed.

4.6.1 IT/Telecommunications Layout Diagram

The planned development area is expected to have communication systems varying from wi-fi to dedicated fiber optics for critical information systems. Building management systems rely on BACnet, Modbus or Lonworks (ISO/IEC 14908) over serial or Ethernet. Controls for chillers, boilers, CSCRS's existing distributed heating system, thermostats, air-handling units, lighting, and others use various wired or wireless networks and protocols, depending on when they were purchased or upgraded. Often, vendor-specific proprietary networks are deployed as technology progresses with little regard for data consolidation. Especially in a campus environment, networks are set up for research and operations with IT departments, often struggling to maintain services and prevent attacks rather than consolidate various networks and devices.

With the development of CSCRS, whenever possible, existing communications and control infrastructure will be leveraged to avoid re-training operators and excess capital expenditures. This is possible due to the framework of OSISoft's PI Historian[27], which allows for the integration of every major vendor's proprietary protocol and every standard protocol and has been tested and integrated with billions of devices. This includes building and lighting controls, central plant operations, generators, and any other existing equipment that microgrid owners or campus personnel want to monitor from one easy-to-search, easy-to-access system. The OSIsoft PI system can equip the microgrid controller with the supervisory control and data acquisition (SCADA) system for monitoring and regulating the microgrid operation, synchronizing and integrating the data transmitted to and from the microgrid controller via diverse communication protocols. The OSIsoft PI system also provides an intuitive web-client visualization tool that offers access to real-time information in a fast, easy, and secure manner so that a microgrid operator can gain sufficient insights into microgrid conditions based on data-driven analyses.

The high-level communication system architecture for CSCRS is seen in Figure *43*. The major equipment installed on the stakeholder's site would be the proposed solar PV, either roof solar or solar canopy depending on the site, along with combined battery storage. A local controller hosted in an onsite server or in the cloud would be de deployed to monitor, communicate with and control the local DERs and loads. Each stakeholder will operate with its own internal network, with wireless cellular backhauls connecting the systems with a cyber-secure cloud database. New grid controls and any upgraded building controls, along with master controller inputs and control points, will also be connected. The microgrid owner/operator(s) will have full control of and access to the microgrid systems. This could be the CSCRS operators running their own system, Eversource operating some of the system, or a contracted Operations and Maintenance (O&M) firm running the entire system.

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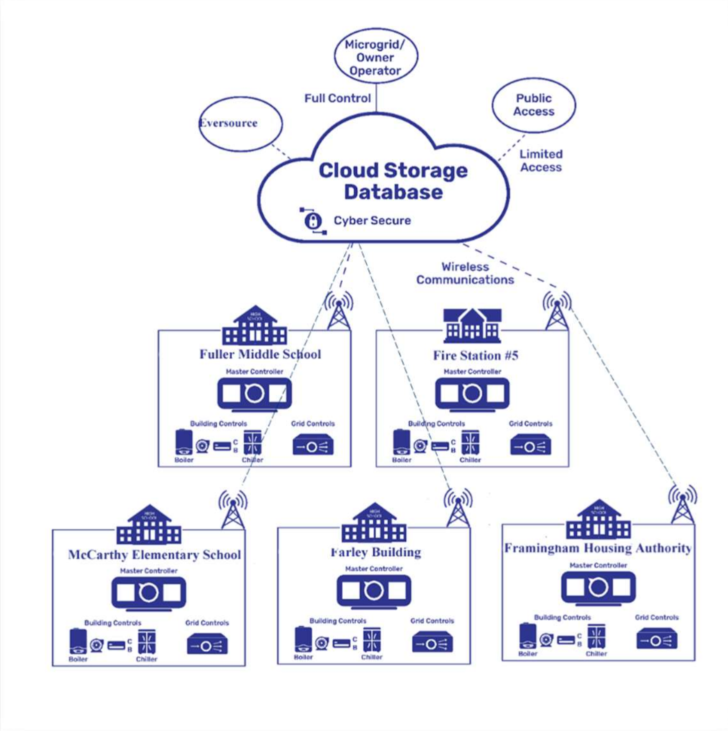
[27] PI System is developed by OSISoft, LLC which belonged to Aveva Group

Figure 43. CSCRS Proposed Communications and Control Diagram



Public access to the high-level generation and operation of the system can be granted through a simplified online portal or on-campus display to allow for education and community engagement.

4.6.2 IT/Telecommunications Operation

The CSCRS would be connected efficiently and productively, with modern communication architectures and equipment, enabling a master controller to optimize the microgrid control and giving operators the tools that they need to maximize the benefits of the microgrid to the stakeholders. Exact upgrades or additions to existing communications infrastructure will need to be determined during a detailed design phase.

The grid operations equipment, IE circuit breakers, relays, reclosers and other switchgear are vital to the control of the CSCRS. While some distributed switchgear can utilize wireless infrastructure, with data being fed through Eversource's substations instead of through a cloud network, the control equipment is more vital to the safe operation of the microgrid and would ideally use a fiber-optic backbone between the CSCRS master controller substations and grid switches. The substation relays will be upgraded or designed to communicate using the DNP3 protocol over TCP/IP, the de facto standard for modern utility communications, which will be used to monitor and control the proposed DER as well. Once collected locally, the data will be fed into an upgraded or added SCADA system to allow operators to access, visualize, and control all the microgrid assets from a central control center located on or off the campus.

If an O&M firm is contracted, they can be responsible for the communications infrastructure and associated electrical and controls equipment that is critical to the operation of the microgrid. If the CSCRS decides to hire staff and operate the system itself, the existing IT department will be trained on the maintenance and operation of the communications system.

The microgrid status and operation data will be shared with Eversource at the microgrid stakeholder's discretion. This could be limited data provided through an online Application Programming Interface (API) or portal, which would be subject to internet availability and its associated reliability. However, the use of the planned controller allows for a dedicated connection of real-time operations and control data using the OSIsoft PI database. Additionally, Eversource could use its own backhaul network to bring microgrid operations data back to its emergency operations center if it plans to leverage the microgrids for a black-start capability to re-energize its lines. In the case of operating or controlling the DER asset within the proposed microgrid, Eversource would need to send the request to the microgrid controller through which the control commands are sent to the target units. The proposed microgrid would provide Eversource or other regulation departments with an interface that could oversee or monitor the microgrid running status for grid reliability and stability purposes.

4.7 Conclusion

In the proposed CSCRS, the generation resources in different stakeholder locations would be optimally dispatched, coordinated, and controlled to provide economic benefit and better resiliency in service for current customers toward zero-emission communities. The proposed community microgrid would improve power supply reliability and resiliency and provide a clean, green energy service for current communities and customers.

Following Section 3 (Task 2), a preliminary technical design and system configuration was proposed for CSCRS per the site assessment findings and characteristics identified in Task 2. The proposed microgrid infrastructure and operations were presented to both utility and stakeholders in which the PCCs were identified. The load characteristics of different stakeholders and aggregated hourly load profiles for the CSCRS were calculated and summarized. Solar-Battery combined solution to be operated in the CSCRS were studied and summarized for each of the sites (Table 17 to Table 22), resulting in a total of 1.693MW solar PV and 6MWh battery for resiliency 1.56MWh battery for the economic scenario. The preliminary costs and relevant CO_2 emissions are calculated for the current system, i.e., the base scenario and the proposed system.

An optimization-based DER Planning model developed by Willdan is applied for the optimal DER mix calculation by considering the hourly load shape, electricity tariff, resiliency expectation, historical weather data, historical outages, etc. Based on the calculation results, the CSCRS distribution system has the potential to benefit from investments in microgrids and DER technologies. Solar PV and battery storage enable the proposed community microgrid to operate in islanded mode during power grid outages or in extreme conditions, improving the overall power supply quality and increasing the reliability and resiliency of the whole community, adding an extra layer of protection in addition to the existing backup generators. The coordination between solar generation and battery operation would maximize economic benefits while also considering resiliency and environmental benefits and reducing the system's dependency on natural gas, which may be unavailable during extreme conditions such as storms, heatwaves, floods, etc.

The current annual energy costs and CO_2 emissions for the existing loads are $1.58 million and 5,294 metric tons, respectively. This represents the baseline for the proposed microgrid solution. The hourly load shape, electricity tariff, Eversource emission parameter in Framingham area, the electricity cost, investment cost, and CO2 emission are calculated in Table 17 to Table 22. The proposed community microgrid would have a 28.6% annual saving compared with the base case and a 13.7% annual saving on CO_2 emission. The annual CO_2 emission reduction is 426 metric tons.

5. Financial Solutions

5.1 Financial and Economic Analysis Objectives

The proposed project includes solar photovoltaic (solar PV) and battery storage distributed energy resources (DERs) and other efficiency enhancements within the microgrid system. The installation would seamlessly integrate key objectives of the CLEAR Program (described above) and the City's Municipal Vulnerability Preparedness (MVP) plan (2018) that identified initiatives to increase resiliency and reduce impacts from utility outages, greenhouse gas emissions (GHGs), and energy costs.

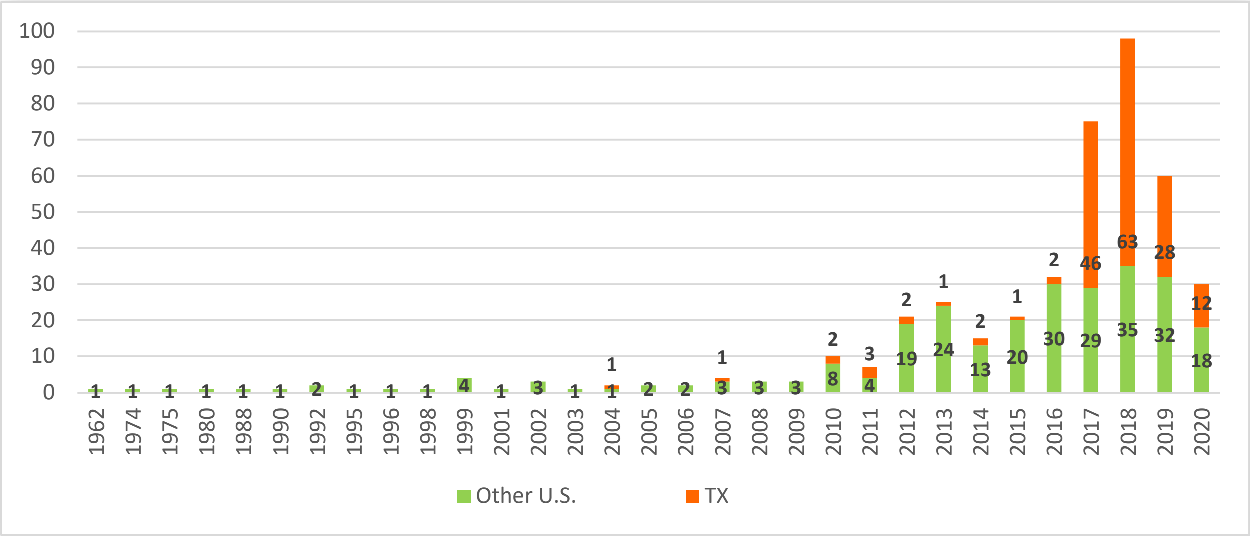
5.2 Microgrid Development & Investment Trends

To inform the City of Framingham's evaluation of microgrid installations on public property, the following overview of development and investment trends provides a brief history of the geographic expansion, purposes, and ownership structures that influence the current state of the microgrid market.

5.2.1 History of U.S. Microgrid Development

According to U.S. Department of Energy (DOE) data[28] illustrated in Figure 44 and Figure 45, there are approximately 461 active microgrid projects in the United States containing 821 distributed energy resources (DERs). Texas leads the nation in installations, followed by California, New York, Hawaii, and Massachusetts. Combined, these states and the Commonwealth account for nearly 60 percent of the total installations in the U.S. and its territories.

Figure 44. Active U.S. Microgrid Projects by Year of Construction



Source: https://doe.icfwebservices.com/microgrid; Willdan, 2021

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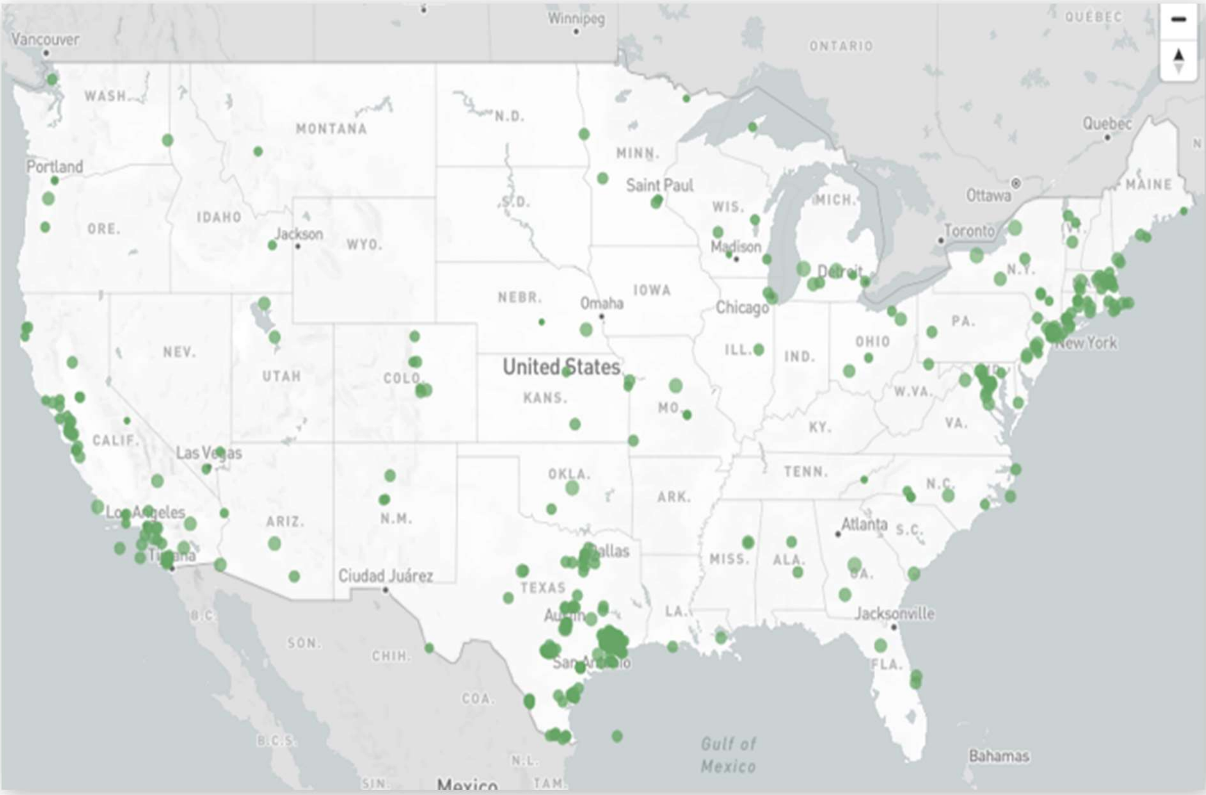
[28] https://doe.icfwebservices.com/microgrid

Figure 45. Active U.S. Microgrid Projects by State



Source: U.S. Department of Energy; Willdan, 2021

Commercial deployments are the largest setting for microgrids, accounting for 42 percent of the U.S. total. This figure is skewed by the development of microgrids by H-E-B supermarkets in Texas, which began deploying microgrids in the Houston market to address power-related operational costs (spoilage).

