City of Melrose Community Microgrid

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DISCLAIMER

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ACRONYMS

AC	Alternating Current	**Li-Ion**	Lithium Ion
AHU	Air Handling Unit	**M&V**	Measurement and Verification
BAS	Building Automation System	**MaaS**	Microgrid as a Service
BCA	Benefit Cost Analysis	**MAPC**	Metropolitan Area Planning Council
BESS	Battery Energy Storage System	**MassCEC**	Massachusetts Clean Energy Center
CAIDI	Customer Average Interruption Duration Index	**MBCx**	Monitoring-Based Commissioning
CFL	Compact Fluorescent Light	**MG**	Microgrid
CHP	Combined Heat and Power	**MVP**	Municipal Vulnerability Preparedness
CSP	Curtailment Service Provider	**NG**	Natural Gas
Cx	Commissioning	**NHMP**	Natural Hazards Mitigation Plan
DC	Direct Current	**NWA**	Non-Wires Alternative
DER	Distributed Energy Resource	**O&M**	Operations and Maintenance
DR	Demand Response	**OPR**	Owner's Project Representative
DTT	Direct Transfer Trip	**PACE**	Property Assessed Clean Energy
ECM	Energy Conservation Measure	**PLC**	Programmable Logic Controller
ESI	Energy Storage Initiative	**PPA**	Purchase Power Agreement
EV	Electric Vehicle	**PV**	PhotoVoltaic
FEMA	Federal Emergency Management Agency	**RFP**	Request For Proposal
HVAC	Heating, Ventilating, and Air Conditioning	**RTU**	Roof Top Unit
ICE	Interruption Cost Estimate	**SAIDI**	System Average Interruption Duration Index
IRC	Interruption Related Cost	**SLA**	Sealed Lead Acid
IRR	Internal Rate of Return	**SMART**	Solarize Massachusetts Renewable Target
IT	Information Technology	**SSC**	System Supervisory Controller
ITC	Investment Tax Credit	**UPS**	Uninterruptable Power Supply
LAN	Local Area Network	**V2G**	Vehicle to Grid
LCCA	Life Cycle Cost Analysis	**VFD**	Variable Frequency Drive
LED	Light Emitting Diode		

Introduction and Project Background

B2Q Associates, together with the City of Melrose, Albertsons Companies, and Shaw's Supermarket, have joined together to study the feasibility of developing a local multi-user, public-private microgrid infrastructure in downtown Melrose comprised of three municipal facilities and one private business, Shaw's Supermarket. Refer to Figure 1 below for the site layout of the proposed microgrid.

Traditionally, implementing resilient community infrastructure utilizing clean energy resources has been cost-prohibitive when considered for that singular purpose. Improving resiliency for emergency services and operations is becoming increasingly important to community welfare, especially so in densely populated areas such as downtown Melrose. Coupled with the goal of reducing operating costs and the City's and Shaws' commitment to energy efficiency and reducing greenhouse gas emissions, this project presents an opportunity to study a number of benefits and interrelated factors associated with community microgrids, which can then be used to inform the development of a repeatable model that can be applied to similar communities across the Commonwealth.

Figure 1: Layout of proposed microgrid facilities.

The goals of this feasibility study were to:

1. Investigate and quantify the non-energy benefits for improving resiliency at four critical community buildings in the downtown Melrose area:
    - Memorial Hall (emergency shelter)

- Fire Station (emergency services)
- City Hall (emergency operations)
- Shaw's Supermarket (microgrid anchor load/food/supplies);

2. Study the technical feasibility of implementing a host of clean energy, resiliency, and energy efficiency technologies all operating in concert together as the infrastructure of a public-private community microgrid;
3. Investigate and quantify how investments in such resiliency-based infrastructure could leverage energy cost-savings, utility incentives and grant funding to provide economic benefits and project payback;
4. Seek to understand how a public-private microgrid partnership can be developed, owned, operated, managed, and maintained such that the needs of all stakeholders are met;
5. Promote and support the Commonwealth of Massachusetts goals of relieving grid congestion, supporting Massachusetts-based clean energy technologies, reducing energy use and greenhouse gas emissions, and overall community and taxpayer benefit from the lessons learned.

This document represents the Task 6 final deliverable in this project, combining the investigation and analysis from the technical, commercial, and financial feasibility Tasks 2 - 5 into a comprehensive final feasibility report, and synthesizing the results into valuable and actionable recommendations for MassCEC, the Commonwealth of Massachusetts, and other stakeholders. This report is organized to present the Task 6 Summary of Findings discussion first, followed by the content of the interim reports from Feasibility Tasks 2 – 5.

Executive Summary

The study of a microgrid in the downtown Melrose area and the resulting discussion presents a tremendous, game-changing opportunity to expand community support and further the market adoption of similar microgrids for community resiliency within the Commonwealth. The results of this study show that there is a compelling case for clean energy-based community microgrids which is evident in multiple levels of direct and indirect community benefits. The direct community benefits are primarily clean energy proliferation and improving the energy resilience of the facilities participating in the microgrid. The indirect benefits extend beyond the city limits of Melrose and cross over multiple industries ranging from emergency response to retail supplies and commodities to energy infrastructure and equipment.

Many other cities and towns in the Commonwealth of Massachusetts have a similar mix of critical municipal buildings and facilities such as grocery stores in a centralized area, where the concepts of a microgrid that are outlined in this study could be directly applied. This study of a community microgrid built from a public-private partnership in downtown Melrose demonstrates that while this particular microgrid concept is not presently feasible for this location, these participants, and at this time, the approach could be adapted to become feasible with modifications to address the barriers identified in this report. More importantly, if the Melrose microgrid concept can be further developed and refined into a financially viable microgrid, the scope of the impact is potentially much more expansive.

The results of this study indicate that community microgrids have the potential to create the following opportunities within Commonwealth and support the advancement of clean energy initiatives:

1. This application of a microgrid concept presents the opportunity to create a repeatable model for clean, energy resilient community microgrids in downtown areas that could be scaled to many other communities within the Commonwealth of Massachusetts.
2. The holistic approach of combining electric vehicle charging with solar photovoltaic (PV) and battery energy storage presents communities with the opportunity to re-imagine what the downtown area looks, feels, and operates like with resilient, clean energy and abundant Electric Vehicle (EV) charging options. Solar, storage, and EV charging combinations offer mutual benefits and flexibility to the microgrid concept, and are particularly compelling considering the projected growth of the electric vehicle market and goals of the Commonwealth's Energy Storage Initiative.
3. The opportunity to develop more formalized communication pathways for microgrid planning and coordination between the utility, communities who are interested in microgrids, and other microgrid industry stakeholders. This is critical to supporting the growth of microgrid adoption in the Commonwealth because it promotes access to information necessary to evaluate microgrids at scale, creates a venue to align microgrid planning with utility and municipal capital plans, and supports dialogue of the microgrid benefits to the utility so that they can be considered and provide input into the planning process. The absence of such dialogue is a cultural paradigm and results in inhibiting

progress towards the development of microgrids and their benefits which could include lower societal costs related to utility infrastructure.

4. The ability to foster the deep penetration of clean energy and energy storage within densely populated downtown areas with the purpose of working towards overarching state and local goals of climate change mitigation and preparedness.

Proposed Melrose Microgrid

A summary of the buildings comprising the proposed microgrid is shown below in Table 1.

Table 1: Summary of buildings comprising the proposed microgrid.

Building	Gross Square Footage	Annual Natural Gas Use	Annual Electricity Use	Peak Demand	Baseload Demand	Load Factor	Energy Use Intensity
-	sq. ft	therms	kWh	kW	kW	%	kBtu/sf
Shaw's Supermarket	36,000	35,891	2,004,403	332	163	69%	289.7
City Hall	30,288	8,419	213,482	84	15	29%	51.8
Memorial Hall	28,477	8,751	103,981	51	8	23%	43.2
Fire Station	11,533	4,462	96,423	24	5	45%	67.2
Total	**106,298**	**57,522**	**2,418,289**				**131.7**

A connection of electrical infrastructure and Distributed Energy Resources (DERs) must be made in order to establish the microgrid to serve the public and private buildings. This Microgrid (MG) bus connection concept includes underground infrastructure from the Plaza Parking Lot, behind the municipal buildings to Essex Street. The MG bus would be routed via an underground connection across Essex Street into Shaw's. Each microgrid DER asset and load would be connected via automatic breakers to the MG bus.

A new system supervisory controller (SSC), also referred to as a microgrid controller, would perform supervisory control of the microgrid and would have the capability to communicate with all DERs, utility and microgrid automatic breakers, meters, and the utility.

This microgrid concept includes the construction of a new duct bank under Essex Street that would be installed to house both the MG bus and communication conduits to support the SSC. EV charging stations would be installed in the Plaza Parking Lot and would generate revenue and support the use of the DERs during normal operation. The table below shows the proposed DERs included in the microgrid. Refer to the appendices for detailed electrical drawings.

Table 2: Summary of proposed and existing DERs to be utilized in proposed microgrid.

Location	Asset Type	New/Existing	Fuel Source	Electric Capacity	Thermal Capacity
Fire Station Basement	Diesel Generator	Existing	Diesel	33 kW	--
City Hall Exterior	NG Micro-CHP	New	NG	10 kW	57.3 kBtu/h
Shaw's Rooftop	PV	New	--	186 kW	--
Memorial Hall Rooftop	PV	New	--	73 kW	--
Plaza Parking Lot	PV	New	--	560 kW	--
Plaza Parking Lot	BESS	New	--	500kW/3300kWh	--

The microgrid business model that was analyzed in this study is known as Microgrid as a Service (MaaS). This model was used so that each entity could have a contract with the service provider but would not have to provide capital funding for the project.

SUMMARY OF FEASIBILITY ANALYSIS

The microgrid isn't feasible as currently conceived for the reasons identified below, with each of these issues discussed in more detail later in this report. The first of which is that the technical, commercial, and financial performance of this project is inherently hindered due to regulatory issues (M.G.L. c. 164, § 1B(a)) and interpretation precedents in the Commonwealth. The regulations prohibit the distribution of energy utilities between participants in the microgrid. This in turn, prevents cost-optimization of the DERs and forces the design away from a grid-paralleling, energy-optimized microgrid, to a collection of buildings with solar PV which are capable of forming a microgrid for resiliency purposes only when there is no power available from the utility grid. The regulations also force any excess generation to be sold back to the utility at wholesale rates. Modifications to or new interpretations of these regulations to allow exceptions for community microgrids would give developers freedom to design impactful microgrid applications with more compelling economics, and would ultimately be a benefit for the microgrid industry within the Commonwealth.

Second, the project results show unfavorable economics, however this investigation found that there is significant opportunity to improve the economics by modifying the approach to address the capital cost challenges identified below. Because the concept is not presently favorable with the current microgrid configuration, another solution is for program administrators to offer a grant or other financial instruments to help close the economic gap. Key financial metrics are shown in the table below and are a result of a number of factors, which are described in more detail later in this report.

Table 3: Summary of key financial metrics.

Party	Capital Costs	Internal Rate of Return
Project Developer		
MaaS Provider	$9,409,600	-0.5%
Customer		
Shaw's	$448,025	13.3%
City of Melrose	$126,546	0.8%

The biggest impacts on return on investment are the electric infrastructure costs, capital cost of solar PV canopies and costs driven by the need for the battery energy storage capacity to be sized to meet Shaw's overnight baseload. The costs associated with utilizing solar PV canopies may be unavoidable due to physical space constraints. The costs associated with the electric infrastructure cannot be avoided, however they may be able to be reduced by careful planning and coordination with planned capital upgrades by the utility and/or Melrose. The energy storage must be sized for Shaw's baseload because Combined Heat and Power (CHP) is not financially feasible due to limited thermal loads and because the clean energy requirements of the project do not support new standby fossil-fuel generators in the MG concept studied. One important takeaway is that the capital cost may be able to be reduced by up to 10% if the current clean energy requirements were able to be relaxed and standby fossil-fuel generation was able to be used in a hybrid solution to meet the microgrid base load during islanding. This would allow the energy storage capacity to be optimized to meet cost-benefit criteria, rather than sized to meet Shaw's overnight baseload.

An important dialogue related to lessons learned is warranted with regard to how to value resiliency in a municipal project involving buildings (resiliency in vertical construction as opposed to resiliency in horizontal construction) as well as how to value the integration of resiliency in private community businesses who are part of providing essential services to a community. The primary purpose of a community microgrid involving buildings is typically resiliency, and there is very little data substantiating the value of resiliency in non-industrial buildings. However, as noted above and in subsequent sections of this report, there is a compelling case for making these specific facilities resilient. Moving forward, it is important that a method of determining the value of having resiliency in municipal and private essential buildings and their infrastructure, including the costs of not having resiliency, be developed if investments in community microgrids are going to be made based on economic returns. The realization of this value to the project developer could take the form of initial first cost investments from the microgrid participants or rate increases for "pay to play" resiliency.

Third, crossing the Essex St. right-of-way is a hurdle for this project. Capital costs could be reduced significantly if the crossing were able to utilize the existing utility duct bank. However, the utility has indicated that they will not allow this unless they were to own and operate the microgrid. While this could work, it is also possible for the microgrid developer to install their own duct bank for the MG bus, which is considered in this study.

Lastly, another barrier to the feasibility of the microgrid identified in this study is that any impact to the utility, positive or negative, is not presently well-understood. This relates to whether existing transformers, meters, distribution wire, duct banks etc. can be re-used, the details of the protective relaying and controls that may or will be required for an interconnection, and whether the interconnection of battery energy storage through the microgrid and the associated peak demand reduction from discharging the battery offer the opportunity to defer capital investments. While the unknowns are technical in nature, the implications to the project feasibility are economic and impact the confidence in the cost estimates and financial performance metrics. The following actions are recommended to gain a better understanding of the impact on the utility and its infrastructure for this project and aid in the development of future community microgrids which may be considered:

1. It is recommended that this microgrid be reviewed as a potential Non-Wires Alternative (NWA) to understand what, if any, opportunity exists to defer capital investment and if there is an opportunity, whether NWA incentives could apply.
2. The MassCEC and other Microgrid program administrators and industry stakeholders should work with the utilities to build upon the conversation which developed through this microgrid feasibility study cohort and create a more formalized channel for dialogue related to the following:

- Advanced notification of infrastructure planning between utilities and prospective microgrid partners
- Sharing of high-level cost metrics related to utility infrastructure costs which may be associated with DER installations for community microgrids
- Development of a screening and evaluation process for community microgrids
- Development guidance for prospective developers and industry stakeholders which outlines at a high-level standard interconnection minimum protective relaying and controls requirements and the utility's preferred scenarios for interconnection of a multi-user community microgrid.

KEY LESSONS LEARNED

The key lessons learned are summarized below and described in more detail in the following sections.

- One of the most impactful barriers to this type of microgrid is associated with regulations which do not allow the distribution of electricity between different parcels within the Commonwealth. This impacts fundamental microgrid system design and operational intent, as well as project first cost.
- There are opportunities to reduce the project first cost with modifications to the approach, such as the inclusion of fossil-fuel standby generators.
- There appears to be mutually beneficial opportunity to combine solar PV, battery storage, and EV charging in a way that can also be used for resiliency, particularly at municipal facilities.
- For a clean energy-based resiliency project, the value of resiliency must be considered in order to close the gap in project economics.
- Tools and available data for quantifying the benefit of resiliency for vertical construction are very limited.
- This type of microgrid with a high mix of solar generation is inherently challenged with providing most or all of the annual energy for these sites because of practical DER sizing limitations (space, economics) and the high supermarket baseload. Thus, without introduction of fossil fuel generators or new legal interpretations allowing distribution of electricity between parcels, approximately 65% of the energy is still purchased from the grid.
- There are clear differences in the philosophical decision making and justification processes between public and private entities when considering resiliency projects. These philosophical differences need to be taken into consideration when evaluating the opportunity to create a public-private partnership.

- There is very little dialogue between the utility and customers related to longer term capital planning, and there is an opportunity to create a path for this dialogue so that capital plans can be aligned.
    - Melrose new Public Safety Building Combining the Fire Station and Police Station, proposed in the location of the current Fire Station is in planning stage.
    - National Grid's 5-year capital plan includes distribution upgrades related to the sites included in the microgrid
    - Currently, there is no way to take advantage of this to account/coordinate for both party's plans in future microgrid design. If these two capital upgrades were coordinated, microgrid infrastructure could be designed into the projects. It is anticipated that this would have a significant cost reduction.
- The only condition the utility would accept using existing utility infrastructure as a part of the microgrid was if the utility owned, operated and maintained the microgrid.

RECOMMENDATIONS FOR FUTURE INVESTIGATION

The following list summarizes the recommendations for future investigation.

1. Investigate MG design utilizing standby fossil-fuel generators to meet Shaw's baseload and reduce first costs.
2. Develop summarized technical and budgetary guidelines for MG interconnection from the utility's perspective.
3. Develop a screening process and/or technical guidelines for preliminary evaluations of other MG applications.
4. Investigate a mechanism to create a forum for increased dialogue between potential MG stakeholders and the utility for sharing information and capital planning.
5. Explore whether the MG in this form or in another configuration has any value as a NWA.
6. Perform a more in-depth and focused investigation to quantify the value of resiliency including additive non-energy benefits, in the event of an extended outage or disaster scenario. This effort should also explore what participants and off-takers would be willing to pay for increased resiliency.
7. Consider under what circumstances a public utility and a municipality may be able to co-exist as electric infrastructure providers.
8. Consider what it could mean for the utility to be in the role of owner-operator and maintainer of the microgrid interconnection between participant buildings.
9. Consider how a MG could be created with partners who are together on one side of major roadway, such that a costly and challenging street crossing is unnecessary.

10. Research the market potential for EVs in downtown Melrose as it relates to revenue streams from EV chargers within this MG. Investigate how EV market growth could be leveraged to support MG market growth.
11. Study the next generation of EV chargers, known as Vehicle To Grid (V2G) chargers, for added benefits of utilizing EV batteries for Demand Response (DR) and energy storage as it relates to the MG.
12. Study the potential resiliency impact and cost-benefit associated with expanding the MG concept in downtown Melrose to encompass a larger area and more customers, as well as how that could impact other future downtown MGs at scale. Identify the potential cost implications and any identifiable factors or metrics which could indicate the relative level of economy.
13. Explore the franchise rights clause in M.G.L. 164 to determine if there is any opportunity for regulators and policy makers to revise or modify the interpretation in a way that would advance Community MGs.

SUMMARY OF FINDINGS

This report section presents a summary of the study findings, and the discussion encompasses the commercial, financial, and technical considerations as they relate to this project and to community microgrids in the Commonwealth in general.

COMMERCIAL AND FINANCIAL CONSIDERATIONS

There are several considerations for the commercial and financial feasibility of this microgrid concept and similar ones, namely:

1. Project first costs are high and create a hurdle to implementing microgrids.
2. The value of resiliency presents the most compelling case for a community microgrid, therefore it must be considered in the project economics.
3. Regulations preventing distribution of electricity between adjacent parcels inhibits project economics.

There are opportunities to address these considerations and improve the project's commercial and financial feasibility. The considerations and suggested opportunities to mitigate them are described below.

PROJECT FIRST COSTS

The project cost analysis identified that the first cost for the project and the associated monetizable revenue results in unfavorable economics. This investigation led to a few key discussion topics, namely that 1) if the microgrid concept was optimized to reduce first costs, such as using fossil fuel generator(s) to meet the supermarket overnight baseload, the economic feasibility could be significantly improved, 2) the costs and mutual benefits associated with utility distribution infrastructure upgrades in support of the proposed microgrid are not well known at this time, and similarly, 3) the benefits of a microgrid to the utility as it relates to the potential to defer capital utility upgrades is also not fully understood.