The aftermath of Hurricane Harvey (late August 2017) tested the chain's ability to maintain operations at multiple Houston stores for several days following that event even the storm knocked out power for 300,000 utility customers[29]. Eighteen stores received full-facility backup power for five consecutive days during the storm. This led to the expansion of its microgrid program across the company, marketing "reliability as a service."

Table 24. U.S. Microgrid Installation Settings

	U.S. Total	%	Total w/o TX	%
Commercial	194	42%	51	17%
City/Community	57	12%	55	19%
Military	49	11%	47	16%
College/University	44	10%	41	14%
Schools	27	6%	27	9%
Hospital/Healthcare	22	5%	19	6%
Public Institution	16	3%	16	5%
Research Facility	16	3%	13	4%
Multi-Family	15	3%	14	5%

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[29] https://microgridknowledge.com/h-e-b-microgrid-hurricane/

Water Treatment/Utility	9	2%	2	1%
Agriculture	8	2%	8	3%
Other	4	1%	4	1%
TOTAL	461	100%	297	100%

Source: U.S. Department of Energy; Willdan, 2021

Excluding the Texas data, commercial, city/community, military, and college/university deployments are the primary settings, accounting for approximately two-thirds of the 297 microgrids in the remainder of the U.S.

Natural gas [turbines] are the most common energy resource, totaling 191 and accounting for 23 percent of all microgrid resources. Within this total, there are 121 H-E-B natural gas microgrids in Texas.

Outside of Texas, natural gas totals 41, or 6 percent of the total U.S. microgrid energy resources. Dominant technologies are solar and [battery] storage, accounting for more than half the non-Texas total.

Table 25. U.S. Microgrid Total Distributed Energy Resources

	U.S. Total	%	Total w/o TX	%
Natural Gas	191	23%	41	6%
Solar	181	22%	175	27%
Storage	171	21%	165	26%
CHP	102	12%	98	15%
Diesel	92	11%	82	13%
Wind	35	4%	35	5%
Fuel Cell	15	2%	15	2%
Unknown	13	2%	13	2%
Biogas	13	2%	13	2%
Hydro	5	1%	5	1%
Thermal	3	< 1%	2	< 1%
Total	821	100%	644	100%

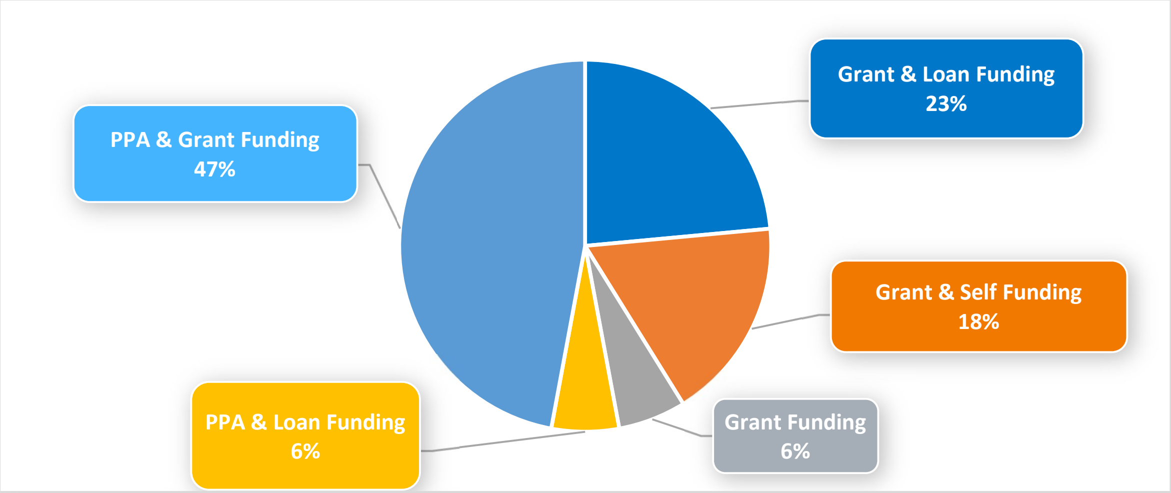
Source: U.S. Department of Energy and Willdan, 2021

5.2.2 Microgrid Funding Trends

To evaluate microgrid financing alternatives, Willdan conducted case study research on 93 microgrid projects throughout the U.S. The research concluded that the most common form of financing is the Power Purchase Agreement (PPA).

Of those with detailed funding information, nearly half of all microgrid project deals utilized a combination of grant and PPA financing. Another 23 percent utilized a combination of grant and loan funding, while 18 percent included a combination of self-funding and grants, as shown in Figure 46.

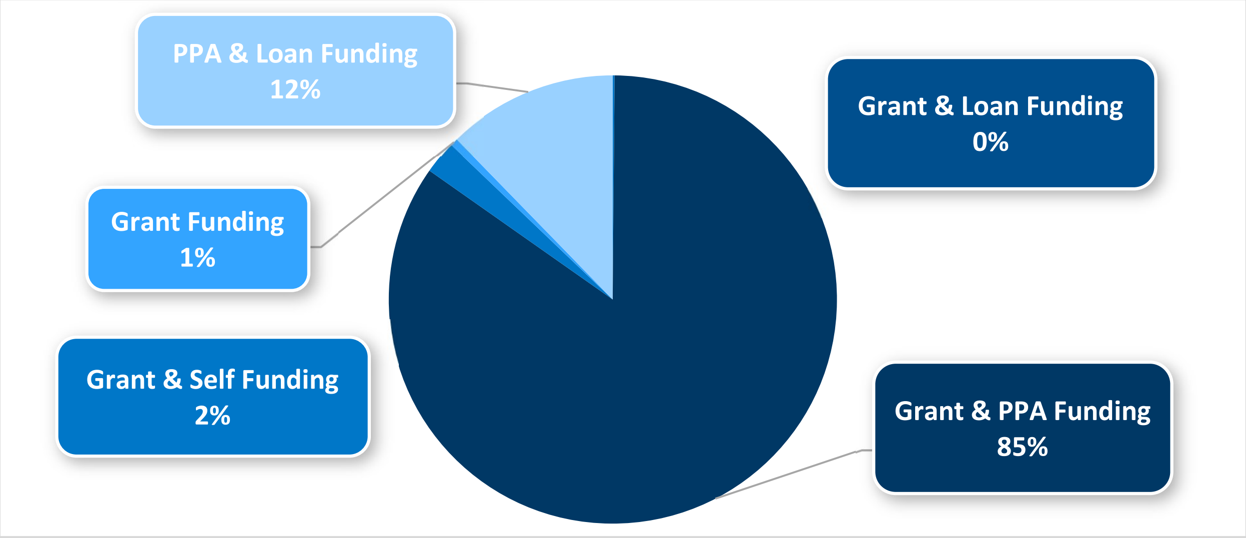
Figure 46. Volume of Microgrid Project Deals by Funding Source



On a dollar volume basis, the following figure illustrates that PPAs are the dominant funding source in the industry, providing 97% of the total capital investment analyzed within the case study projects (the sum of PPA & Loan Funding plus Grant & PPA Funding).

The disparity between the distribution of deals by funding category and the quantity of capital deployed perhaps exposes the challenge of raising capital outside of a PPA structure, or conversely, the relative ease of PPA financing. In the rare cases where non-PPA sources are utilized, the data indicates that the deals have much smaller capital needs.

Figure 47. Volume of Microgrid Dollars Invested by Funding Source



5.2.3 Trends in Ownership Structures

By virtue of the dominance of PPA financing, third-party ownership is the most common structure. A PPA is the only ownership structure that would enable a public entity to participate in downstream benefits from federal incentives. The importance of the federal investment tax credits and depreciation benefits cannot be overstated as a key consideration for the ownership structure. These items represent significant potential sources of investment cash flow that are not available to the public sector.

Every funding mechanism has the pros and cons. Elements of traditional infrastructure funding mechanisms (i.e., Special-Purpose Vehicles, Build-Operate-Transfer (BOT) models, and Public-Private Partnerships (PPPs)) are embodied within the agreements themselves, and are unwieldy for the projects studied in this report.

For example, PPA agreements may stipulate buy-back provisions at key junctures, likening them to a BOT. Special-purpose vehicles are generally unnecessary, as their primary benefit of moving the investment transaction “off balance sheet” is de facto accomplished by a PPA or other third-party mechanism.

PPPs are more typically deployed for very complex projects with significant capital needs ($100M+) and timelines that are often multiple times longer than PPA deal terms, which typically run for 20 years or less.

5.3 Potential Funding Alternatives

5.3.1 Direct Funding

Ownership through direct funding via the Capital Improvement Planning (CIP) and/or General Fund (GF) could include a mix of capital sources, including direct budget appropriations, general obligation bonds, revenue bonds, grants, green bonds, and other opportunities that are described below (refer to Appendix B: State & Federal Grant Programs, Incentives, and Capital Enhancements for detailed background information).

Direct public ownership allows the owner (City) to fully realize the full operational revenue stream and direct the deployment of those assets (i.e., how the energy resources are used), but eliminates the substantial benefits arising from federal investment tax credits (see ITC description) and depreciation. Debt and budget capacities are also substantial considerations, as these sources are not always readily available. The expertise and manpower to maintain and operate the microgrid are still another concerns or constraints, as Public Works Departments may not possess the knowledge, skills, or expertise to effectively execute, or must invest in human capital to do so.

Direct funding can be enhanced utilizing a variety of available tools to supplement investment capital, or more often, enhance or guarantee borrowing terms that facilitate the flow of capital.

5.3.2 Third-Party Funding Mechanisms

In addition to traditional funding through a combination of public debt and equity, there are financing mechanisms that utilize third-party capital, but shift ownership and most, if not all, operational control as well. These structures include Energy Services Agreements, recently enacted Massachusetts SB-9, PACE financing, and the more commonly deployed Power Purchase Agreement (PPA). Each of these is described in further detail below and in Appendix B: State & Federal Grant Programs, Incentives, and Capital Enhancements.

Power Purchase Agreement

A PPA is a financial agreement where a developer arranges for the design, permitting, financing and installation of an energy system on a customer’s property at little to no upfront capital cost. The developer sells the power generated to the host customer at a fixed rate that is typically lower than the local utility's retail rate. This lower electricity price serves to offset the customer's purchase of electricity from the grid while the developer receives the income from the sale of electricity, as well as any tax credits and all incentives generated from the system, unless modified contractually.

PPAs typically range in duration from 10 to 25 years and the developer remains responsible for the operation and maintenance of the system for the duration of the agreement. At the end of the PPA contract term, a customer may be able to extend the PPA, have the developer remove the system or choose to buy the solar energy system from the developer.

PPAs are one of the most common forms of financing infrastructure because there is usually a high upfront cost that the host cannot afford. Choosing a PPA also means that the host is not responsible for the maintenance and saves money throughout the PPA. However, usually at the end of the leased agreement, the infrastructure has reached its useful life and needs to be replaced, so the host does not benefit much after the PPA.

The PPA provider is the owner of the assets through the term of the agreement and will seek to retain future incentive savings from programs that do not currently exist. This may preclude the host's ability to claim environmental benefits against targets (e.g., greenhouse gas reductions or carbon markets).

As these deals are typically longer term, consideration should also be given to the host's ability to affect future changes to buildings or property where the assets are sited.

Energy Services Agreement

An Energy Service Agreement (ESA) is a pay-for-performance, off-balance sheet financing solution that allows customers to implement energy efficiency projects with no upfront capital expenditure. Through the ESA, the ESA provider pays for all project development and construction costs. Once a project is operational, the customer makes service charge payments for actual realized savings. The price per unit of savings is a fixed output-based charge that is set at or below a customer's existing utility price, resulting in immediate reduced operating expenses.

Unlike a PPA, customers do not assume performance risk since they only pay for the actual savings. Instead, the ESA provider takes the project performance risk and gets paid less if the project savings are less than expected.