STANDBY GENERATORS TO REDUCE ENERGY STORAGE CAPACITY

From a lowest first cost perspective, standby generators would be the first choice to create a redundant power source and resiliency for City Hall, Memorial Hall, and Shaw's. While Shaw's has a small backup generator, it only has capacity to meet the building emergency loads which are required by code. The fire station is the exception as it is the only building that presently has full redundant emergency generator in the event of a loss of grid power. Fossil-fuel generators are inherently not a clean energy source and were therefore not the focus of this study. However, an alternative concept for further investigation could be to incorporate standby fossil-fuel generators into the microgrid, which would have a favorable economic trade off as it would diversify the mix of DER's and most notably, the energy storage capacity could be significantly downsized. For example, if a 100kW standby generator with a minimum of 24 hours of fuel storage/supply capacity was incorporated into the microgrid, it would reduce the required size of the battery by approximately 1,000kWh. Based on industry metrics for installed costs of fossil fuel generators, this could translate to a first cost reduction of an estimated $400,000. Also, the year 10 maintenance cost of an engine overhaul compared to replacing 1,000kWh of energy storage cells results in a savings on major maintenance items of approximately $200,000. This cost-savings tradeoff could be incorporated in the microgrid strategy to reduce the first costs of increased resiliency with a limited sacrifice on the clean energy goal of the project. This is because if incorporated into this concept, a fossil-fuel generator would not be utilized on a regular basis unlike the solar PV and battery energy storage. Rather, the standby generator would only be needed to maintain Shaw's overnight refrigeration load or when there was low solar production in the event of an extended outage. It is recommended that this topic be investigated in a follow-on effort to understand the implications to this and other similar potential microgrids in more detail.

Consideration of a standby generator is especially important for the City Hall since it houses an information technology (IT) hub that does not currently have a backup solution other than a small Uninterruptible Power Supply (UPS). The hub supports the phone system serving City Hall, the Police and Fire stations, and six of the City's eight schools. Multiple city staff described the IT services as essential, which typically have redundant power from a standby generator. Melrose is presently pursuing funding to support a generator through multiple grants and have recommended that a project be funded in their capital investment program report. If a generator is installed at City Hall and could be utilized, it would improve the microgrid project economics.

Utility Infrastructure Cost Unknowns

The technical analysis identified that there are upgrades associated with the utility distribution system and protective controls which are necessary in order to enable and support the microgrid. This study provides high level opinions of the cost associated with implementing these upgrades; however these estimates are budget allowances as the total scope of the upgrade to the utility distribution that would be required to support the microgrid is presently unknown. System upgrade cost data was not made available by National Grid, and they have indicated that the costs associated with the utility distribution service upgrades necessary to support the microgrid would not be able to be provided until an interconnection application with a PE stamped single line microgrid electrical power plan and protective control scheme is submitted and approved.

The developer and/or project stakeholders need to commit to the project and develop a design to a level that can be PE stamped and submitted to the interconnection process in order understand the cost of utility upgrades at even a budgetary level. Depending on the size and characteristics of the DER that is intended to interconnect, the utility requirements for interconnection can be substantial and would undoubtedly be compounded by the additional protective control requirements of the multi-user microgrid. The interconnection stage is too late in the project development cycle for a developer to make adjustments to manage and account for these costs without impacting the project schedule, scope, budget and/or overall project economics that the stakeholders assumed when committing to the project. Because the current development path does not provide enough information for the utility costs to be understood early in the process, and because of the commitment required of all parties to understand the total costs associated with the project, the gap in cost information limits the prospective developers and stakeholders' confidence in the proposed economics of a microgrid and makes commitment by stakeholders a hurdle to implementing the project and to the adoption of microgrids in general within the Commonwealth.

One area for future work would be to develop summarized technical and budgetary guidelines for microgrid interconnection from the utility's perspective, in particular as it relates to the protective control schemes that would be required in order to interconnect DERs with the utility grid under various use-case scenarios. This should be identified both generally for interconnecting a diverse mix of DERs in a multi-user microgrid to the utility grid and specifically to certain microgrid configurations and/or scenarios. Another area which could be considered for future investigation is to develop ranges and identify key inputs for various utility distribution upgrade cost metrics in microgrid applications.

Microgrid Alignment with Utility Capital Planning

National Grid has indicated that their 5-year capital plan includes making investments in distribution infrastructure serving the area and specifically with regard to Shaw's. While a rough estimate of the value of transmission and distribution system upgrades based on national averages is provided later in this report, the total scope of National Grid's planned system upgrades outside of what they have discussed related to Shaw's is not known to the project team. Therefore, the magnitude of the impact of the potential reduction in construction costs that could be realized by aligning the design of the microgrid with the planned utility upgrades to optimize construction costs is presently unknown. Similarly, whether any potential economies of scale from constructing planned utility distribution upgrades concurrently with the distribution upgrades required to support the microgrid could apply, is also unknown. Another related issue to utility infrastructure capital planning is the speed with which microgrids can be evaluated and developed as they are a new, complex market with many stakeholders. This creates the need for a planning interaction between the utility capital planning process and microgrid development.

One of the noteworthy and promising observations of this study is that the utility was receptive to customer input as it relates to their infrastructure planning and provided thoughtful preliminary feedback on the microgrid concept. There is a clear opportunity to improve communication and discussion between stakeholders and the utility with the goal to leverage utility planned infrastructure investments so that they align with community microgrid goals both in Melrose and elsewhere in the Commonwealth. If this opportunity can be realized, utility investments could help close the financial gaps in the project and lower the utility and ratepayers' costs for necessary infrastructure upgrades.

This relationship between the utility and the other project stakeholders is a key success factor to any potential microgrid in order to create an environment that community microgrids could be developed in a manner that is mutually beneficial to both the community and to the utility. The community needs to be able to engage the utility in a meaningful way with sufficient timing that allows for the evaluation and development phases. Therefore, it is also important for microgrid supporters and program administrators to build on the discussion which occurred in support of this cohort of community microgrid studies to develop and/or define a pathway for the utility to engage the community in the planning process with a specific discussion of the benefits of microgrid development. It is critical to microgrid adoption that both the utilities and regulators work to create opportunities to integrate the consideration of microgrids in the utility infrastructure planning process more routinely and in a broader scope. The following question would open up dialogue between the utility and potential microgrid stakeholders as part of the utility infrastructure capital planning process: "what could be done specifically to evaluate the opportunity for microgrids as they relate to utility infrastructure and the utility's capital plan?"

Value to the Utility is Unknown

A key element which is not presently fully understood is the value of a microgrid to the utility. The actual value to National Grid that could result from using battery energy storage to offset system load and/or islanding the entire microgrid to remove system loads during peak periods, and any capital investment of system upgrades that could be deferred and how long they could be deferred for, is presently unknown. It is also not known whether there are other utility grid interconnection points which could be utilized for the plaza PV canopy, battery energy storage system, and EV charging stations which may be more impactful to National Grid in regards to deferring capital investments through utilization of the DERs during peak periods, or which may require less costly upgrades to accomplish.

A better understanding is needed whether a microgrid in its current configuration or in another form that would incentivize the utility to make infrastructure investments which support the microgrid economics. It would be beneficial to this and future project development whether the microgrid in this form or in another configuration has any value as a NWA and, if so, what that value is. Therefore, it is recommended that this specific microgrid in Melrose should be considered for the utility's NWA review. The intent of the NWA evaluation would be for the utility to develop a wholistic review of what the cost-benefit impact of this potential microgrid concept would be on the existing utility infrastructure and the planned capital upgrades. The review is also recommended to evaluate from the utility's perspective whether the concept could and should be modified and/or expanded to serve more of the utility's customers and/or other sections of this distribution area (beyond the four buildings included in this study) to maximize the mutual impact on the cost-benefit and value of a microgrid to the utilities and the community stakeholders.

Discussion on The Value of Resiliency

The value of resiliency from a community microgrid is realized for the stakeholders and the community through the avoided costs which would otherwise be incurred if the measure or project to increase resiliency were not implemented. There are multiple benefits of energy resiliency which are quantifiable for short-term outages; however, the benefits during an extended outage are far more difficult to quantify.

Two common methods used to quantify the value of resiliency in a short-term outage (24 hours or less) are the Interruption Related Cost (IRC) and the Interruption Cost Estimator (ICE). These methods are described later in this report and produce similar results for the value of an 8-hour outage. An outage duration of 8 hours was selected based on historical data and anecdotal information from municipal and Shaw's staff. The analysis shows that using either the IRC or the ICE method to quantify the value of resiliency, three to four 8-hour outages would be required every year in addition to the other energy-related value streams of the microgrid in order for the benefits to exceed the costs. Induced costs from a short-term outage, which are comprised of societal costs that emerge from services being interrupted, should also be considered. The induced costs could stack on top of the IRC or ICE method, requiring only two to three 8-hour outages every year for the benefits of the microgrid to exceed the costs. This indicates that while the short-term benefits of energy resiliency have a quantifiable value which can and should be attributed to the project, the benefits of a community microgrid of this nature for mitigating short-term outages alone currently may not make the case for such a significant investment in energy resiliency, especially if the main driver is energy based return on investment and/or greenhouse gas reduction. However, the estimates for the value of non-energy related resiliency benefits of mitigating short term outages that are identified in this study push project return on investment metrics in the positive direction when included in the economic calculation. More importantly, the economic benefit estimates developed for this study show that there is a significant, quantifiable value which can be placed on these non-energy benefits for a community microgrid in the bigger picture of microgrid adoption.

Table 4: Summary table of estimated value of resiliency.

Cost	IRC	ICE
Direct/Indirect	$97,140	$116,526
Induced	$168,904	$168,904
Total	**$266,044**	**$285,430**

The investigation of the impact of an extended outage indicates that the value of a microgrid to provide resiliency that supports the improved operation of mitigation efforts and emergency response services and functions serving the community in the event of a disaster far exceeds the quantifiable value of one or even many short-term outages. This value is far more difficult to quantify specifically for these facilities due to the lack of data for vertical construction and the limited body of work to date surrounding community microgrids in the region. Metrics which are readily available online and within the scope of this study to obtain or roughly estimate indicate that the value of resilience in an extended outage may be an order of magnitude greater or more than the value of resilience in a short-term outage. While significantly more difficult to quantify, the potential value in a disaster presents the opportunity to develop a more compelling narrative to make the case for a community microgrid.

The conclusion is that a more in-depth and focused investigation should be undertaken by the stakeholders to quantify the value of resiliency, including additive non-energy benefits, in the event of an extended outage or disaster scenario. The benefits of a microgrid in an extended outage should be combined with the benefits of mitigating short-term outages to present a more compelling narrative of the value of investing in a microgrid to the community. Therefore, in order for a community microgrid like the one considered in this study to have development potential, the stakeholders must take it upon themselves to perform a rigorous evaluation to not only qualify and quantify the benefits of resiliency to the direct project stakeholders, but also to qualify and quantify what it means to the members of the local community and larger society for the microgrid to be energy resilient and economically valued. All stakeholders need to establish the value of resiliency to determine whether they are willing to pay for increasing it. The starting point of dialogue needs to focus on the total costs to a community (and to society) of not being resilient. Quantifying the value of resiliency is a challenging, yet necessary, task because it provides a complete and more compelling project narrative needed to strengthen the support base for developing a community microgrid and to unlock broader funding resources and advocates. Since the value of a microgrid in a disaster is much more compelling than in a short-term outage, and since quantifying this value is so difficult, in order to gain traction and community support, microgrid stakeholders must endeavor to further investigate and develop this value both qualitatively and quantitatively. The questions should be asked "what does it mean to the community of this microgrid could operate off-grid for three days? One week? Three weeks? How could the community place a value on this?

This study identified a few key questions for both Shaw's and the City of Melrose to contemplate further as the answers could not be defined within the scope of this project:

Questions which Shaw's should contemplate:

- What is the estimated value to the supermarket in terms of additional revenue which could be realized if they were able to remain open while other grocers/supermarkets were closed due to an extended local or regional outage?
- Is there any marketable brand benefit to being able to have one facility in an urban location which is energy-resilient, energy efficient, and holistically environmentally passionate?

Questions which the City should ask themselves are:

- What is the value of being able to operate Memorial Hall as a disaster shelter in the event of extreme (and possibly catastrophic) weather?
- What is the value of being able to operate Memorial Hall as a goods/supplies distribution center and/or community meeting place in the event of an extended outage?
- What is the value to the community if Shaw's were to remain open for business in the event of an extended outage?
- Other than dispatch communications, what is the value of being able to operate the City Hall as a center for operations during a disaster or extended outage? Would being able to use City Hall as the operations center in an extended outage result in increased efficiency of emergency operations or improved disaster management?

These questions as well as the methods used to quantify the value of resiliency are critically dependent upon how the question of resiliency is framed, and the potential value of resiliency could be under- or over-estimated if the scope of the impact of a lack of resilience is undefined. While historical outage data and anecdotal information can provide the framework for assumptions on the duration of short-term outages, the affected population is difficult to quantify based on current data. This presents an opportunity for further study to better define the affected populations under various scenarios. As noted throughout this report, quantifying the value of resiliency, particularly from an extended outage, is a challenge and in general, a hurdle to more wide spread market adoption of microgrids. Future investigations into the value of resiliency for a community microgrid would benefit from a more specific definition of the event-scenarios that should be evaluated. This includes defining the duration of the outage and the affected population, and as they relate to modeling the potential microgrid benefits to the community from extended outages and disasters. This presents an opportunity for regulators and market stakeholders within the Commonwealth to investigate and develop event-case scenarios that could be evaluated on a broader level and used to analyze specific microgrid applications. Additionally, in support of advancing market adoption of microgrids in the region, the Commonwealth should consider creating guidelines for analyzing various event-scenarios in order to assist developers and potential stakeholders to more easily and quickly place a value on the resiliency benefits of a proposed microgrid.

Regulations Prohibit Sale of Electricity Between Adjacent Parcels

Provisions in Massachusetts General Law (M.G.L.) 164 give the utilities the exclusive right to distribute electricity within their service territory. This means that electricity which is generated at one site cannot be distributed or sold to the neighboring site, even if they are both city buildings. It also means that the microgrid can only operate in islanding mode when there is no utility power available (i.e. during an outage). This creates a potential economic mismatch in the sizing of the plaza parking lot solar system vs the potential EV charging load. This is because the plaza parking lot solar system is actually sized to meet Shaw's resiliency loads, and not the EV chargers, although 99% of the time when the microgrid is not connected, the plaza canopy PV will still generate the energy that Shaw's would need. The result is a lot of energy being exported back to the utility grid at wholesale rates, because net metering is no longer available in this service area. These regulations also have technical implications which are discussed in the Technical Considerations section.

This constraint undermines the feasibility of a microgrid because the MaaS provider can't take full market value of the energy that the DERs are generating, associated with about a 10% increase in overall revenues for this microgrid configuration. It is a particularly cumbersome constraint in a downtown microgrid where the availability of space is a major factor in siting DERs and developers need to be able to use whatever space is available for generation. If these regulations were modified or a future legal interpretation allowed community microgrids to distribute and sell electricity between adjacent parcels, it would help community microgrid economics and development in general.

Utility Crossing Right-of-Way

This study investigated crossing right-of-ways with National Grid. The utility is not going to allow an easement for a privately-owned microgrid bus to cross the Essex Street right-of-way to connect the microgrid sites electrically. The exception is that the utility would only consider allowing it if they owned and maintained the microgrid including the islanding and protective lockout controls. The reason for such a requirement is in large part currently based on safety concerns. We agree that the safety of the public and utility employees is best served by a public entity designing, owning, and maintaining the electrical infrastructure, however it is apparent that other municipalities design, own, and maintain safe electrical infrastructures. One question that should be considered at a state and local level is: under which circumstances can a public utility and a municipality co-exist as electric (and/or gas) infrastructure providers? Notwithstanding this question, another opportunity that should be evaluated today for this project is: what it could mean for the utility to be in the role of owner-operator and maintainer of the microgrid interconnection between the participant buildings? An evaluation of the cost-benefit (including legal implications) of this approach, particularly as it relates to the utility's capital infrastructure investment planning is recommended for further study. The investigation and development of future downtown community microgrids should consider how microgrid owners, operators, partners and participants could be selected to address or minimize the impact of this issue.

Closing the Gap in Project Economics

The financial analysis shows that there is a gap between the microgrid project first cost investment and the quantifiable revenue streams which could be created by the proposed microgrid. In addition to the value and economies of scale which could be realized through alignment with the utility's capital plan and NWA review, consideration should be given to the following topics to support improvement of microgrid project economics.

Need for Grants/Enhanced Incentives

The economics presently do not account for any future grants and/or enhanced incentives specifically for microgrids that could be created by stakeholders such as State and/or Federal agencies and/or the utilities. This is an obvious approach to closing the economic gap for this project while encouraging microgrid deployment and supporting market growth. A concept based on current programs could be to create a smaller, specialized Solarize Massachusetts Renewable Target (SMART) block or similar incentive designed only for applicants which are part of a microgrid. A further step towards making the broader application of microgrids in the commonwealth financially viable is for state regulators to strengthen policies which support microgrid development such as policies which enable utilities to fast track approval for interconnect agreements and/or utility easements across public ways for private interconnections of buildings integrated into microgrids for the purpose of resiliency.

Future Grants and Funding

Future opportunities for Municipal Vulnerability Preparedness (MVP) grant funding may also be available to be leveraged by Melrose. The impact to Melrose of a potential MVP grant is not presently accounted for in the project economics. Melrose is currently involved with an MVP action grant to reduce flooding in the City Hall parking lot, so the opportunity to apply for MVP grant funding to support some aspect of the microgrid could potentially be pursued by Melrose in the future. The City is also pursuing a Federal Emergency Management Agency (FEMA) grant to fund the design and installation of an emergency backup generator in the City Hall. It should be investigated whether additional resiliency grants and funding could be available for this MG project in the future.

ROI and Resiliency

The economics presented in the study to date do not include the value of being resilient or the cost of not being resilient. If the only evaluation criteria for a resiliency project is an ROI calculation based on energy and does not account for the value of being resilient, then the project will be undervalued and will may not have the necessary support of the participants to become a reality. This in turn limits the potential for municipal and commercial capital funding to support the community's energy resilience and negatively impacts the business case to attract developers. In a situation where the participants are capital-averse, one possible way which could be considered to tie the value of resiliency to the project ROI and improve the business case to attract developers is to create a "pay to play" rate structure for participants in the microgrid. In addition to the energy cost, this rate structure would have cost-adders for being included in the microgrid. This way, the added costs of resiliency can be paid by participant operating budgets in the MaaS commercial model.

TECHNICAL CONSIDERATIONS

There are several considerations for the technical feasibility of this downtown community microgrid concept applied here and elsewhere. It should be noted that many of the technical considerations and challenges presented arise from the inability to feasibly implement CHP technologies, primarily at Shaw's due to the lack of easily accessible thermal loads that could readily utilize the waste heat from the CHP. This design limitation resulted in microgrid generation assets primarily consisting of PV and battery storage. Technical considerations for this and similar microgrid applications include:

- Available physical space is a design constraint in a downtown microgrid.
- Regulations preventing sales of electricity between adjacent parcels imposes design constraints on DERs.
- Solar plus storage plus EV charging gives microgrid design flexibility: how an anchor load and clean energy infrastructure can be created by combining the mutual benefits of these technologies.
- Implement Energy Conservation Measures first to reduce building load and the size of DERs.
- Utilizing only new clean energy DERs in the microgrid mix limits opportunities to leverage fossil-fuel generators which have an attractive trade-off.
- The benefits to the utility from a technical perspective need to be better understood in order to optimize the microgrid design concept and take advantage of mutual cost benefits between the utility and the microgrid stakeholders.
- Battery energy storage is a necessary technical component for this type of microgrid because of the flexibility it offers, although it provides no actual generation.

PHYSICAL SPACE LIMITATIONS

Physical space or available land is a premium commodity in any downtown area, and the space which is available to install and operate DERs and storage assets necessary to support the microgrid is a significant consideration for a community microgrid. The physical space limitations have a direct impact on the design and project economics:

- The solar PV system designed for Shaw's roof has a design capacity of about 40% of Shaw's peak demand, while utilizing nearly all of the available roof space. It is not possible to completely cover the supermarket in enough solar to offset its load. These considerations naturally push the solar PV design in downtown areas towards canopies to meet the peak loads, which have a significantly higher installation cost per kW installed than roof- and ground-mount solar.