Generally, an ESA is an effective tool for property owners looking to stabilize utility costs and make progress on their corporate social responsibility goals without making a large capital outlay. While ESAs offer long-term benefits due to the ability to buy out the contract and take ownership of the installed equipment, their primary benefit is the flexible nature of the contract structure. An ESA provides the host entity an opportunity to reduce energy consumption within facilities with minimal management and little to no upfront costs.

Massachusetts SB-9

In March 2021, Massachusetts Senate Bill 9 (SB-9) legislation was signed into law by Governor Baker. The bill outlined comprehensive climate change legislation to meet the Commonwealth's commitment to achieving net-zero emissions by 2050 and interim targets of 50 percent by 2030 and 75 percent by 2040.

The legislation also authorizes the Secretary of Energy and Environmental Affairs (EEA) to establish emissions limits every five years and sector limits for electric power, transportation, commercial and industrial heating and cooling, residential heating and cooling, industrial processes, and natural gas distribution and service.

Other provisions of the bill:

- Increase the percentage of electricity from renewable sources by 3% annually between 2025 and 2029 to achieve a 40% overall target by 2030
- Raise the state's total target of offshore wind to 5,600 MW by authorizing 2,400 additional MW of additional capacity
- Improve access to solar for low-income communities by establishing a solar program trust
- Enhance gas pipeline safety
- Create a pilot program to deploy geothermal heat pumps within micro-districts
- Include equity and reductions in greenhouse gas emissions among the Department of Public Utility's existing priorities for safety, security, reliability, and affordability
- Requires municipal light plants, which serve specific cities or towns, to purchase 50% of their power from non-carbon sources by 2030 and achieve net-zero emissions by 2050
- Provide local property tax exemptions under certain situations (see Local Property Tax Exemption)

A pertinent element of SB-9 is a provision that makes electric and gas distribution companies eligible to assist a municipality at high risk from climate change by constructing, owning, and operating solar PV and energy storage facilities on land owned by the electric or gas distribution company within a municipality. Focus is given to those municipalities with environmental justice populations. These systems are built at no cost to the city and may receive DPU approval for cost recovery.

This change is significant, as distribution companies were previously prohibited from owning generation assets. The provision also limits the amount of energy to 10 percent of the total installed megawatt capacity of the Commonwealth's solar generation facilities as of July 31, 2020.

Petitions for the development and cost recovery of utility-owned solar facilities must demonstrate site-specific environmental or climate change benefits to the community, municipality, or the Commonwealth. They are required to demonstrate consistency with the Commonwealth's energy policies, contribute to the climate change resiliency of the host municipality, and mitigate peak energy demand.

At the time of this writing, there are no known petitions or completed developments for utility-owned solar PV installations or associated battery storage. Importantly, the ability of a municipality to direct the energy produced to any single asset or location(s) may be limited in this ownership context.

PACE

The Property Assessed Clean Energy (PACE) model is an innovative mechanism for financing energy efficiency and renewable energy improvements on private property. PACE programs exist for commercial properties (C-PACE) and residential properties (R-PACE). PACE programs allow a property owner to finance the up-front cost of energy or other eligible improvements on a property and then pay the costs back over time through a voluntary assessment. The unique characteristic of PACE assessments is that the assessment is attached to the property rather than an individual.

PACE financing for clean energy projects generally is based on an existing structure known as a "land-secured financing district," often referred to as an assessment district, a local improvement district, or other similar phrases. In a conventional assessment district, the local government issues bonds to fund projects with a public purpose such as streetlights, sewer systems, or underground utility lines.

The recent extension of this financing model to energy efficiency and renewable energy allows a property owner to implement improvements without a large up-front cash payment. Property owners that voluntarily choose to participate in a PACE program repay their improvement costs over a set period—typically 10 to 20 years—through property assessments, which are secured by the property itself and paid as an addition to the owners' property tax bills. Nonpayment generally results in the same set of repercussions for failure to pay any other portion of a property tax bill, including loss of property.

5.3.3 Grants and Capital Enhancements

Following is a summary list of grant funding programs and cost-of-capital reductions. The detailed descriptions of their purposes, eligibility criteria, and other details are provided in Appendix B: State & Federal Grant Programs, Incentives, and Capital Enhancements.

- Biden Bipartisan Infrastructure Law (Infrastructure Investment and Jobs Act 2021)
- Building Resilient Infrastructure and Communities (BRIC) Grants
- DOE Loan Guarantees
- EPA Grants
- Green Bonds
- Green Banks
- Massachusetts Clean Water Trust
- Property Assessed Clean Energy (PACE)
- Massachusetts SB 9 (Net Zero Emissions by 2050)

5.4 Operational Benefits, Incentives, and Other Cash-Flow Opportunities

Energy companies and ISOs (see ISO) often maintain a variety of market-based opportunities that can monetize microgrids and their energy resources. It could be as simple as a solar PV array selling energy directly into the grid or as complicated as demand response (peak shaving), where energy is actively managed (called) to ensure adequate energy supplies and to balance energy loads on the grid.

Specific to the CSCRS, it is anticipated that the secondary market opportunities will likely focus on the Clean Peak Energy Credit Program and Demand Response, where the full, available capacity of both the solar PV and battery energy storage can be utilized for both purposes simultaneously, eliminating mutual exclusivities that arise with other options.

In addition, third-party ownership will enable the capture of Federal Investment Tax Credits and depreciation benefits. Several additional secondary market opportunities that could generate financial benefits are less likely and more complicated due to mutual exclusivity challenges associated with the deployment of the stored battery energy and increased operational complexity. These challenges would not necessarily preclude participation but make it less likely given the financial upside of the “more likely” programs listed above. These additional opportunities detailed in Appendix A: Financial Analysis – Glossary of Terms include:

- Black Start Support
- Curtailment
- Clean Peak Energy Credits
- Depreciation
- Local Property Tax Exemptions
- Forward Capacity Market (FCM) Savings
- Frequency Regulation
- Regional Network Services (RNS)
- Reliability/Resiliency
- SMART Solar Incentives

5.5 City of Framingham Financing Requirements

Following data collection interviews with City staff, Willdan validated the City's key financial objectives to limit upfront capital outlays and ongoing operating responsibilities associated with microgrid development.

Based on these established funding plan parameters, third-party financing through a PPA is the recommended source of project capital. The following financial analysis is based on this understanding and provides the respective deal terms for the City of Framingham and a PPA provider (likely to be Eversource, the local power and natural gas utility).

This analysis is structured to identify key financing assumptions and deal terms and, potentially, areas of negotiation for the City.

5.6 Capital Cost Estimate

Capital costs are estimated from system sizing parameters presented in Section 4 and the current market cost per KW of capacity. These estimates assume that a third-party provider may be able to gain some volume purchasing power but will likely fall between the costs published in National Renewable Energy Laboratory's (NREL) *Annual Technology Baseline* report and general consumer pricing.

According to the NREL report, median solar PV costs for larger commercial applications decreased from $8,500 per kW in 2007 to $1,762 per kW in 2020, reflecting a 79 percent overall decrease and an average annual reduction of just under 13 percent per year.

Future annual cost reductions are estimated to range between 2.0% and 9.0% for NREL's conservative and aggressive estimates, respectively, through 2030. Thereafter, reductions range between 1.0% and 2.0% percent, reflecting the maturation of the market and the more conservative nature of long-range projections in a rapidly evolving technology space.

NREL's average price estimate for future battery energy storage reflects a similar level and pattern of reductions with the unit cost for large-scale commercial applications decreasing from $1,762 per KW in 2020 to just over $1,000 by 2030, and $870 by 2040.

The estimated hard costs for the CSCRS are higher than the NREL research but, importantly, include necessary microgrid components such as inverters, software, and other ancillary items. Moreover, it is assumed that a PPA provider's purchasing power would not rise to the level of large commercial installations, lending a more conservative bias to the analysis.

Interconnection fees are separately estimated based on very preliminary discussions with Eversource. It is important to note that this cost estimate may be subject to modification by the energy company based on the final system specifications and a more comprehensive review of capacities impacted by the microgrid development.

Future reinvestment costs are modeled at the end of the estimated useful life for each asset and include an average year-over-year cost reduction of 3.0 percent and 3.5 percent for solar PV and battery energy storage resources, respectively. Baseline inputs are as follows:

Solar Photovoltaic	$3,000/kW
Battery Energy Storage (4-hr rating)	$2,300/kW

Timing for the proposed improvements include investment and operation commencing in 2022, with 30 percent of the operational capacity realized in 2022 (i.e., all DERs operating over approximately the last one-third of the year, considering the time of installation and interconnection process).

Total hard costs are estimated at $6.07 million including installation cost, exclusive of a 30 percent soft cost estimate and interconnection fees that increase estimated total capital expenditures to $7.86 million.

Table 26. Key Timing and Sizing Assumptions and Estimated Capital Costs

Timing Assumptions		FMS	FS5	FHA	MCES	PB	Total
Investment Year/Construction Start		2022	2022	2022	2022	2022	
First Operational Year		2022	2022	2022	2022	2022	
1st Year Operational Capacity %		30%	30%	30%	30%	30%	
Microgrid Capacity Inputs							
Solar PV	kW	499.8	54	242	369	528	1693
Battery Output	KW	50	15	100	100	125	390
Battery Energy Storage (4-hr rating)	kWh	200	60	400	400	500	1,560
Capital Cost Estimate							
Solar PV		$1,449,400	$163,200	$726,000	$1,107,000	$1,584,000	$5,079,600
Battery Energy Storage (4-hr rating)		$115,000	$34,500	$230,000	$230,000	$287,500	$897,000
Interconnection Fees							$90,000
						Subtotal	$6,066,600

Project Overhead @30%							$1,819,980
Total Estimated Cost							$7,886,580

Source: Willdan, 2021

Other Battery-Related Sizing Considerations

The size relationship between the battery energy storage and solar photovoltaic resources, aside from the general energy strategy, has several financial implications that were considered and evaluated.

The Investment Tax Credit benefit is perhaps the most significant. It requires that the battery be charged at a minimum of 75% from renewable sources. The actual ITC benefit for the battery depends on the percent of the time the battery is charged by combined solar. Above 75 percent, the amount of the ITC is reduced to the actual percentage. For example, a system charged by renewable energy 80% of the time is eligible for the 30% ITC multiplied by 80%, which equals a 24% ITC instead of 30%[30]. Below, the benefit is zero.

Similarly, this relationship impacts the Clean Peak Energy Credits calculation, which requires a 75 percent charging threshold from renewable sources to realize those benefits.

These relationships indicate diminishing financial benefits when the battery is oversized relative to its renewable charging source. Third-party owners will most likely seek to optimize this relationship to maximize the financial returns.

Specific to the recommended programs for the Concord Street site, the system elements and their relative sizes all possess the theoretical capacities to exceed 100 percent battery energy storage charging from their associated solar photovoltaic arrays and would maximize the ITC benefit potential for owners that incur a federal tax liability.

5.7 Financial Analysis

The financial analysis is structured to profile the perspective of the City of Framingham entering into third-party owner/operator agreements for the microgrid improvements. This perspective is based on feedback and guidance from the City after consideration of available financial resources, lack of capacity to operate and maintain the assets, and other related factors.

It is anticipated that the City of Framingham will execute Power Purchase Agreements (PPAs) for the solar PV assets and/or Energy Services Agreements for the battery energy storage assets. The estimated sources of financial inflows (revenues, tax credits, expense savings, etc.) and outflows (operational costs) are summarized in Table 33 and Table 34.

5.7.1 Key Assumptions

The following key assumptions underlie the financial analysis:

Inflation/Deflation: All estimates are presented in constant value 2021 dollars.

Solar PV Output: Energy output from the Concord Street microgrid's solar PV arrays is a function of both the relatively fixed engineering of the installed solar panel and the variability of sunlight,

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[30] https://www.nrel.gov/docs/fy18osti/70384.pdf

the latter dictated primarily by geographic location and orientation of the system to the sun. These variable elements are the primary definers for a location's "solar shape," data that is gathered from Folsom Lab's web-based subscription service Helioscope (www.helioscope.com). This service provides location-specific solar energy potentials across all 8,760 hours in a year at a given geographic location, enabling the calculation of total annual energy potential or more granular detail, such as output during defined peak hour periods.

Energy Resource Performance Degradation: Solar PV energy output and battery energy storage performance does not remain constant year over year. They slowly degrade with time, with batteries susceptible to higher levels of degradation with increased "cycling" or charging/discharging. Solar degradation is typically slower, constant, and more a function of wear and tear over time. Solar PV energy output and battery storage performance, for the purposes of the financial analysis, are modeled to degrade by 0.5% and 1.0% per year over their estimated useful life, respectively. These factors are both well within actual performance ranges.

Capital Reinvestment: Capital reinvestment is modeled at the end of each asset's useful life, with assumed annual reductions in pricing as detailed in the capital investment section and summarized below.

	Est. Useful Life	CapEx Price Reduction per Yr.
Solar PV	25 yrs.	-3.0%
Battery Energy Storage (4-hr rating)	12 yrs.	-3.5%

Term: All financial estimates are modeled over a 20-year horizon.

5.8 Revenue and Other Financial Inflows

5.8.1 Investment Tax Credit

The value of the investment tax credit (ITC) is dependent on the timing of construction start, not operations. The ITC benefits are under constant evaluation and have been subject to prior extensions. Pending federal legislation could further adjust the percentage and/or timing of the ITC benefits as well. Consideration of this variability within a PPA or similar agreement may be warranted, as the value potential is substantial.

The current schedule for the ITC (based on construction start) is as follows:

Year	Commercial
2021	26%
2022	26%
2023	22%
2023+	10%

The financial model presented herein assumes that construction would commence prior to the end of 2022, creating a benefit for federal tax liable entities equal to 26 percent of project capital expenditures.