- Similarly, the available physical space prevents batteries from being installed at Shaw's, where they would be most valuable for demand response, because Shaw's is bordered by roads and municipal parking space, and placing batteries on the roof is a safety concern.
- The space constraint in the downtown area precludes the use of wind turbines of any useful size. Micro-wind may possibly be an opportunity to be leveraged, but the cost-benefit and overall capacity which could be installed do not appear on the surface to have any potential for impact on the microgrid project as a whole.

Impact of Regulations Prohibiting the Sale of Electricity Between Parcels

The regulations which prohibit the sale of electricity between parcels fundamentally affect how the microgrid is designed and how it could operate. Unless there is no utility power available, the utility's interpretation of the regulations does not allow for energy produced by a DER on one of the sites in the microgrid to be sold to and used by another site within the microgrid during normal power. This issue essentially prevents the microgrid from being designed to parallel the utility grid, because the added cost does not provide any value. As a result, the design is forced to only consider open-transition islanding and precludes any consideration of close-transition grid paralleling, which inherently prevents the microgrid from being designed in a way that it could automatically initiate and cease islanding when utility grid power is available. The other major implication is that DER capacity is not optimized for microgrid loads. Rather, the design is in a large part driven by economic constraints such as sizing DERs so that all the energy produced on a parcel is consumed on that parcel so that it is not sold back to the utility grid at wholesale rates.

Solar Plus Storage Plus EV Charging Creates Design Flexibility

The combination EV charging with a solar plus storage system presents an interesting opportunity for downtown community microgrids to site the primary DERs that would serve critical buildings in a resiliency scenario in a nearby parking lot. The mutual benefits are numerous and a preliminary list is identified below:

- Demand for EV chargers is expected to increase. EV chargers could be incorporated into downtown microgrid where consumer demand for EV charging infrastructure is likely to increase with increased EV market share. Projections by BloombergNEF show EV sales increasing to more than 50% of new passenger car sales by 2040 and that EVs are expected to be a considerable representation of the municipal vehicle fleet (Henze 2020).
- The EV chargers provide a load that is necessary for "behind the meter" interconnection of the solar and storage assets, as well as for demand response activities.
- Battery energy storage can be used to offset demand charges associated with EV charging stations. This is a common issue for EV chargers which can be mitigated when coupled with batteries. The demand charges can be considerable depending on the service area and number and type of charging stations.

- Revenue can be generated through paid EV charging revenue as well as demand response (discharging the batteries upon utility dispatch, while limiting the EV charging loads during peak periods)
- Solar PV in the mix keeps EVs running on clean and emissions-free energy, or close to it.
- Economies of scale can be realized for the electrical infrastructure costs associated with each of these technologies when they are designed and implemented together.
- The next generation of EV chargers, known as Vehicle To Grid (V2G) technology, may provide even more flexibility to the microgrid. This added flexibility could be realized by using future V2G technology to leverage the batteries on board the EVs for demand response and potentially even for auxiliary energy storage. This represents an area for future investigation.

The net result of the flexibility that EV charging stations offer when coupled with solar plus storage is:

- The energy storage assets and DERs can be designed to be sited in a local parking lot and do not necessarily need to be attached to/inside of/on the site of a building to have an impact on the microgrid
- The solar plus storage plus EVs have the potential to be an attractive standalone project, even without the microgrid aspects.

IMPLEMENT ENERGY CONSERVATION MEASURES FIRST

The economics presented in this study assume that Energy Conservation Measures (ECMs) are implemented at each site prior to installing microgrid assets. The ECMs include upgrading to light emitting diode (LED) lighting in all facilities, control upgrades at the municipal buildings, and a new desiccant dehumidifier roof top unit (RTU) and refrigerated case doors at Shaw's. In addition to the annual energy use reduction, implementing the ECMs first can reduce the overnight and peak loads of the facilities, allowing DER and storage assets to be selected at a smaller size. The impact is realized in reduced capital costs as well as the reduced energy operating costs for the facility. The analysis in this study shows that the ECMs save approximately $50,000 in annual energy costs for Shaw's and nearly $7,000 in annual energy costs for Melrose. If the ECMs were not implemented and all other parameters of the microgrid remained the same, the additional first cost for the energy storage component of the project would be on the order of $1 Million.

The value and impact of the ECMs on the MG concept is significant, however there is a balance to how deep is appropriate for the energy retrofits to go in support of the microgrid project. For example, at Shaw's there is an opportunity to use CHP if the thermal load is able to be increased, but this can only be done by adding a glycol hot water loop to the facility and the Heating, Ventilating, and Air Conditioning (HVAC) equipment is retrofitted with hot water coils and the natural gas heat is removed. Another example is that energy use could be reduced by 10-20% if the refrigeration system at Shaw's was replaced with a CO2 refrigerant system. Both of these options are technically viable and have technical benefits which would allow the microgrid battery energy storage and solar PV asset sizes to be reduced. However, both of these options are also cumbersome and disruptive installations, with very high associated capital costs, unattractive paybacks, and represent new systems which were not originally present and are not directly a part of the microgrid for the facility to manage, maintain and operate.

Therefore, considering this microgrid concept and for other similar community microgrids in a broader sense, it is important that practical ECMs should be identified and implemented prior to or concurrently with developing, designing and implementing a community microgrid. Moreover, this review has clearly indicated that there is a balance which must considered during the planning process as to how complicated, disruptive, and mutually beneficial the ECMs should be compared to the value they bring to the microgrid.

Impact of Utilizing only Clean Energy DERs in Microgrid Concept

The design criteria for the microgrid concept considered in this study was for only clean energy DERs to be utilized. From the standpoint of matching the peak energy generation with the peak load, solar PV is an excellent choice for a supermarket (the anchor load in this microgrid) because of the similarities in the supermarket demand and solar PV generation load shapes when the sun is shining. However, the clean energy requirement is a challenge in a high-solar PV mix of DERs, particularly with supermarkets due to their overnight baseload. This ultimately forces the battery energy storage capacity to be sized to meet the overnight load when the solar PV is not producing. This is also a commercial and financial consideration and is discussed earlier, however from a technical perspective, relaxing and/or modifying the clean energy requirements would allow developers to reduce project first costs through strategic use of- fossil fuel standby generators in a way that still meets the clean energy intent of the microgrid. For example, using the standby generators to meet the base load when islanded during a resiliency event and only exercising the generators during normal power to maintain the equipment.

Utility Technical Benefits Need to be Better Understood

Similar to the discussion earlier in the Commercial and Financial Considerations sections, the technical benefits to the utility need to be understood. In addition to the NWA review of this microgrid, the following questions should be asked to generate further discussion:

- Does the microgrid concept as presented in this report offer any technical benefits to the utility, and if so, what are they?
- Could the point of interconnection of any of the assets be modified or could some aspects of this microgrid be re-imagined to improve the technical benefits to the utility?
- How could technical guidance for common utility benefits/issues/questions related to downtown community microgrids be provided to industry professionals in a generalized way that enables more informed discussion and supports development of similar community microgrids within the Commonwealth?

Battery Energy Storage is Necessary

Batteries are a necessary component to support this microgrid or a similar concept with a high percentage of solar PV. This is because PV is inherently a passive generation source, meaning it needs a voltage reference (the grid) in order to generate. When the utility grid is unavailable during an outage, and when there are no other primary generation sources to provide a reference voltage, batteries must be used to “form the grid” during islanded mode and provide a reference voltage for the solar PV to follow so the primary DER of the microgrid can generate.

SCALABILITY

REPLICABILITY AND COMMUNITY SUPPORT

There is a large potential to replicate/scale this microgrid study due to the similar characteristics that can be found in most of the 351 towns and cities in Massachusetts. New England is routinely subjected to severe winter storms that cause electric power outages ranging in duration from a few hours to several days. Many towns have critical facilities that need to remain operational during these outages but lack the budget allocations needed to implement resiliency. One of the most critical aspects to the development of a community microgrid is that the community supports the microgrid. This community support for increasing resiliency is necessary to gain traction for the MG, pursue funding opportunities, and develop MG concepts.

There is community support in Melrose for resiliency and it can be seen in the pursuit of studies like this one, as well as the city’s utilization of the MVP program to identify and plan for the impacts of climate change. The inclusion of a backup generator for City Hall was a top action in the 2018 MVP priorities and the number one project in both the 2019 Natural Hazard Mitigation Plan and in the FY 2020 Capital Improvement Plan. Their environmental and sustainability leadership is seen in their history of implementing numerous energy conservation and renewable energy projects and in the mayor signing net zero by 2050 commitments.

Shaw’s support for resiliency and climate change mitigation can be seen in direct examples such as at this supermarket location where the refrigeration system was upgraded ahead of the refrigerant phaseout schedule, as well as through Albertson’s track record of implementing thousands of energy conservation and sustainability projects across their nationwide network of stores.

All the participants in this study are interested in understanding the potential energy and non-energy benefits of a microgrid at this location and in a broader sense, as it supports their commitment to energy efficiency and sustainability. This support framework of interested stakeholders is a necessary foundation for overcoming commercial and financial feasibility hurdles and can and should be used to generate increased momentum in developing a practical and impactful microgrid. Framing the value of a microgrid in both the energy-related benefits as well as the benefits of resiliency and weighing it against the cost of not being resilient is critical to strengthening community support and making the case for financial investment.

CONSIDERATIONS FOR FUTURE COMMERCIALIZATION STRATEGY

The proposed MaaS model has been successfully implemented by several companies, including Ameresco, Schneider Electric, and Scale Microgrid Solutions. To bring the business plan towards commercialization in a greater scope than this singular proposed microgrid site, the following questions would need to be answered. Some of these questions are discussed to some extent in this report, however all would require further analysis and exploration to develop into a commercialization plan to go to market.