In addition, the energy output from the solar PV arrays in all Concord Street energy resource locations exceeds 100% of collocated battery charging requirements, indicating the potential to maximize the battery ITC as well.

The value of the investment tax credit is estimated to total just under $2.04 million in current value dollars. The early timing and amount of cash flow are important investment considerations, as the amount is more than double the estimated $1.0 million net operational proceeds generated annually by the five Concord Street locations.

5.8.2 MA SMART Solar Program Incentive Payment

As described in the overview of the Commonwealth's SMART Solar Incentive Program in **Appendix A: Financial Analysis – Glossary of Terms**, the development of clean energy resources generates a substantial incentive opportunity to their owners. The CSCRS was evaluated utilizing DOER's Value of Energy and Incentive Calculator. The calculator considers project type, size, distribution company service territory, customer rate class, and capacity block.

SMART incentive amounts for the CSCRS resources ranged from $0.25 to over $0.31 per kWh of solar PV energy output. Aside from variances in the base rates and the low-income adder for FHA, the other adders are generally consistent throughout.

The duration of the incentive is based on total capacity output, with those exceeding 25 KW AC provided a 20-year benefit, all others receiving a 10-year benefit.

Table 27. SMART Solar Incentive Rates

	FMS	FS5	FHA	MCES	FB
SMART Solar Base Generation Rate ($/kWh)	$0.15883	$0.21658	$0.18049	$0.18049	$0.15883
Location Adder ($/kWh)	$0.01920	$0.01920	$0.01920	$0.01920	$0.01920
Off-Taker Based ($/kWh)	$0.03064	$0.03064	$0.03064	$0.06000	$0.03064
Energy Storage Adder ($/kWh)	$0.04450	$0.04410	$0.04470	$0.04460	$0.04460
Total SMART Solar Payment ($/kWh)	$0.25317	$0.31052	$0.27503	$0.30429	$0.25327
SMART Duration of Benefits	20 Years	10 Years	20 Years	20 Years	20 Years

Source: MA SMART Solar Calculator and Willdan Financial Services, 2021

Total value of the SMART solar payment is estimated at just under $535,000 per year, calculated on estimated annual solar at each location and totaling 2 million kWh across the entire microgrid.

5.8.3 On Bill Savings

On bill savings are calculated utilizing Integral Analytics' *Site Optimizer*, a comprehensive DER sizing and support tool for integrating renewable energy investments.

Dollar value benefits are calculated by comparing the customer's current load profile against a solar load shape. This estimate utilizes the customer's current total electricity tariff (demand charge price, energy price, and basic meter charges), considering both peak/off peak hours and winter/summer seasonal pricing variations.

Battery benefits are isolated by calculating energy savings and demand charge reductions for the entire system, then subtracting the calculation for those benefits arising from solar alone. These cash values are then converted to a $/kWh value for calculation against the quantity of energy produced (solar PV) or energy stored (battery), capturing the degradation factor in the financial output.

Stabilized year estimates for on bill savings total just over $368,300 annually. From a practical perspective, the solar PV array is the primary source of energy savings, while the battery is responsible for almost the entirety of demand charge savings, again highlighting the importance of this resource's ability to shift/lower demand during peak consumption periods.

5.8.4 PPA Solar PV Energy Payment from Host to Provider

Under the anticipated PPA structure, the host/city would likely be contractually obligated to purchase the energy produced by the solar PV array(s) from the PPA provider. For the purposes of calculating this value, a price of $0.125 per kWh was assumed, representing a discount of approximately $0.05 per kWh from the current average energy price for the microgrid sites. In a typical year, this equates to just over $248,900 that is paid to the provider. A corresponding outflow, representing the host/city perspective, is detailed in the description of outflows later in this section of the report.

5.8.5 Demand Response (aka Connected Solutions)

Demand response is currently valued by Eversource Energy at $225 per kWh of battery capacity. Based on recommended system parameters, this equates to an estimated annual value of $117,000 across the five CSCRS sites.

5.8.6 Clean Peak Energy Credits

The calculation of Clean Peak Energy Credits (CPECs) is based on program parameters that delineate "multipliers" for each megawatt of energy produced during certain defined time periods during "normal" days and the "monthly peak" day.

Table 28. CPEC Seasonal and Time of Day Windows

Season Date and Times	Begin	End	Days in Season	Seasonal Peak Days	Monthly Peak Days	Peak Hours (between these values)		
Spring	1-Mar	14-May	75	73	2	5:00 PM	to	9:00 PM
Summer	15-May	14-Sep	123	119	4	3:00 PM	to	7:00 PM
Fall	15-Sep	30-Nov	77	74	3	4:00 PM	to	8:00 PM
Winter	1-Dec	28-Feb	90	87	3	4:00 PM	to	8:00 PM
Total			365	353	12			

Source: 225 CMR: MA Department of Energy Resources

The multipliers encourage participation by greatly increasing the quantity of CPECs and the economic value by increasing value when demand is highest. One additional positive multiplier is available for systems that enhance resiliency (1.5x), while others reduce the quantity of CPECs generated. This latter group includes resources already benefitting from SMART solar benefits (0.3x, applicable to the Solar PV arrays), the existing resource multiplier (0.1x), and the contracted resource multiplier (0.01x). These last two are not applicable to the CPEC calculations for the CSCRS.

Table 29. CPEC Multipliers

Day Type	Seasonal Day Type	Seasonal Multiplier	Monthly Peak Multiplier	Resilience Multiplier	Existing Resource Multiplier	Contracted Resource Multiplier	SMART ES Resource Multiplier
Normal Days	Spring Normal Day	1	1	1.5x	0.1x (Not applicable to this microgrid)	0.01x (Not applicable to this microgrid)	0.3x (Applicable only to solar PV energy)
	Summer Normal Day	4	1				
	Fall Normal Day	1	1				
	Winter Normal Day	4	1				
Monthly Peaks	Spring Peak Day	1	25				
	Summer Peak Day	4	25				
	Fall Peak Day	1	25				

	Winter Peak Day	4	25				

Source: 225 CMR: MA Department of Energy Resources

The CSCRS is estimated to generate 3,240 CPECs annually, presented in the table on the following page.

The market value of these CPECs is estimated at $145,800 at the current $45 Alternative Compliance Payment (ACP)[31]. The value of CPECs is estimated to decline, both as a factor of output degradation and the planned $1.54 annual reduction in the ACP commencing in 2025. This value may further shift (up or down) as the ACP price is adjusted through an annual review process and the number of CPECs issued. Oversupply relative to CPEC targets will generate small price decreases, while conversely, undersupply will raise the price, increasing the economic rationale for clean energy resource investment.

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[31] https://www.mass.gov/service-details/annual-compliance-information-for-retail-electric-suppliers

Table 30. Estimated Clean Peak Energy Credits

		Solar PV			Battery Energy Storage			
		Peak Hour (kWh)	Daily CPECs	Annual CPECs	Discharge (kWh)[32]	Daily CPECs	Annual CPECs	Total CPECs
Normal Days	Spring Normal Day	326.5	0.1	10.7	1,326.0	2.0	145.2	155.9
	Summer Normal Day	1,701.0	3.1	364.4	1,326.0	8.0	946.8	1,311.1
	Fall Normal Day	217.3	0.1	7.2	1,326.0	2.0	147.2	154.4
	Winter Normal Day	175.9	0.3	27.5	1,326.0	8.0	692.2	719.7
Monthly Peaks	Spring Peak Day (2 days)	326.5	3.8	7.6	1,170.0	16.4	32.8	40.4
	Summer Peak Day (4 days)	1,701.0	79.6	318.4	1,170.0	65.5	262.1	580.5
	Fall Peak Day (3 days)	217.3	2.5	7.6	1,170.0	16.4	49.1	56.8
	Winter Peak Day (3 days)	175.9	8.2	24.7	1,170.0	65.5	196.6	221.3
						Grand Total		3,240.1

Source: Willdan Financial Services, 2021

5.8.7 Depreciation

Depreciation represents a significant source of value to the owner's subject to federal income tax. As detailed in depreciation opportunities, the timing and selected depreciation methodology (Bonus vs. MCARS 5-year) can drive significant differences in value for the project.

For simplicity purposes and assuming an opportunity to claim 100 percent bonus depreciation (i.e., claimed in 2022), the difference in net present value when claiming the bonus, versus spreading the benefit over five years, generates an estimated net present value benefit of more than $120,000 (@ 8.25% discount rate).

5.9 Expenses and Other Outflows

5.9.1 Operations and Maintenance Expenses

Ongoing operations and maintenance expenses are estimated utilizing NREL research. Costs are estimated at $18 per KW for the solar PV resources and $45 per KW for battery resources. Annual O&M expenses total just over $100,000 per year, with 70% attributed to the battery components.

5.9.2 Host Solar PV Energy Payment to PPA Provider

An ongoing, contractual cost of any PPA agreement is the commitment to purchase the solar PV energy at a fixed annual rate. While the cost per kWh is anticipated to be a negotiated element of a PPA agreement, the financial model assumes an energy value of $0.125. This equates to an annual payment of

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[32] Using battery for other avenue stream could impact the resiliency service negatively.

just over $248,800, based on nameplate capacity combined historical solar radiation data in this area, by the City/host to the PPA provider.

5.9.3 Battery Round-Trip Energy Loss

Round-trip energy costs reflect the net expense associated with recharging a battery storage energy resource. The expense reflects the fact that the amount of energy needed to charge a battery is more than the amount of energy that is discharged. Round-trip efficiency is estimated at 80 percent. The value of the loss is equated using the average SMART solar rate across the entire project. The dollar value of this expense is estimated at just under $33,800 in a stabilized year.

5.10 Net Operating Revenues (Stabilized Operations)

Net operating revenue, exclusive of the ITC and depreciation benefits, is estimated at $1.03 million. This includes $1.41 million in operational inflows against $383,000 in direct operating expenses. This value excludes consideration of the timing of benefits and represents a snapshot of performance based on the nameplate or theoretical capacities of the energy resources.

Table 31. Stabilized Year Statement

Microgrid Capacity Inputs	**Accrues to:**	**Fuller MS**	**Fire No. 5**	**FHA**	**McCarthy Elem.**	**Mass Bay CC**	**Total**
Solar PV (kW)		500	54	242	369	528	1,693
Battery Energy Storage (4-hr rating) (kWh)		200	60	400	400	500	1,560
Battery Power (KW)		50	15	100	100	125	390
Battery Power (MW)		0.05	0.02	0.10	0.10	0.13	0.39
Annual Solar Generation (kWh)		553,936	70,637	278,100	403,947	684,557	1,991,177
Initial Capital Investment							
Solar PV	Provider	$ 1,499,400	$ 163,200	$ 726,000	$ 1,107,000	$ 1,584,000	$ 5,079,600
Battery Energy Storage (4-hr rating)	Provider	115,000	34,500	230,000	230,000	287,500	897,000
Interconnection & Infrastructure Upgrades	Provider	24,311	2,977	14,396	20,134	28,182	90,000
Project Administration/Overhead (30% of hard costs)	Provider	484,320	59,310	286,800	401,100	561,450	1,792,980
Total Initial Capital Investment		**$ 2,123,031**	**$ 259,987**	**$ 1,257,196**	**$ 1,758,234**	**$ 2,461,132**	**$ 7,859,580**
Operating Inflows	**Accrues to:**						
MA SMART Solar Program Incentive Payment 3/	Provider	140,240	21,934	76,486	122,917	173,378	534,955
On-Bill Savings - Demand Charge	Split	28,704	3,191	35,265	28,451	31,662	127,272
On-Bill Savings - Energy Charge	Host	67,229	10,658	33,972	49,018	80,105	240,982
PPA Solar PV Energy Payment from Host to Provider 4/	Provider	69,242	8,830	34,762	50,493	85,570	248,897
Demand Response aka Connected Solutions	Split	15,000	4,500	30,000	30,000	37,500	117,000
Clean Energy Peak Credit-Solar PV	Split	-	9,705	1,234	5,096	7,419	34,572
Clean Energy Peak Credit-Battery Storage	Split	14,261	4,278	28,521	28,521	35,652	111,234
Total Operating Inflows		**$ 334,675**	**$ 63,097**	**$ 240,241**	**$ 314,497**	**$ 451,285**	**$ 1,414,911**
Operating Outflows	**Accrues to:**						
Operations & Maintenance Expenses							
Solar PV	Provider	$ 8,996	$ 979	$ 4,356	$ 6,642	$ 9,504	$ 30,478
Battery Energy Storage (4-hr rating)	Provider	9,000	2,700	18,000	18,000	22,500	70,200
Total Operations and Maintenance		$ 17,996	$ 3,679	$ 22,356	$ 24,642	$ 32,004	100,678
Host Solar PV Energy Payment to PPA Provider 4/	Host	$ 69,242	$ 8,830	$ 34,762	$ 50,493	$ 85,570	248,897
Battery Round Trip Energy Loss	Split	$ 4,332	$ 1,300	$ 8,664	$ 8,664	$ 10,830	33,789
Total Operating Outflows		**$ 91,570**	**$ 13,808**	**$ 65,782**	**$ 83,799**	**$ 128,403**	**$ 383,364**
Net Operating Cash Flow		**$ 243,105**	**$ 49,288**	**$ 174,459**	**$ 230,697**	**$ 322,882**	**$ 1,031,547**
Investment Tax Credit							
Solar PV Investment Tax Credit (ITC) 1/	Provider	$ 512,668	$ 55,801	$ 248,230	$ 378,500	$ 541,594	$ 1,736,793
Battery Storage Investment Tax Credit (ITC) 1/ 2/	Provider	39,320	11,796	78,641	78,641	98,301	306,698
Total ITC		$ 551,988	$ 67,597	$ 326,871	$ 457,141	$ 639,894	$ 2,043,491
Depreciation 5/							
Bonus Depreciation Percentage		100%	100%	100%	100%	100%	
Bonus Depreciation Taxable Basis		1,338,406	163,902	792,565	1,108,430	1,551,553	4,954,855
MACRS Taxable Basis 6/	Provider	-	-	-	-	-	-
Depreciation Benefit @ 22% Federal Tax Rate	Provider	294,449	36,058	174,364	243,855	341,342	1,090,068
Net Cash Flow after ITC and Depreciation		**$ 1,089,542**	**$ 152,943**	**$ 675,694**	**$ 931,693**	**$ 1,304,118**	**$ 4,165,106**

1/ Investment Tax Credit percent is 26.0% if construction commences in 2021 or 2022, 22.0% in 2023, and 10.0% thereafter.