Business Plan Development Criteria	Considerations Related to This Microgrid Concept
Timing vs Market Conditions	- What are the current and anticipated trends related to gas and electric utility costs? Technology and equipment costs?
Target Regions	- What towns, states, or utilities are in need of the resiliency provided by a microgrid? - What states and/or utilities offer favorable incentives or grants that can make the project economical?
Target Market	- What business sectors value resiliency? - What businesses within those sectors have leadership that are willing to become early adopters?
Financial	- How many microgrids would indicate a successful commercialization effort? - What level of staffing and contracting will be needed to design, implement, and manage the microgrids? - What level of capital will be needed from outside investors? - What ROI is needed? - What level of risk is involved?
Resources	- What commercial partners will be needed for asset procurement, construction, and maintenance?

Feasibility Study Tasks

Below is a summary of the key components of each of the tasks included in this project.

Task 1

This task is comprised of the administrative and project management components of this project.

Task 2

This section provides an overview of each facility's services, mechanical and electrical systems, energy usage and load characterization. The section concludes with a discussion of the required and preferred microgrid characteristics that have been identified by the project team.

Task 3

This section explores and presents:

- Microgrid interconnection strategies
- Proposed DER sizing and selection
- Evaluation of existing and proposed electrical, thermal, control, and IT infrastructure and their role in the proposed microgrid
- Various microgrid services and control strategies

Task 4

This section explores and presents:

- The importance of these sites to the community and the value they add through the services they provide.
- The proposed microgrid's business model, examining the potential microgrid customers, value proposition, project team, creation and delivery of value.
- The commercial hurdles which this microgrid and other similar microgrids would encounter.
- The value and challenges associated with the selected DERs and control strategies.

Task 5

The purpose of this section is to:

- Develop the inputs and supporting information for a wholistic cost-benefit analysis of the microgrid.
- Estimate and quantify the resiliency benefits to the extent possible.
- Investigate the costs associated with the planning, design, implementation and operation of the resiliency driven microgrid.
- Investigate the revenue streams associated with the services provided by the microgrid.
- Determine the financial feasibility for all stakeholders of the proposed microgrid.

Task 6

The purpose of this section is to present the project results from the previous tasks, and summarize lessons learned, key considerations, findings and recommendations.

TASK 2: SITE OVERVIEW

The proposed microgrid consists of four buildings, each providing critical services to the City of Melrose and surrounding communities. The proposed microgrid consists of:

- Shaw's Supermarket, the only supermarket in the local area and one of only two in the City of Melrose
- Melrose City Hall, serving as the 24/7 operations center during an emergency event the City Hall also plays a crucial role in emergency dispatch via the local IT server
- Melrose Main Street Fire Station, providing fire & rescue as well as primary ambulance service for the area
- Melrose Memorial Hall, serving as an emergency shelter during an emergency event

The following section provides an overview of each facility's services, mechanical and electrical systems, and energy usage. The section concludes with a discussion of the required and preferred microgrid characteristics that have been identified by the project team. These characteristics guided the microgrid design and other technical and financial considerations.

SITE ASSESSMENT

OVERVIEW

This section provides an overview of the four sites included in the proposed microgrid, with a separate section on each describing:

- Mechanical systems
- Lighting
- Energy management systems
- Prior and planned microgrid asset installations
- Prior and planned energy efficiency improvements

Existing microgrid assets are shown in Table 5 and are discussed further in each site's individual building assessment. The existing UPS at City Hall utilizes a sealed lead acid (SLA) battery.

Table 5: Asset summary for microgrid facilities.

Building	Existing Microgrid Assets
Shaw's Supermarket	20 kW natural gas generator
City Hall	15 kVa SLA UPS for data center
Central Fire Station	33 kW diesel generator

In addition to the above microgrid assets, sites have put forth energy efficiency efforts to reduce their existing load including the implementation of energy efficiency measures identified in a 2013 energy audit. As part of the site assessment, the project team has identified energy efficiency opportunities to further reduce building consumption as discussed in the New Energy Efficiency Improvements section on Page 81. Note that the energy efficiency improvements discussed are likely to qualify for prescriptive rebates and/or be eligible for custom incentives through utility and state programs. These incentives are discussed in greater detail in Task 5: Financial Feasibility.

SHAW'S SUPERMARKET

FACILITY DESCRIPTION

GENERAL

Shaw's Supermarket located at 34 Essex Street is the only grocery store in downtown Melrose and primarily serves the community living within a half a mile radius. A Whole Foods Market and Stop & Shop are located approximately 1 and 3 miles away, respectively. The store is approximately 36,000 square feet. The operating hours are Monday to Saturday – 7 am to 11 pm and Sunday - 7am to 10 pm, although product refrigeration loads are continuous.

As shown in Figure 2, Shaw's Supermarket is located on the South side of Essex street, opposite the three municipal facilities considered in this study. The building is located near senior housing apartment buildings and is adjacent to a parking lot and other downtown businesses. Figure 2, below, shows the Shaw's Supermarket's rooftop and visible mechanical equipment.

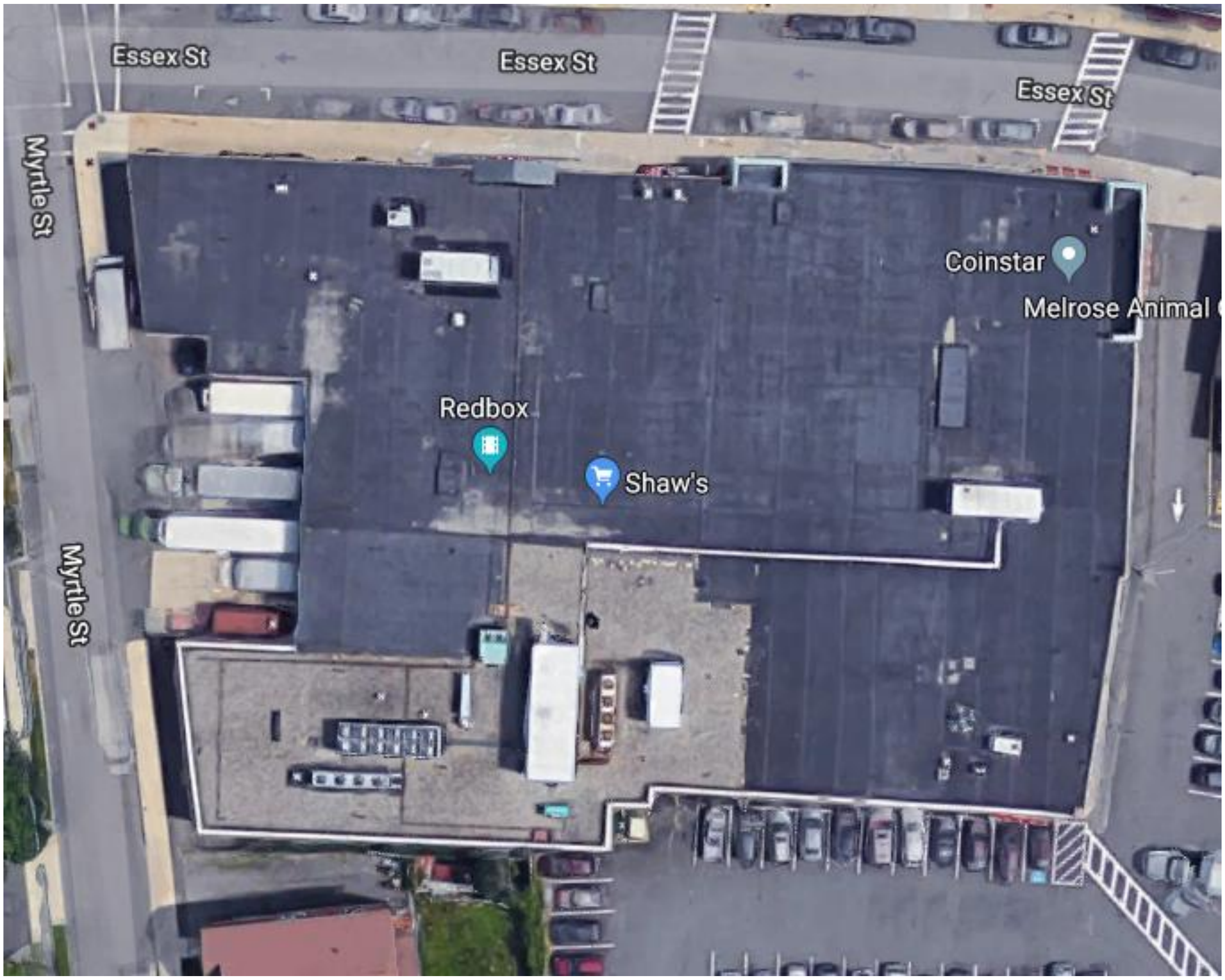


Figure 2: Overview of Shaw's Supermarket.

Airside Mechanical Systems

Shaw's Supermarket is served by (5) roof-top units (RTUs). The units provide ventilation, dehumidification, and cooling to various spaces within the building. These units operate according to a fixed equipment schedule with a 5 °F nighttime setback. RTU-2 serves as the primary source of dehumidification for the store, servicing the left entry refrigerated aisles and sales area. RTU-2's cooling setback is scheduled from 12:00 am to 3:00 am and its heating setback is scheduled from 12:00 am to 5:00 am. All other units have both their heating and cooling setbacks scheduled from 12:00 am to 5:00 am. RTU-2 was identified to have a 20 hp supply fan equipped with a variable frequency drive (VFD), although it was noted to be running at 100% during the site visit. RTU-2's cooling load is met by the refrigeration loop and heating is provided by the refrigerant hot gas. All other RTUs have packaged DX systems for cooling and gas fired heating. A summary of Shaw's Supermarket's RTUs is shown in Table 6. Note that entries labeled "--" were unable to be attained at the time of this report.

Table 6: RTU summary matrix for Shaw's Supermarket.

Unit	Area Served	Design Airflow	Ventilation Airflow
-	-	cfm	cfm
RTU-1	Lounge	1200	300
RTU-2	Left Entry & Refrigerated Aisles	15800	2400
RTU-3	Sales	9370	2400
RTU-4	Offices	--	280
RTU-5	Offices	1200	--

According to available drawings, Shaw's contains (7) general exhaust fans and (1) kitchen exhaust fan. The exhaust fans located throughout the building are shown below in Table 7.

Table 7: Exhaust fan summary matrix for Shaw's Supermarket.

Unit	Design Airflow	SP	Motor
-	cfm	in. WC	hp
EF-1	300	0.25	1/25
EF-2	400	0.25	1/25
EF-3	1300	1.5	1/2
EF 4	200	0.25	1/50
EF-5	300	0.25	1/25
EF-6	100	0.25	1/25
EF-7	150	0.25	1/100
KHEF-1	1870	1.25	1

Supplemental heat is provided to spaces within the building through (4) unit heaters and (1) gas-fired duct furnace as shown in Table 8. UH-1 and UH-2 serve storage areas while UH-3 and UH-4 serve receiving areas.

Table 8: Supplemental heat equipment summary matrix for Shaw's Supermarket.

Unit	Manuf. No	Design Airflow	Total Capacity
-	-	cfm	MBH
UH-1	F-50	650	40
UH-2	F-50	650	40
UH-3	F-50	650	40
UH-4	F-50	650	40
DF-1	EEEDU100	1390	80

Mechanical Cooling and Refrigeration

Several air-cooled condensing units located on the rooftop serve the refrigeration systems and DX coils for the AHUs. (2) 1-ton and (1) 5-ton split AC systems serve single zone areas within Shaw's. RTU-1, RTU-3, RTU-4, and RTU-5 contain packaged compressors and condenser fans to meet their design cooling capacity. The refrigeration loops' condensing is met by the following condensers:

- (1) Hussman 12 fan condenser, each 1 hp
- (1) Trenton 4 fan condenser
- (1) Bohn 4 fan condenser
- (1) Husmann Protocol High Efficiency condenser located inside

Note that each condenser fan bank is served by a common VFD, although some VFDs are in poor condition and appear non-functional.

The refrigeration loops that serve the refrigerated and frozen goods within Shaw's are shown in Table 9 and organized by loop, with multiple compressors serving a single loop. Note that entries labeled "--" were unable to be attained at the time of this report. Alternating colors represent different refrigeration loops served by multiple compressors. The refrigeration loop is currently being renovated to reduce the system's environmental impact by converting from R-22 to R-408. The conversion process requires the replacement of nearly all valves within the refrigeration system.

Table 9: Refrigerant compressor summary matrix for Shaw's Supermarket.

Model Number	Nameplate Power	Cooling Capacity	Total Loop Capacity	Design Load	Loading vs Capacity	Refrigerant	Service
-	hp	MBH	MBH	MBH	%	-	-
060R228	7.5	40	94.1	91.9	98%	R-22	Grocery Freezer, Bakery Freezer, Ice Cream
060R337	10	54.1					
060R228	7.5	51.8	103.6	104.4	101%	R-22	Frozen Food, Frozen Fish, Frozen Seafood
060R228	7.5	51.8					
060R724	6.5	67.2	302.3	300.1	99%	R-22	M/D Meat, Lunch Meat, Service Fish, Meat Cooler, Diary Cooler, VAC-PACS, Produce Cooler, Lobster
060M337	10	103.2					
060M150	15	131.9					
090M337	10	162.4	880.3	829	94%	R-22	Meat Prep, Produce Prep, Subcooling, Desuperheating, Low Stage Load, AC Stage 1
060M150	15	214.6					
060M150	15	214.6					
060A265	25	288.7					
2DA0500	5	--	280.7	267.1	95%	R-22	M/D Dairy, Deli Cooler, Bakery Retarder, Cream Case, Floral
2DA0750	7.5	--					
3DA0750	7.5	--					
3DB1000	10	--					
2DD0500	5	--	96.5	86.7	90%	R-22	Fresh Meat, Service Deli, Fish Cooler, M/D Deli
3DA0750	7.5	--					
2B38KCE	5	44.3	193.6	156.5	81%	R404A	Produce, Hi-Capacity Produce
2B38KCE	5	44.3					
2B45KCE	6	52.5					
2B45KCE	6	52.5					

Lighting

Shaw's Supermarket lighting is primarily 4 foot, 32W T8 fluorescents with some metal halide and compact fluorescent light (CFL) fixtures.

Electrical Distribution

Shaw's existing electrical service is provided via a National Grid 500kVa, 4160VAC primary, 208VAC secondary, pad mount utility transformer located in the rear parking lot of Shaw's. Shaw's main service entry gear is located on the main floor. The existing service entrance switchboard is 3,000A, 3 phase, 4 wire, 208Y/120VAC and is fully utilized with no spare positions. The switchboard was installed circa 1989. The electric room is fully populated with no space for additional electric panels. In order to accommodate new assets as part of the microgrid, some reworking of these panels will be required. The main disconnect is a 3,000A, 480VAC rated, fused pringle switch. The main disconnect fuse protection should be verified. Electric consumption data is collected by a digital utility meter as well as a Parasense Smart E Monitor for internal system reporting.

Refrigeration Management Systems

The refrigeration control system is comprised of three generations of controls overlaid on one another. The existing control system manages the freezers and coolers, compressors and condensers, and the RTUs. The controls allow for up to 5 psi of floating pressure control. Condensers are equipped with summer and winter run modes. During the winter, one bank of condenser fans shut off to reduce fan energy consumption.

Microgrid Assets

Existing

This facility has a 20 kW natural gas emergency generator which can power emergency lighting but is not sized to meet normal lighting power, HVAC, or refrigeration loads. During an extended loss of power, products requiring refrigeration are likely to be lost.

Planned

Prior to the ongoing microgrid study, Shaw's Supermarket did not have any planned microgrid asset installations.

Efficiency Improvements

This section provides information on existing and planned facility efficiency improvements that are currently being considered by the facility independent of the microgrid study. For a discussion regarding proposed efficiency improvements discussed in conjunction with the study, please refer to the New Energy Efficiency Improvements section on page 81.

Existing

Shaw's is currently in the process of converting the remaining R-22 refrigeration loops with R-408.

Planned

Shaw's Supermarket is continuously identifying cost-effective energy efficiency improvements to reduce the facility's load. Currently, Shaw's does not have any efficiency improvements scheduled.

City Hall

Facility Description

General

Melrose City Hall is a three-story building originally constructed in 1874. Under normal operations, it functions as the main city administrative building, the regional IT network hub, and contains the offices of Emergency Management, Operations and the Health Department. City Hall houses the central server and network hub for all the city departments, police and fire dispatch and mobile units, the Mobile Data Terminals on fire apparatus, and six of the City's eight schools. The City Hall is typically open from 8:30 am to 4:30 pm Monday through Wednesday and 8:30 am to 12:30 pm on Friday. During an emergency event the City Hall becomes a 24/7 operations center. Melrose City Hall is located on the corner of Essex Street and Main Street as shown in Figure 3.

Figure 3: Overview of Melrose City Hall.

Airside Mechanical Systems

City Hall is served by (3) air handling units (AHUs). RTU-1 is a dedicated outdoor air system (DOAS) and provides ventilation air to the majority of the building. The unit is gas-fired and has DX cooling. RTU-1 operates to maintain a discharge air temperature (DAT) setpoint between 55 °F to 75 °F according to an outside air temperature (OAT) reset. RTU-2 is a gas-fired, DX-cooled, mixed air unit that serves the Aldermanic Chambers. The unit cycles to maintain occupied zone temperature setpoints of 72 °F in cooling and 70 °F in heating and unoccupied zone temperature setpoints of 85 °F in cooling and 55 °F in heating. The third airside unit is a DX-cooled AC unit that serves the basement vault. The AC unit's condensing unit is located in the basement mechanical room.

Individual zones are served by approximately (69) fan coil units (FCUs). Each FCU is equipped with a dual-temperature coil, which is served with either chilled water (CHW) or hot water (HW), depending on the time of year.

B2Q identified (4) exhaust fans (EFs) during site walkthroughs. The exhaust fans range in size from ¼ hp to 1 hp nameplate power and serve general and mechanical room exhaust.

Waterside Mechanical Systems

City Hall's waterside mechanical infrastructure is comprised of one dual-temperature loop, with a set of two, 3 hp dual-temperature pumps, and is served by a single, split chiller and a hot water boiler. The chiller is a 70-ton Daikin model WGZ Scroll chiller located in the basement. Its remote condenser is an 80-ton Daikin model ACH condenser located on the rooftop. The boiler is a gas-fired Thermal Solutions model EVS-1000 with a rated output capacity of 880 MBtu/h. The dual temperature loop serves the building's (69) FCUs. An additional gas-fired AO Smith Cyclone XI BTH 120 provides domestic HW to the facility.

Lighting
The building's lighting is primarily fluorescent, including T8 tubes and CFLs. Some bathrooms contain T12 strips. The parking lots and exterior utilize high pressure sodium (HPS) fixtures.

Electrical Distribution
City Hall's existing electrical service is provided via a National Grid 150kVa, 4160VAC primary, 208VAC secondary, pad mount utility transformer located directly outside Melrose City Hall at the corner of the Essex Street entrance into the parking lot. City Hall's main service entry gear is located in the basement level, referred to as the ground level on building documentation. The existing service entrance switchboard is 1,200A, 3 phase, 4 wire, 208Y/120VAC and was installed circa 1989. The existing distribution panel has an available spare position. Circuit relocation within the distribution panel may be necessary to utilize the spare position. The basement electric room is fully populated with no space for additional electric panels. The main disconnect is a 1,200A, 480VAC rated, fused pringle switch. The fused protection is shown on building drawings and should be verified. Electric consumption data is collected by a standard G-2 customer utility meter.

Energy Management Systems

City Hall is on the City of Melrose's Facility Explorer network, enabling a single operator to manage all systems on the network. The Facility Explorer network controls the building's boiler, chiller, air handling units, dual temperature pumps, and fan coil units.

Microgrid Assets

Existing
IT servers are currently backed up by a UPS which can provide power for data servers and emergency telephone services for approximately one hour following a power interruption. The data servers are cooled via (2) window AC units.