2/ Battery must receive a minimum of 75% of charging over the entire year from renewable sources; tax credit is then proportioned by the percentage of power 75% or higher.

3/ MA Smart Program Incentive duration is 10 years for systems ≤ 25 kW AC or 20 years for systems >25 kW AC.

4/ PPA Energy Payment $0.125 per kWh

5/ Bonus depreciation capture requires all assets be depreciated under this methodology; if bonus amount is less than 100 percent, any remainder is depreciated under MACRS schedule.

6/ MACRS depreciation schedule is variable year-to-year; this basis (less one-half of the federal ITC) is calculated using the annual average of 16.67 percent.

7/ Model assumes zero ($0) residual value of assets at end of useful life

Source: Willdan Financial Services, 2021

5.11 Multi-Year Financial Analysis

The multi-year presentation of estimated cash flows presents a clearer understanding of the benefits over time and allows for the incorporation of the important ITC and depreciation tax advantages that comprise significant elements of overall project value over a 20-year term.

Moreover, the analysis provides an opportunity to segregate estimated revenues and expenses to the City/host, PPA provider, or split the values between the parties and then evaluate the relative position of each from a total cash flow and discounted cash flow perspective. Lastly, the model provides the opportunity to test variables and modify assumptions to understand the relative position of each party and identify terms that could be negotiated that would continue to provide adequate (although lower than targeted) returns to a PPA provider.

As noted earlier, ITC and depreciation benefits have specific time parameters. These values are modeled to achieve their maximum potentials. This requires commencement of construction in 2022, providing the full ITC benefit and capture of 100 percent bonus depreciation by the PPA Provider.

Assumed allocation of the remaining inflows and outflows are presented below.

Table 32. Summary of Allocation Assumptions

Category	Accrues to:
Initial Capital Investment	
Solar PV	Provider
Battery Energy Storage (4-hr rating)	Provider
Interconnection & Infrastructure Upgrades	Provider
Project Administration/Overhead (30% of hard costs)	Provider
Operating Inflows	
MA SMART Solar Program Incentive Payment	Provider
On-Bill Savings - Demand Charge	Split
On-Bill Savings - Energy Charge	Host
PPA Solar PV Energy Payment from Host to Provider	Provider
Demand Response	Split
Clean Energy Peak Credit-Solar PV	Split
Clean Energy Peak Credit-Battery Storage	Split
Operating Outflows	
Operations & Maintenance Expenses	Provider
Host Solar PV Energy Payment to PPA Provider	Host
Battery Round Trip Energy Loss	Split
Investment Tax Credit	Provider

Depreciation	Provider

Source: Willdan Financial Services, 2021

Split items within the financial analysis are allocated 60 percent to the PPA provider and 40 percent to the City/Host.

Multi-year net cash flows are somewhat lower than the stabilized year figure, reflecting the effects of battery storage and solar PV performance degradation. The estimated net cash flow roundly totals $968,000 in the first full year, decreasing to $819,000 in the last full year (in constant value 2021 dollars).

The following assumptions support the cash flow analysis detailed in Table 33:

1. Investment Tax Credit percent is 26.0% if construction commences in 2021 or 2022, 22.0% in 2023, and 10.0% thereafter.
2. Battery must receive a minimum of 75% of charging over the entire year from renewable sources; tax credit is then proportioned by the percentage of power 75% or higher.
3. MA Smart Program Incentive duration is 10 years for systems ≤ 25 kW AC or 20 years for systems >25 kW AC.
4. PPA Energy Payment assumes $0.125 per kWh.
5. Bonus depreciation capture requires all assets be depreciated under this methodology; if bonus amount is less than 100 percent, any remainder is depreciated under MCARS schedule.
6. Model assumes zero ($0) residual value of assets at the end of useful life

Table 33. Statement of Estimated 20-Year Cash Flow

Total Capital Investment: Years 1-10	**Accrues to:**	**Yr1 2021**	**Yr2 2022**	**Yr3 2023**	**Yr4 2024**	**Yr5 2025**	**Yr6 2026**	**Yr7 2027**	**Yr8 2028**	**Yr9 2029**	**Yr10 2030**
Effective Capacities/Outputs (assumes degradation over time)											
Consolidated Heat & Power (kW)		-	-	-	-	-	-	-	-	-	-
Solar PV (kW)		-	508	1,685	1,676	1,668	1,660	1,651	1,643	1,635	1,627
Battery Energy Storage (4-hr rating) (kWh)		-	468	1,544	1,529	1,514	1,499	1,484	1,469	1,454	1,439
Battery Power (KW)		-	117	386	382	378	375	371	367	364	360
Battery Power (MW)		-	0.12	0.39	0.38	0.38	0.37	0.37	0.37	0.36	0.36
Annual Solar Generation (kWh)		-	597,353	1,981,221	1,971,315	1,961,458	1,951,651	1,941,892	1,932,183	1,922,522	1,912,909
% of Initial Battery Storage Capacity		-	30.0%	99.0%	98.0%	97.0%	96.1%	95.1%	94.1%	93.2%	92.3%
% of Initial Solar PV Output		-	30.0%	99.5%	99.0%	98.5%	98.0%	97.5%	97.0%	96.6%	96.1%
Initial Capital Investment											
Solar PV	Provider	-	4,927,212	-	-	-	-	-	-	-	-
Battery Energy Storage (4-hr rating)	Provider	-	865,605	-	-	-	-	-	-	-	-
Interconnection & Infrastructure Upgrades	Provider	-	90,000	-	-	-	-	-	-	-	-
Project Administration/Overhead (30% of hard costs)	Provider	-	1,737,845	-	-	-	-	-	-	-	-
Total Initial Capital Investment		$-	$7,620,662	$-	$-	$-	$-	$-	$-	$-	$-
Capital Reinvestment											
Solar PV	Provider	-	-	-	-	-	-	-	-	-	-
Battery Energy Storage (4-hr rating)	Provider	-	-	-	-	-	-	-	-	-	-
Project Administration/Overhead (30% of hard costs)	Provider	-	-	-	-	-	-	-	-	-	-
Total Reinvestment		$-	$-	$-	$-	$-	$-	$-	$-	$-	$-
Total Capital Investment		$-	$7,620,662	$-	$-	$-	$-	$-	$-	$-	$-

Source: City of Framingham; Willdan, 2022

Table 33: Statement of Estimated 20-Year Cash Flow, Continued

Total Capital Investment: Years 11-20		**Yr11**	**Yr12**	**Yr13**	**Yr14**	**Yr15**	**Yr16**	**Yr17**	**Yr18**	**Yr19**	**Yr20**
	Accrues to:	**2031**	**2032**	**2033**	**2034**	**2035**	**2036**	**2037**	**2038**	**2039**	**2040**
Effective Capacities/Outputs (assumes degradation over time)											
Consolidated Heat & Power (kW)		-	-	-	-	-	-	-	-	-	-
Solar PV (kW)		1,619	1,610	1,602	1,594	1,586	1,578	1,571	1,563	1,555	1,547
Battery Energy Storage (4-hr rating) (kWh)		1,425	1,411	1,397	1,560	1,544	1,529	1,514	1,499	1,484	1,469
Battery Power (KW)		356	353	349	390	386	382	378	375	371	367
Battery Power (MW)		0.36	0.35	0.35	0.39	0.39	0.38	0.38	0.37	0.37	0.37
Annual Solar Generation (kWh)		1,903,345	1,893,828	1,884,359	1,874,937	1,865,563	1,856,235	1,846,954	1,837,719	1,828,530	1,819,388
% of Initial Battery Storage Capacity		91.4%	90.4%	89.5%	100.0%	99.0%	98.0%	97.0%	96.1%	95.1%	94.1%
% of Initial Solar PV Output		95.6%	95.1%	94.6%	94.2%	93.7%	93.2%	92.8%	92.3%	91.8%	91.4%
Initial Capital Investment											
Solar PV	Provider	-	-	-	-	-	-	-	-	-	-
Battery Energy Storage (4-hr rating)	Provider	-	-	-	-	-	-	-	-	-	-
Interconnection & Infrastructure Upgrades	Provider	-	-	-	-	-	-	-	-	-	-
Project Administration/Overhead (30% of hard costs)	Provider	-	-	-	-	-	-	-	-	-	-
Total Initial Capital Investment		$-	$-	$-	$-	$-	$-	$-	$-	$-	$-
Capital Reinvestment											
Solar PV	Provider	-	-	-	-	-	-	-	-	-	-
Battery Energy Storage (4-hr rating)	Provider	-	-	-	564,479	-	-	-	-	-	-
Project Administration/Overhead (30% of hard costs)	Provider	-	-	-	169,344	-	-	-	-	-	-
Total Reinvestment		$-	$-	$-	$733,822	$-	$-	$-	$-	$-	$-
Total Capital Investment		$-	$-	$-	$733,822	$-	$-	$-	$-	$-	$-

Source: City of Framingham; Willdan, 2022

Table 33: Statement of Estimated 20-Year Cash Flow, Continued

Net Cash Flow after ITC & Depreciation: Years 1-10		**Yr1**	**Yr2**	**Yr3**	**Yr4**	**Yr5**	**Yr6**	**Yr7**	**Yr8**	**Yr9**	**Yr10**
	Accrues to:	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**
Operating Inflows											
MA SMART Solar Program Incentive Payment 3/	Provider	-	160,486	532,280	529,619	526,970	524,336	521,714	519,105	516,510	513,927
On-Bill Savings - Demand Charge	Split	-	38,182	126,230	125,197	124,173	123,159	122,153	121,157	120,169	119,190
On-Bill Savings - Energy Charge	Host	-	72,295	239,777	238,577	237,384	236,197	235,015	233,840	232,670	231,506
PPA Solar PV Energy Payment from Host to Provider 4/	Provider	-	74,669	247,653	246,414	245,182	243,956	242,737	241,523	240,315	239,114
Demand Response aka Connected Solutions	Split	-	35,100	115,830	114,672	113,525	112,390	111,266	110,153	109,052	107,961
Clean Energy Peak Credit-Solar PV	Split	-	-	-	-	-	-	-	-	-	-
Clean Energy Peak Credit-Battery Storage	Split	-	`	110,121	109,020	104,236	99,537	94,922	90,389	85,937	81,565
Total Operating Inflows		$-	$380,732	$1,371,890	$1,363,499	$1,351,471	$1,339,574	$1,327,807	$1,316,166	$1,304,652	$1,293,263
Operating Outflows	Accrues to:										
Operations & Maintenance Expenses											
Solar PV	Provider	-	9,143	30,325	30,174	30,023	29,873	29,723	29,575	29,427	29,280
Battery Energy Storage (4-hr rating)	Provider	-	21,060	69,498	68,803	68,115	67,434	66,760	66,092	65,431	64,777
Total Operations and Maintenance		$-	$30,203	$99,823	$98,977	$98,138	$97,306	$96,483	$95,667	$94,858	$94,056
Host Solar PV Energy Payment to PPA Provider 4/	Host	$-	$74,669	$247,653	$246,414	$245,182	$243,956	$242,737	$241,523	$240,315	$239,114
Battery Round Trip Energy Loss	Split	$-	$16,911	$55,954	$55,540	$55,130	$54,723	$54,320	$53,920	$53,523	$53,129
Total Operating Outflows		$-	$121,784	$403,430	$400,931	$398,450	$395,986	$393,539	$391,109	$388,696	$386,299
Net Operating Cash Flow		$-	$258,948	$968,461	$962,568	$953,021	$943,588	$934,267	$925,057	$915,957	$906,964
Investment Tax Credit	Accrues to:										
Solar PV Investment Tax Credit (ITC) 1/	Provider	$-	$1,684,689	$-	$-	$-	$-	$-	$-	$-	$-
Battery Storage Investment Tax Credit (ITC) 1/ 2/	Provider	-	295,964	-	-	-	-	-	-	-	-
Total ITC		$-	$1,980,653	$-	$-	$-	$-	$-	$-	$-	$-
Depreciation 5/	Accrues to:										
Bonus Depreciation Taxable Basis		-	4,954,855	-	-	-	-	-	-	-	-
Modified Accelerated Cost Recovery System (MACRS) Taxable Basis		-	-	-	-	-	-	-	-	-	-
Depreciation Benefit @ 22% Federal Tax Rate	Provider	-	1,090,068	-	-	-	-	-	-	-	-
Net Cash Flow after ITC and Depreciation		$-	$1,349,016	$968,461	$962,568	$953,021	$943,588	$934,267	$925,057	$915,957	$906,964

Source: City of Framingham; Willdan, 2022

Table 33. Statement of Estimated 20-Year Cash Flow, Continued

Net Cash Flow after ITC & Depreciation: Years 11-20		**Yr11**	**Yr12**	**Yr13**	**Yr14**	**Yr15**	**Yr16**	**Yr17**	**Yr18**	**Yr19**	**Yr20**
	Accrues to:	**2031**	**2032**	**2033**	**2034**	**2035**	**2036**	**2037**	**2038**	**2039**	**2040**
Operating Inflows											
MA SMART Solar Program Incentive Payment 3/	Provider	511,358	487,939	485,499	483,072	480,656	478,253	475,862	473,483	471,115	468,760
On-Bill Savings - Demand Charge	Split	118,220	117,258	116,305	124,579	123,550	122,531	121,521	120,519	119,527	118,544
On-Bill Savings - Energy Charge	Host	230,348	229,196	228,049	226,920	225,785	224,656	223,532	222,414	221,301	220,194
PPA Solar PV Energy Payment from Host to Provider 4/	Provider	237,918	236,729	235,545	234,367	233,195	232,029	230,869	229,715	228,566	227,423
Demand Response aka Connected Solutions	Split	106,882	105,813	104,755	117,000	115,830	114,672	113,525	112,390	111,266	110,153
Clean Energy Peak Credit-Solar PV	Split	-	-	-	-	-	-	-	-	-	-
Clean Energy Peak Credit-Battery Storage	Split	77,272	73,056	68,917	73,167	68,667	64,249	59,913	55,657	51,481	47,382
Total Operating Inflows		$1,281,997	$1,249,990	$1,239,070	$1,259,105	$1,247,684	$1,236,390	$1,225,222	$1,214,178	$1,203,256	$1,192,456
Operating Outflows	Accrues to:										
Operations & Maintenance Expenses											
Solar PV	Provider	29,133	28,988	28,843	28,698	28,555	28,412	28,270	28,129	27,988	27,848
Battery Energy Storage (4-hr rating)	Provider	64,129	63,488	62,853	70,200	69,498	68,803	68,115	67,434	66,760	66,092
Total Operations and Maintenance		$93,262	$92,475	$91,695	$98,898	$98,053	$97,215	$96,385	$95,563	$94,748	$93,940
Host Solar PV Energy Payment to PPA Provider 4/	Host	$237,918	$236,729	$235,545	$234,367	$233,195	$232,029	$230,869	$229,715	$228,566	$227,423
Battery Round Trip Energy Loss	Split	$52,739	$52,352	$51,968	$54,658	$54,250	$53,845	$53,443	$53,045	$52,650	$52,258
Total Operating Outflows		$383,919	$381,556	$379,208	$387,924	$385,498	$383,089	$380,697	$378,322	$375,963	$373,621
Net Operating Cash Flow		$898,078	$868,435	$859,862	$871,181	$862,186	$853,301	$844,524	$835,856	$827,293	$818,835
Investment Tax Credit	Accrues to:										
Solar PV Investment Tax Credit (ITC) 1/	Provider	$-	$-	$-	$-	$-	$-	$-	$-	$-	$-
Battery Storage Investment Tax Credit (ITC) 1/ 2/	Provider	-	-	-	-	-	-	-	-	-	-
Total ITC		$-	$-	$-	$-	$-	$-	$-	$-	$-	$-
Depreciation 5/	Accrues to:										
Bonus Depreciation Taxable Basis		-	-	-	-	-	-	-	-	-	-
			-	-	-	-	-	-	-	-	-
Modified Accelerated Cost Recovery System (MACRS) Taxable Basis		-									
Depreciation Benefit @ 22% Federal Tax Rate	Provider	-	-	-	-	-	-	-	-	-	-
Net Cash Flow after ITC and Depreciation		$898,078	$868,435	$859,862	$871,181	$862,186	$853,301	$844,524	$835,856	$827,293	$818,835

Source: City of Framingham; Willdan, 2022

Table 34. 20-Year Cash Flow & Investment Deal Structuring

Financial Summary & Investment Analytics	**Yr1** **2021**	**Yr2** **2022**	**Yr3** **2023**	**Yr4** **2024**	**Yr5** **2025**	**Yr10** **2030**	**Yr15** **2035**	**Yr20** **2040**
Estimated Cash Flows								
Total Provider Inflows	$0	$3,349,845	$991,241	$985,366	$977,314	$938,271	$898,680	$861,830
Total Provider Outflows[1]	0	(7,661,012)	(133,396)	(132,301)	(131,216)	(125,934)	(130,603)	(125,295)
Net Provider Cash Flow	$0	$(4,311,167)	$857,846	$853,065	$846,098	$812,337	$768,077	$736,535
Cumulative Provider Cash Flow ($millions)	$0	$(4.31)	$(3.45)	$(2.60)	$(1.75)	$2.37	$5.54	$9.28
Provider's Total Cumulative 20-Yr Cash Flow	$10,275,404							
NPV of Provider's Estimated 20-Yr Cash Flow @ 8.25% Discount Rate	$2,643,922							
IRR of Provider's Estimated 20-Yr Cash Flow	17.9%							
First Year of Positive Cumulative Cash Flow	Year 7							
Total Host/City Inflows	$0	$101,607	$380,649	$378,133	$374,158	$354,992	$349,004	$330,626
Total Host/City Outflows	0	(81,434)	(270,034)	(268,630)	(267,234)	(260,365)	(254,895)	(248,327)
Net Host/City Cash Flow	$0	$20,174	$110,615	$109,503	$106,924	$94,627	$94,109	$82,299
Cumulative Host/City Cash Flow ($millions)	$0	$0.02	$0.13	$0.24	$0.35	$0.84	$1.31	$1.74
Host's Total Cumulative 20-Yr Cash Flow	$1,897,838							
NPV of Host's 20-Yr Estimated Cash Flow @ 3.00% Discount Rate	$1,356,689							

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[1] Assumes Provider reinvests total value of initial capital in Year 14 at the end of equipment's estimated useful life.

Source: City of Framingham; Willdan, 2022

5.12 Financial Analysis Conclusions

The allocations of inflows and outflows indicate strong financial positions for both the PPA provider and the city/host. The PPA provider's internal rate of return (assuming an all-cash deal) equates to 17.9 percent and a net present value of $2.64 million, calculated using a discount rate of 8.25%.

The city's cash flow over the 20-year term is estimated at $1.9 million, generating a net present value of $1.36 million when discounted at a rate of 3.0 percent annually. This discount rates reflect the relatively lower cost of capital typically available to a public entity.

5.13 Financial Sensitivity Analysis

What represents an acceptable rate of return, to either party in a PPA deal, is a difficult figure to isolate, as motivations and risks are all measured and valued differently by those involved. This question is the basis for negotiation. Yet to negotiate effectively, it is helpful to understand the various drivers that can be modified and their impact on financial returns.

The financial analysis is based on the primary objective to solve for a PPA provider return of 12 percent, a purely theoretical assumption for planning purposes only. It is unlikely that any negotiation would focus on just a single assumption, but rather a combination of adjustments that identify mutually beneficial returns and other benefits to each of the parties. The following table provides the results of financial sensitivity analyses of the impact of a broad range of variables to the relative negotiation position of each party.

Variable	Financial Feasibility Impact
Capital Costs	Capital expenditures could increase by 32%
Split to City:	The allocation of "split" revenue and expense items could increase to 100 percent to the City/host versus the modeled 40 percent, generating an estimated internal rate of return of 13.8% to the provider.
PPA Energy Price:	PPA energy price could decrease to $0.022 per kWh, a reduction of $0.103 per kWh below what is currently modeled.
Battery Useful Live	Battery useful life is estimated at 12 years, requiring one reinvestment cycle over the 20-year term that is modeled to accrue to the PPA provider. Reduction of the useful life to 10 years and the addition of a second replacement cycle at the end of the 20-year term would reduce the provider's estimated internal rate of return to 17.6 %.

Importantly, future expansion or modification of existing programs, implementation of new incentives, grants, and other financial enhancements are possible but not modeled. Preservation of rights to these benefits, carbon credits, and other efforts to monetize environmental benefits may be additional points of consideration and sources of negotiation.

6. Conclusion

The City of Framingham's Concord Street CLEAR study demonstrates both technical and financial options to solve threats to the municipal assets in the community. The threats to the infrastructure are both climate change and human-created disasters. Energy is essential to municipal operations and basic constituent services. Resilient solutions are needed to carry the City of Framingham through interruptions to the power grid in the region.

For this resiliency community study funded by MassCEC, the technical team first met with all the stakeholders to understand their current energy asset reliability concerns to meet future resiliency needs. A request for information (RFI) and a resiliency questionnaire were issued to collect key data informing both the technical and financial solutions.

The responses further informed the technical team's knowledge of each stakeholder's assets and resiliency priorities. Finally, site visits with the help of the City and stakeholders allowed the technical team to visualize each site's opportunities and threats.

State-level and local relevant Regulations, Definitions, and Assumptions related to this study report are presented. The collected energy data and energy system information from both the stakeholders and utility are reviewed and analyzed. The requested information and resiliency questionnaire responses are reviewed, together with utility and stakeholders. The technical team met with all the stakeholders monthly to understand their current energy asset reliability concerns to meet future resiliency needs.

A preliminary technical design and system configuration is proposed for CSCRS, in accordance with the findings of the site assessment and characteristics identified in the site assessment. The proposed microgrid infrastructure and operations are presented in which the PCCs are identified. The load characteristics of different stakeholders and aggregated hourly load profiles for CSCRS are presented.

The estimated hourly, daily and monthly load profiles are presented for evaluation by CSCRS stakeholders. The proposed DERs planned to be operated in the CSCRS are also discussed. The current and proposed electrical and thermal infrastructure are presented along with the preliminary configurations for the proposed system.

The characterization of the CSCRS master controller and services and benefits provided by the proposed community microgrid are described. The information technology and telecommunication infrastructure necessary for the proposed microgrid solutions are discussed.

Based on these key CSCRS investment and operating parameters, the current annual energy costs and CO_2 emissions for the existing loads are calculated to be $1.58 million and 3,099 metric tons, respectively. This represents the baseline for the proposed microgrid solution. The proposed community microgrid would have 28.6% annual saving compared with the base case, and 13.7% annual saving on CO_2 emissions. The annual CO_2 emission reduction is 426 metric tons.

To utilize federal/state tax incentives such as investment tax credits (ITC) on the proposed Solar and Battery storage installations, an owner must have a tax liability. The proposed community microgrid could be owned jointly by the stakeholders, a third-party investor, or partly owned by a public utility (e.g., battery storage).

Since most of the stakeholders are public or nonprofit, a third-party special-purpose entity (CSCRS Co.) will likely be developed to own and manage the microgrid. The microgrid participants would subsequently draft and enter into long-term agreements (the Power Purchase Agreement) to purchase energy from the microgrid owner/operator.

The financial analysis assumes a third-party PPA funding model, wherein the PPA provider would build and maintain the new generation assets and the community microgrid.

The financial analysis and allocations of City (Host)/PPA inflows and outflows indicate strong financial positions for both the PPA provider and the City (Host).

The PPA provider's internal rate of return (assuming an all-cash deal) equates to 17.9 percent and a net present value of $2.64 million, calculated using a discount rate of 8.25%.

The City's cash flow over the 20-year term is estimated at $1.9 million, generating a net present value of $1.37 million when discounted at a rate of 3.0 percent annually.

The City of Framingham can demonstrate a working community microgrid in Massachusetts.

Appendix A: Financial Analysis – Glossary of Terms

The following key terms (and their acronyms) are defined to inform audiences with limited technical training related to the development of microgrids and their component distributed energy sources (DERS).

Battery Storage

Battery technology is rapidly changing and evolving. Currently, two technologies are poised to dominate the near-term landscape for large-scale commercial applications: Lithium-ion (Li-ion) and Vanadium (V-flow). Older technologies, such as lead/acid (car battery), and nickel/cadmium or NiCad (laptops and camcorders), have either been displaced from or are not viable for commercial storage applications.

One of the key attributes of batteries, aside from basic storage/use, is the ability to displace consumption of high cost/peak demand energy (peak shaving) with energy stored from renewable sources (best) or grid energy produced during lower cost/demand periods during the day or night (better). Another benefit is the instantaneous responsiveness of batteries to support energy needs, either locally or within the broader electrical grid.

Battery lifetimes typically range from 5 to 15 years. Warranties and lifetimes are typically tied to a specific number of recharging cycles or when a battery will only charge to 70 percent of the original nameplate capacity. Battery capacity also degrades over time, with storage losses of typically between one-half (0.5%) and two percent (2.0%) per year.

Capital planning must consider battery replacement costs for longer-term projects, especially if the functional lifetime is closer to 10 years than 15. The good news here is that the future cost to replace may be lower for the same quantity of energy storage. Pricing per kWh of storage has decreased at an average rate of eight (8) percent over the past several years. Forward-looking estimates anticipate annual price reductions ranging between 2.5 percent and 9.2 percent per kW through 2030, and smaller but continuous annual reductions through 2050 (1.3%-2.7%).

Improved design and increased manufacturing capacity, competition and innovation are the primary forces driving lower prices. For illustrative purposes, a $100 battery today could cost less than $50 in 15 years(current year dollars), assuming a five percent (5.0%) average annual price decrease.

Black Start Support

A black start is the process of restoring an electric power station or a part of an electric grid to operation without relying on the high-cost external electric power transmission network to recover from a total or partial shutdown. When available, hydroelectric power sources represent an excellent source of black start capacity due to the low power requirements to bring that asset online, which through a series of steps, can then restart the other power plants in the system. Stored battery power is similarly poised to serve in this capacity, requiring no “startup” and instantaneous responsiveness potential.

Clean Peak Energy Credits (CPEC)

The Clean Peak Standard (CPS) is designed to provide incentives to clean energy technologies that can supply electricity or reduce demand during seasonal peak demand periods established by DOER.

Under the program, all retail electric suppliers in Massachusetts are required to procure a minimum percentage of total annual electricity sales to Massachusetts end-use customers from Clean Peak Resources by either purchasing CPECs or retiring earned CPECs. Starting at 1.5% of retail electricity sales in 2020, the minimum requirement increases over time by at least 1.5% each year, to a target of 16.5% in 2030 and 46.5% in 2050. The program will expire in 2050, unless extended by law.

The value of a CPEC is set annually, based on the total megawatts (MW) of energy produced by qualified units. As of January 2021, the Commonwealth identified 17 qualified resources generating just under 37 MW of energy (nameplate capacity). DOER utilizes monthly reported peak to identify when the Actual Monthly System Peak Multiplier should adjust the number of Clean Peak Energy Certificates.

The value of each CPEC, while variable, is effectively capped by a provision that allows the retail electric supplier to satisfy their Clean Peak Standard's minimum requirement via an alternative compliance payment ("ACP").

The initial ACP rate is $45.00 per MWh through the 2024 compliance year. Thereafter, it is programmed to decline by $1.54 per MWh each year through 2050. Adjustments to the automatic ACP reduction are tied to the market supply of CPECs. If the supply is greater than the targeted level during the program year, the ACP rate reduction would be larger in the following year.

Demand Response (Active and Passive)

There are two types of demand response resources: active and passive, each with its own revenue implications.

Active demand resources comprise what is commonly referred to as Demand Response (DR). ISO-NE has two branded programs – Daily Dispatch and Connected Solutions. These programs both provide payments for being on [active] stand-by to be "called" to lower energy usage when the power grid is anticipated to be stressed or when the risk of failure is too high. This could include customers powering down equipment or switching to an alternative energy source, such as a generator or battery storage. Participants typically receive one-day notification for events that occur most often in July and August for events that last two to three hours.

Under the "active" DR Program, assets under 5 MW are consolidated or "mapped" into larger blocks referred to as Demand-Response Resources. Assets over 5MW comprise their own resource. These "resources" are then the direct participants in the DR program that comprise a small portion of the ISO's overall supply obligations. The market price for active DR varies by location and seasonally. Demand response was valued by Eversource at $200 per kW in the New England market for summer 2020.

Summer peak hours are non-holiday weekdays, 1:00 p.m. to 5:00 p.m., June, July, and August. Winter peak hours are non-holiday weekdays, 5:00 p.m. to 7:00 p.m., December and January. Participation can be limited to the summer months only. Benefits would be reduced by two-thirds under this option.

Seasonal-peak resources provide the same attributes as on-peak resources, but only during the summer months of June, July, and August, and the winter months of December and January, during those hours on non-holiday weekdays when the real-time system hourly load is equal to or greater than 90 percent of the system peak-load "50/50" forecast (50% chance of exceeding the calculated peak load for a New England-wide summer temperature of 90.2°F, and winter temperature of 7.0°F).

Passive demand resources (DR-P) are principally designed to save electricity and cannot be altered or "called" by a dispatch instruction. Examples include energy-efficient appliances and lighting, advanced cooling and heating technologies, and passive behind-the-meter generation, such as solar power. Passive demand resources can only participate in the On-Peak or Seasonal-Peak capacity markets.

Consolidated Heat and Power (CHP)

Consolidated Heat and Power, or cogeneration, is the concurrent production of electricity or mechanical power and the capture of by-product thermal energy from a single source of energy, typically near a point of consumption. CHPs can use a variety of fuels, both fossil- and renewable-based and a variety of technologies (gas turbines, microturbines, reciprocating engines, steam turbines, absorption chillers, and fuel cells). Generally, CHPs deliver energy at an efficiency of 65-75 percent versus a national average of 50 percent when the services are provided separately.

Curtailment Service Providers (CSP)

Curtailment Service Providers are organizations that, through a contractual arrangement, manage Demand Response (DR) programs. Commonly referred to as aggregators, these independent firms market DR opportunities, size the DR opportunity, manage curtailment events/communications, and calculate payments and underperformance penalties. The fee for this service typically ranges between 20 and 40 percent of the benefit amount.

Curtailment

Curtailment is the deliberate reduction in output (below what could have been produced) to address the interconnected issues of oversupply, reliability issues arising from excess energy production, and market pressure to lower pricing, in some instances to negative values.

While several types of curtailment exist, "economic dispatch" (due to low market price) is by far the most common. It is a self-scheduled response to a call for less generation for a fee.

Depreciation

Depreciation is an accounting reduction in the value of an asset with the passage of time. In the simplest application, depreciation would reflect wear and tear and an asset's useful life. Internal Revenue Service (IRS) rules establish rules for the capture of depreciation, at times setting asset schedules that do not align with the anticipated useful lifetime, primarily as an investment incentive. These accelerated schedules increase the capture of depreciation early in the investment horizon, providing a source of savings on federal income taxes. The amount of tax savings, however, is dependent on the effective federal tax rate of the ownership entity.

Under the Investment Tax Credit (see ITC) legislation, two methodologies for depreciation are available: Bonus and Modified Accelerated Cost Recovery System (MCARS).

Under the Bonus depreciation schedule, solar systems placed in service between January 1, 2018, and December 31, 2022, can elect to claim a 100% bonus depreciation of capital equipment in that tax year. Starting in 2023, the percentage drops 20% per year (e.g., 80% in 2023 and 60% in 2024) until the provision drops to 0% in 2027. If the ITC is claimed, the depreciable basis of the asset(s) is decreased by one-half of the ITC amount received (see ITC).

Important considerations when selecting the bonus depreciation methodology are rules requiring that all assets must be placed in the bonus depreciation pool and that assets must be owned for at least six years to fully vest the benefits. If the assets are not held for the duration, the paid tax benefits would be subject to recapture.

Alternatively, under the MCARS methodology, solar PV with associated battery storage could be depreciated under the 5-year Property, Half-Year Convention schedule. The annual amount of capital investment calculated for depreciation would follow this schedule:

Year	Value of CapEx Depreciation
Year 1	20.00%
Year 2	32.00%
Year 3	19.20%
Year 4	11.52%
Year 5	11.52%
Year 6	5.76%

Source: U.S. Department of Energy; Willdan, 2021

This schedule would also apply to any amount not captured by the bonus depreciation (i.e., if 60 percent taken under the bonus rules, then remaining 40 percent could use the MCARS methodology). As with the bonus depreciation option, the actual benefit would equate to the depreciable amount times the effective corporate tax rate.

Solar PV, without the associated battery component, would be subject to a 7-year depreciation schedule. Current full text documentation can be found at: https://www.energy.gov/eere/solar/articles/residential-and-commercial-itc-factsheets.

Distributed Energy Resource (DER)

Distributed energy resources are the physical and virtual energy assets that are deployed across a distribution network and comprise a microgrid. Physical assets typically include solar PV, battery storage, and less frequently consolidated heat and power and wind turbines. Inclusive in this definition is the technology that connects the assets to the bulk energy system (typically referred to as the “electric grid”) and the controls that allow for participation in secondary energy market opportunities (e.g., demand response, peak shaving)

Forward Capacity Market (FCM) Savings

The Forward Capacity Market (formerly referred to as the Installed Capacity Market) is a long-term wholesale electricity market that ensures resource adequacy, locally and systemwide, through an auction process that typically runs three years prior to the commitment year. This longer horizon helps ensure that future resource needs will be met, and if not, that market forces will encourage participation before that need.

Capacity resources may be new or existing, including energy supply from generators, imported capacity, or demand capacity resources that reduce electricity consumption. Added resources must undergo a qualification process that ensures the future availability of committed supply. Annual and monthly “reconfiguration auctions” allow the ISO to shed excess obligations or add additional ones.

Frequency Regulation

This is the effort to maintain electrical grid stability by ensuring all the energy generators are spinning at the same frequency, typically at 60 Hertz (Hz). Frequency is measured by the rate of spin per second and the definition of the term Hertz (Hz). Grid operators must maintain very tight thresholds on grid frequency to maintain stability.

Imbalance occurs when a sudden production surge (imagine a wind gust on a wind farm) suddenly supplies the grid creating an over-frequency event. Alternatively, a power plant goes offline and creates an under-frequency event. Over-frequency events are typically less problematic to solve, and automatic sensors typically kick in to reduce output.

Under-frequency events are inherently more challenging. Increasing production may require a dispatch call to a large power plant that requires time to adjust output. Storage batteries are very advantageous because they can be called to respond almost immediately to frequency regulation requests, responsiveness that grid operators value. However, small- or mid-scale energy storage on the distribution grid can run into challenges in the Frequency Regulation market due to the attendant costs of the telemetry equipment required to participate. Participating in the frequency regulation market requires a set aside for a fixed amount of capacity that would not be available for the day-ahead/real-time energy market.

Installed Capacity Reduction (ICAP)

ICAP management is a customer-centric savings mechanism that is tied to consumption by commercial uses. Programs often utilize an online service that presents a predictive model to alert customers when the grid demand is likely to peak. This knowledge provides an opportunity to proactively lower energy usage during the annual system peak-hour (aka “coincident demand”).

This peak-hour figure sets the value of an Installed Capacity Tag (ICT) that drives the following year’s capacity charges, a figure that accounts for 20 to 30 percent of the electric bill. Participants are required to have an interval meter (records electricity consumption every 30 minutes) with an ICT. Energy providers assign tags once annually, following the assessment period that runs from June 1st to May 31st.

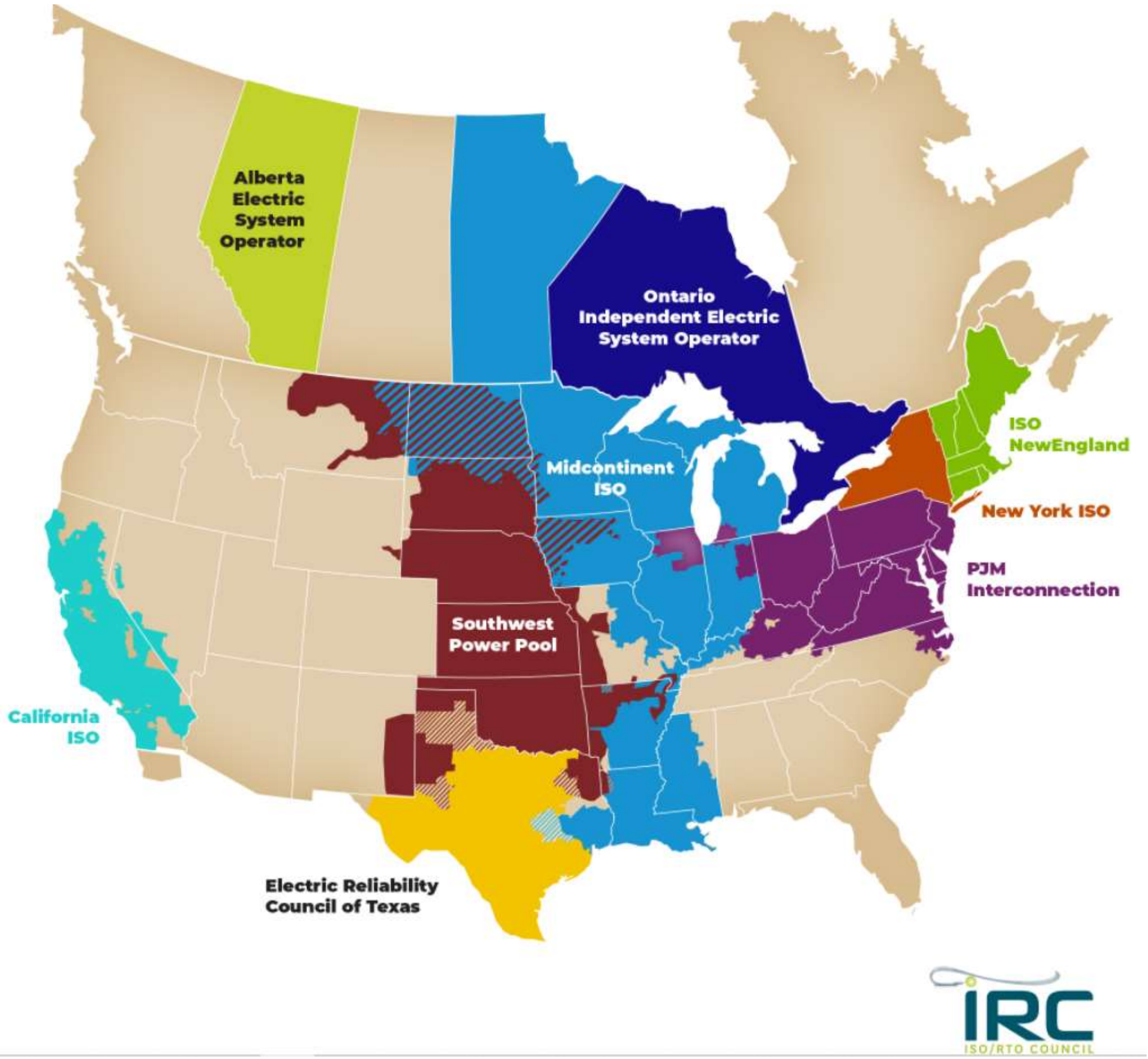
Investment Tax Credit (ITC)

The U.S. government currently offers a credit that can be claimed on federal corporate income taxes (i.e., not available for tax-exempt entities like charities) against the capital cost (purchase, install, and related equipment and soft costs) for new commercial solar photovoltaic systems and associated battery storage. In December of 2020, Congress extended the ITC to provide a federal tax credit of 26 percent of costs for systems commencing construction in 2020, 2021, or 2022, 22 percent in 2023, and 10 percent thereafter.

The battery portion of the tax credit is subject to a further reduction based on the percentage of stored energy produced by a renewable source (e.g., Solar PV generates 80% of stored battery energy, then the credit is reduced to 80 percent of capital cost). Importantly, the renewable source must generate at least 75 percent of the stored battery energy, or the tax credit is eliminated entirely.

Independent Service Operators (ISO)

Independent Service Operators (and their cousin Regional Transmission Operators or RTOs) operate the electricity transmission system and foster competition among market producers. ISOs establish and manage energy and related-service markets that use bid-based systems to optimize electricity output from generation facilities to meet current and future system loads at the lowest possible cost. While major sections of the southeast and west operate under more traditional wholesale market structures, two-thirds of the nation's electricity load is served within ISO/RTO regions.



Kilowatt (kW) and Megawatt (MW)

A kilowatt is a unit of power. One megawatt equals 1,000 kW. These figures represent the size of the discharge flow. A common analogy is a gas can. The size of the spout opening dictates how fast the gasoline can be poured out of the can. The kW or MW rating is the same, but for electricity.

Kilowatt-hour (kWh) and Megawatt-hour (MWh)

A kilowatt-hour is a unit of energy capacity. One megawatt-hour equals 1,000 kWh. A common analogy, again using the gas can analogy (see kW and MW), would be the quantity of fuel that is contained.

Local Property Tax Exemptions

Solar energy systems used as a primary or auxiliary power system for the purpose of heating or otherwise supplying the energy needs of taxable property may be exempt from local property tax for a 20-year period. This incentive requires the system owner to enter into an agreement with the city or town to provide a payment in lieu of taxes (PILOT) that equals at least 5 percent of its gross income during the prior calendar year.

The incentive applies only to the value added to a property by an eligible system and the components used exclusively by that system. It does not constitute an exemption for the full amount of the property tax bill.

Solar facilities that generate electricity to sell to the grid may be eligible for a Tax Increment Financing exemption agreement if they are in an Economic Opportunity or Economic Target Area. Facilities owned by electric generation or wholesale generation companies may be eligible for a payment in lieu of a tax agreement.

Changes to the exemption rules enacted under SB-9:

- Requires that an exempt project produce not more than 125 percent of the annual electricity needs of the property on which it is located, including non-contiguous real property within the same municipality in which there is a common ownership interest
- Limits the size of the eligible system to 25kW or less
- Overrules a prior decision to allow exemptions for a solar project located in one town that allocated bill credits to taxable properties in an adjacent town
- Extends the exemption to solar projects that “supply the energy needs” of property owned by tax-exempt nonprofit entities such as government buildings, schools, universities, nonprofit hospitals and other similar entities so long as the projects meet the 125 percent limitation across the entire campus
- Expands the exemption and PILOTs to include energy storage and fuel cells
- Standardizes the assessment process, terminology, terms, and tax policies across the Commonwealth

Regional Network Services (RNS)

Regional Network Service (RNS) is the transmission service to move electricity that transmission customers purchase to serve their network load in the New England Control Area.

Reliability

Reliability is achieved through the design, operations and maintenance of power supply to provide an adequate, safe and stable flow of electricity.

The ISO-NE has a Reliability Committee (RC) that is responsible for the design and oversight of reliability standards for the power system in New England. This committee focuses on short-term and long-term load forecasts to meet regulatory standards, the collection and exchange of system data for the future, standards and procedures to maintain a reliable and efficient power system in New England, plans for supply and demand-side resources, transmissions, and interconnections, procedures for dispatch infrastructure, and installed capacity requirements and ISO determinations on capacity requirements.

Resiliency

Resilience is directly linked to the concept of reliability, as a system cannot be resilient if it is not reliable. Resilience, however, is broader and tied to the preparation, operation, and subsequent recovery from significant events. It is also the ability to withstand extreme or prolonged events.

Resilience, from an energy perspective, is about ensuring a business has a reliable, regular supply of energy and contingency measures in place in the event of a power failure. Causes of resilience issues include power surges, weather, natural disasters, accidents and even equipment failure. The human operational error can also be an issue and should be factored into resilience planning. Ensuring a business is resilient may help insulate against energy price increases or fluctuations in supply and avoid delays or shutdown of their important processes that impact their ability to deliver goods or services. And while most power outages are shorter term in nature, there is a clear trend in the increasing number of large-scale natural weather events that can have broader, longer-term impacts. Critical industries, such as health care, senior centers, emergency services, and other critical industries will certainly become less susceptible to significant impacts as the resilience of the energy system improves.

Round Trip Energy Costs

Round trip energy costs reflect the net expense associated with recharging a battery storage energy resource. The expense reflects the fact that the amount of energy needed to charge a battery is more than the amount of energy that is discharged.

SMART Solar Incentives

The Solar Massachusetts Renewable Target (SMART) Program is a long-term sustainable solar incentive program operated by the Massachusetts Department of Energy Resources (DOER) with sponsoring electric utilities Eversource, National Grid and Unitil[33]. The program started in 2018 as a replacement for the Solar Renewable Energy Certificate (SREC) program. The programs' goal is to incentivize the development of 3,200 MW of solar generation in the Commonwealth.

The program pays participating photovoltaic system owners fixed incentive compensation rates for either 10 years (for ⩽ 25 kW AC) or for 20 years (for >25 kW AC). Variations to the incentive amounts depend upon location (i.e., behind the meter or within the home or building) and how the system is metered (net metering, quality facility tariffs, or alternative on-bill credit mechanism).

Additional incentive variables include the size of the system, the utility company, and the Capacity Block Compensation Rate (CPCR) set for the utility. The CPCR reflects the goal to encourage the development of "blocks" of solar energy within each of the respective energy company's operating districts, with set-asides for smaller installations (<25kW).

In addition to the base incentive rates, "adders" are provided to encourage solar development in certain settings (e.g., brownfield, building mounted, canopy, eligible landfills, agricultural), the inclusion of energy storage, and solar tracking capabilities. Off-taker (end-user) adders are available for solar installations that serve low-income areas, provide community shared resources, and serve public entities. Full

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[33] https://masmartsolar.com/

program details, guidelines, and an incentive calculator can be found on the SMART program website (https://masmartsolar.com/).

Solar Photovoltaic (PV)

Photovoltaic technology (e.g., solar panel) converts light energy into electricity. In this case, that light source is the sun, thus solar. Solar arrays do degrade over time, with production losses of typically averaging between 0.5 and 1.0 percent per year.

Appendix B: State & Federal Grant Programs, Incentives, and Capital Enhancements

The following State & Federal grant programs and other capital enhancements are defined to inform audiences with limited technical training about the universe of potential funding sources available to public and private microgrid investors. These resources may or may not be applicable to the technical solutions under consideration by the City of Framingham, depending on the ultimate renewable energy system and associated funding mechanism implemented by the City.

Biden Bipartisan Infrastructure Framework

When fully implemented, the federal government's recently passed infrastructure legislation represents a potentially significant source of funding for energy and related infrastructure projects. The framework identifies total funding of $1.2 trillion, allocated within three broad utility, transportation, and pollution remediation categories. Bringing projects closer to a "shovel-ready" status may be an important attribute to secure funds as they are allocated.

Utility Investments	Total $ (Billions)
Power Infrastructure	$73
Broadband	$65
Water Infrastructure	$55
Resilience	$47
Western Water Infrastructure	$8
Subtotal	$240

Transportation Investments	Total $ (Billions)
Roads and Bridges	$110
Railroads	$66
Public Transport	$39
Airports	$25
Ports and Waterways	$17
Electric Vehicles	$15
Road Safety	$11
Reconnecting Communities	$1
Subtotal	$284

Pollution Remediation	**$21** B

Building Resilient Infrastructure and Communities (BRIC) Grants

BRIC Grants provide states, local communities, tribes and territories funding for eligible mitigation activities that build a culture of preparedness, thus reducing disaster losses and protecting people and property from disasters. Total funding in FY2020, the most recently completed cycle, totaled $700 million.

Under this program, each state must designate an agency to serve as the Applicant for BRIC funding to submit a single application to FEMA. An application can be made up of an unlimited number of subapplications. Local governments, including cities, townships, counties, special district governments, state agencies, and tribal governments, are considered subapplicants.

Subapplicants must have a FEMA-approved Hazard Mitigation Plan by the application deadline and at the time of obligation of grant funds for mitigation projects and Capability and Capacity Building activities (C&CB).

Projects must:

- Be cost-effective
- Reduce or eliminate risk and damage from future natural hazards
- Meet either of the two latest published editions of relevant consensus-based codes, specifications, and standards
- Align with the applicable hazard mitigation plan
- Meet all environmental and historic preservation (EHP) requirements

In 2018, Massachusetts received a BRIC Grant support funding of the State Hazard Mitigation and Climate Adaptation Plan (SHMCAP). The plan was the first all-hazard mitigation plan that integrated climate impacts and adaptation strategies to address two primary hazards: coastal flooding and winter storm impacts. The planning process was managed through the Executive Office of Energy and Environmental Affairs (EOEEA), the Executive Office of Public Safety and Security (EOPSS), and the Massachusetts Emergency Management Agency (MEMA). Additional background on the BRIC Grant Program and the full case study description of SHMCAP and other successful subapplicants can be found on the FEMA website (FEMA Hazard Mitigation Action Portfolio).

The fiscal year 2021 (FY 2021) application period for the Hazard Mitigation Assistance (HMA) Notices of Funding Opportunities (NOFOs) for the Building Resilient Infrastructure and Communities (BRIC) grant programs opened on Sept. 30, 2021. This annual application cycle closes at 3 p.m. EST on Jan. 28, 2022.

DOE Loan Guarantees (Title 17 Innovative Energy Loan Guarantee Program)

The Loan Programs Office (LPO) has facilitated more than $40 billion in loans to deploy large-scale energy infrastructure projects in the United States. Over the past decade alone, LPO has participated in more than $30 billion of investment across a variety of energy sectors. Like Green Banks, the DOE's role in financial transactions is one of facilitation, providing financial guarantees that lower the risk for private capital sources.

The LPO's typical role is to bridge financing gaps in the commercial debt market when innovative technologies may not be well understood by the private sector. Project types often include large-scale commercial energy projects, research-development-and-demonstration (RD&D) projects, and smaller projects as well.

Current loan guarantee authorities include:

- $8.5 billion in for innovative advanced fossil energy projects

- $10.9 billion in loan guarantee authority for innovative advanced nuclear energy projects
- $17.7 billion to support U.S. manufacturing of fuel-efficient, advanced technology vehicles
- $4.5 billion for innovative renewable energy & efficient energy projects
- $2 billion in partial loan guarantee authority for tribal energy development projects.

Basic eligibility requirements include:

- A new or significantly improved technology
- Reduction or sequestration of greenhouse gases
- Location in the United States
- Expectation for repayment

Additional information can be found at https://www.energy.gov/lpo/application-process

EPA Grants

The EPA has several grant opportunities for green infrastructure.

EPA Clean Water State Revolving Fund (CWSRF)—The CWSRF program is a federal-state partnership that provides communities a permanent, independent source of low-cost financing for a wide range of water quality infrastructure projects, including stormwater and green infrastructure.

EPA Office of Wetlands, Oceans, and Watersheds (OWOW) Funding—OWOW has created this website to provide tools, databases, and information for practitioners that serve to protect watersheds.

EPA Brownfields Grant Program—EPA's Brownfields program provides direct funding for Brownfields assessment, cleanup, revolving loans, and environmental job training. To facilitate the leveraging of public resources, EPA's Brownfields Program collaborates with other EPA programs, other federal partners, and state agencies to identify and make available resources that can be used for Brownfields activities.

https://www.epa.gov/green-infrastructure/green-infrastructure-funding-opportunities

Green Bonds

A green bond (climate bond) is a type of fixed-income instrument that is specifically earmarked to raise money for climate and environmental projects. These bonds are typically asset-linked and backed by the issuing entity's balance sheet, so they usually carry the same credit rating as their issuers' other debt obligations.

Green bonds come with tax incentives such as tax exemption and tax credits, making them a more attractive investment compared to a comparable taxable bond. These tax advantages provide a monetary incentive to tackle prominent social issues such as climate change and a movement toward renewable sources of energy. To qualify for green bond status, they are often verified by a third party such as the Climate Bond Standard Board, which certifies that the bond will fund projects that include benefits to the environment.

Green Banks

Green Banks are public, quasi-public or non-profit entities established specifically to facilitate private investment into domestic low-carbon, climate-resilient infrastructure. They are publicly capitalized, and their efforts are mission-driven (versus profit-driven) that use financing to accelerate the transition to clean energy and address the impacts of climate change. Additional components of Green Bank missions may include elements that support equity and low-income communities. Green Bank capital is most often leveraged to attract private capital into deals by de-risking deal terms through credit guarantees and other financial means.

Massachusetts Clean Water Trust

The Massachusetts Clean Water Trust (the Trust) is a state agency that improves the water quality throughout the Commonwealth by providing low-interest loans to municipalities and other eligible entities. This program may be relevant to microgrid projects serving water and water treatment infrastructure.

According to the 2020 Green Bond Report, the Trust:

- Helps communities build or replace water quality infrastructure that enhances ground surface water resources, ensures the safety of drinking water, protects public health, and develops resilient communities.
- Provides low-interest loans and grants to cities, towns, and water utilities through the Massachusetts State Revolving Funds (SRF)
- $7.6 billion in water infrastructure projects financed from $2.6 billion in federal grants and state matching funds
- $998.4 million bonds issued as Green Bonds

Eligible Projects:

- Wastewater treatment projects
- Infiltration/inflow and sewer system rehabilitation projects
- Collector and interceptor sewer projects
- Combined sewer overflow (CSO) correction projects
- Non-point source (NPS) sanitary landfill
- Planning projects – developing plans to address water quality and related public health problems
- Drinking water treatment projects
- Drinking water transmission and distribution projects
- Drinking water source and storage projects
- Drinking water planning and design projects