Planned
Prior to the ongoing microgrid study, The City of Melrose was considering purchasing a diesel-powered generator to serve the City Hall for backup and emergency power outage situations. They are also considering black start CHP alternatives to conventional standby emergency generation.

Efficiency Improvements

This section provides information on existing and planned facility efficiency improvements that are currently being considered by the facility independent of the microgrid study. For a discussion regarding proposed efficiency improvements discussed in conjunction with the study, please refer to the New Energy Efficiency Improvements section on Page 81.

Existing
As part of a 2013 Ameresco investment grade audit, several energy efficiency measures were studied, a subset of which have been implemented including piping insulation, infiltration reduction, lighting controls, lighting upgrades, boiler improvements, and chiller replacement.

Planned
There are currently no planned facility improvements.

Fire Station

Facility Description

General
The Melrose Fire Station is a three-story Historic Building, originally constructed in 1895 and currently being considered for renovation and expansion. The fire station, located on Main Street between City Hall and Memorial Hall, operates 24/7 based on the critical nature services it provides: it is the central fire station and the primary ambulance service for the area, a service provided by the City and not an outside agency. Additionally, Melrose shares Mobile Data Terminals on fire apparatus functions with Chelsea, Wakefield, Saugus, Malden and Lynn through mutual aid agreements.

Figure 4: Overview of Melrose Main Street Fire Station.

Airside Mechanical Systems
The Melrose Fire Station's airside mechanical infrastructure consists of (2) AHUs and (2) unit heaters (UHs). Both AHUs are gas-fired, DX-cooled, Carrier AHUs and are located on the third floor. (1) AHU serves the second floor, which is comprised of sleeping quarters, a lounge area, dining area, bathroom, offices, and a meeting room. The second AHU serves the third floor, which

consists of a gym area and showers and a sauna that are no longer used. Each AHU has a dedicated condensing unit that is located on the first-floor call center roof.

The UHs are both gas-fired and serve the first-floor apparatus area and the back workspaces. Supplemental heat for the call center and office areas on the first floor of the building is provided by limited electric baseboard.

Waterside Mechanical Systems

The building's waterside mechanical infrastructure consists of a single domestic hot water (DHW) loop that is served by a State Industries ANSI model gas-fired 40 MBtu/h DHW heater that was installed in 2017. The DHW heater features a 40-gallon tank that is refilled approximately two times per year, according to staff. The loop is circulated by city water pressure and does not feature a circulation pump.

Lighting

The fire station's lighting is mostly fluorescent, with a mixture of T8, T12 and CFLs. Some areas utilize incandescent fixtures as well.

Electrical Distribution

The Fire Station's existing electrical service is provided via a National Grid 4160VAC primary, 208VAC secondary, utility transformer located in the Vault. Memorial Hall's main service entry gear is located in the basement level. The existing service entrance is a single phase, 208VAC service connected via a fused disconnect switch panel rated for 200 Amp, 1 phase, 3 wire, 208Y/120VAC. The basement main electric room is fully populated, so there is no room for additional electrical panels within the room; however, the area outside the room is free of any installations. Electric consumption data is collected by a digital utility meter; however, the existing digital meter is not equipped for "smart" metering.

Energy Management Systems

The Fire Station does not feature a Building Automation System (BAS) and all equipment is controlled to maintain zone temperature setpoints set at local thermostats.

Microgrid Assets

Existing

The fire station has an existing 33 kW diesel generator which can meet a portion of the facility's electric load for approximately 12 hours before refueling.

Planned

Prior to the ongoing microgrid study, the Fire Station did not have any planned microgrid asset installations.

Efficiency Improvements

This section provides information on existing and planned facility efficiency improvements that are currently being considered by the facility independent of the microgrid study. For a discussion regarding proposed efficiency improvements discussed in conjunction with the study, please refer to the New Energy Efficiency Improvements section on Page 81.

EXISTING
As part of a 2013 AMERESCO investment grade audit, several energy efficiency measures were studied, a subset of which have been implemented including infiltration reduction, lighting controls and lighting upgrades.

PLANNED
There are currently no planned facility improvements.

MEMORIAL HALL

FACILITY DESCRIPTION

GENERAL
Memorial Hall is two story building built in 1912, primarily comprised of a large performance hall and stage. Memorial Hall has an open auditorium space of 7,000 square feet along with a fully equipped commercial kitchen. It seats 800-1,000 and is handicap accessible. In an emergency event, it serves as a critical community shelter for affected residents. Memorial Hall is located on Main Street, directly North of the Main Street Fire Station.

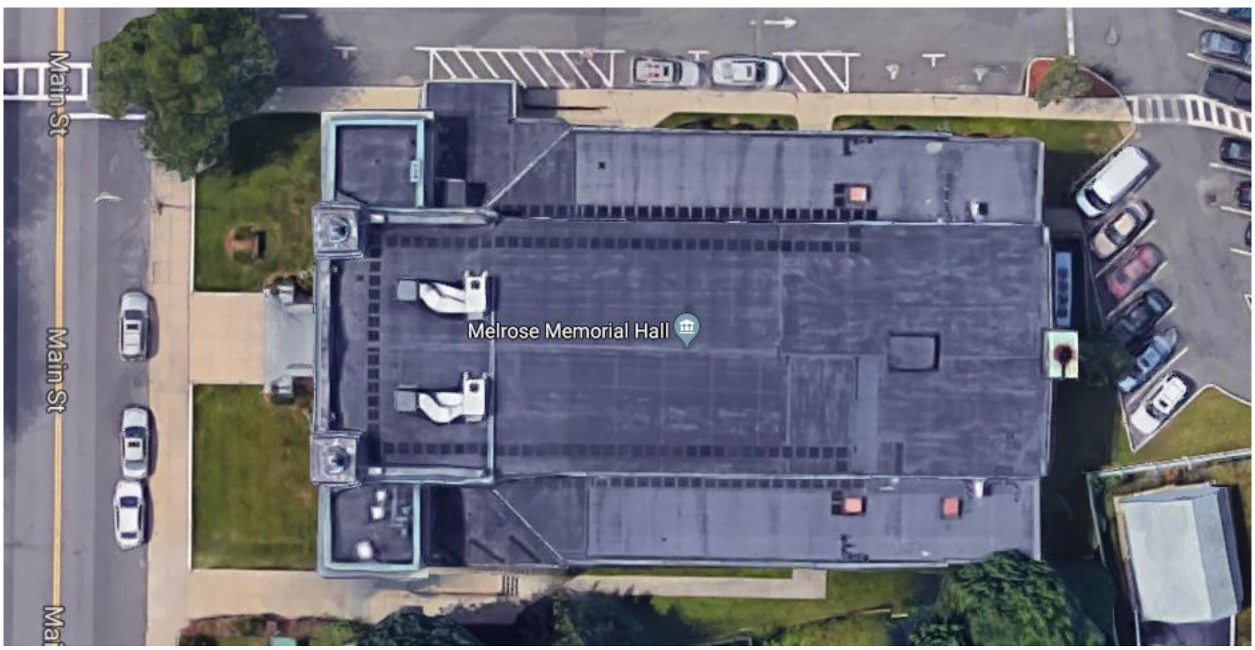


Figure 5: Overview of Melrose Memorial Hall.

AIRSIDE MECHANICAL SYSTEMS
Memorial Hall's main airside mechanical infrastructure includes (3) Trane AHUs. (1) AHU located in the basement serves the auditorium and is equipped with HW and CHW coils. (2) gas-fired, DX-cooled AHUs are located on the roof and serve the G.A.R. room.

In addition to the (3) AHUs, mechanical drawings indicate a total of (7) fan coil units (FCUs), (1) unit heater (UH), and (2) AC units. (2) FCUs serve the stage area, (2) serve the lower level lobby, (2) serve the lower level bathrooms, and (1) serves a lower level office. All FCUs are equipped with HW coils and the (2) FCUs serving the stage area are also equipped with CHW coils with a 4-

ton cooling capacity. The unit heater is located in the mechanical room and has a rated output of 52.2 MBtu/h. The (2) AC units are split Sanyo units and provide mechanical cooling for the dressing rooms.

Waterside Mechanical Systems

Memorial Hall's waterside infrastructure consists of one HW loop and one CHW loop. The HW loop is served by (4) gas-fired Munchkin 399M series boilers, each with a 371 Mbtu/h capacity and a dedicated boiler pump. The HW loop is circulated to the basement AHU and all FCUs via a set of (2) 2 hp pumps that operate lead/standby. The CHW loop is served by a 70-ton air-cooled chiller located outside of the building on the ground. The CHW is circulated to the basement AHU and the stage FCUs via a set of (2) 3 hp pumps that operate lead/standby. A summary of the building's pumps can be found in Table 10 below.

Table 10: Memorial Hall pump summary matrix.

Unit	Service	Manufacturer	Nameplate Power	Design Flow	Design Head	Motor Nameplate Power	Motor Voltage	Motor Phase
-	-	-	hp	gpm	ft	hp	V	ϕ
P-1	CHW	Armstrong	3	136	30	3	208	3
P-2	CHW	Armstrong	3	136	30	3	208	3
P-3	HW	Armstrong	2	140	30	2	208	3
P-4	HW	Armstrong	2	140	30	2	208	3
P-5,6,7,8	Boilers	Armstrong	1/4	32	15	1/4	208	1

Lighting

Memorial Hall contains a mixture of incandescent and fluorescent lighting.

Electrical Distribution

Memorial Hall's existing electrical service is provided via a National Grid 4160VAC primary, 208VAC secondary, pad mount utility transformer. Memorial Hall's main service entry gear is located in the lower level electric room. The existing service entrance switchboard is 1,000A, 3 phase, 4 wire, 208Y/120VAC. The existing distribution panel has available spare positions. The basement electric room has some remaining wall space for expansion panels. The main disconnect is a 1,000A, 208VAC rated circuit breaker. Electric consumption data is collected by a standard G-2 customer meter.

Energy Management Systems

Memorial Hall is on the City of Melrose's Facility Explorer network, enabling a single operator to manage all systems on the network. The Facility Explorer network controls the building's boilers, chiller, air handling units, rooftop units, and pumps.

Microgrid Assets

Existing

Memorial Hall has no existing microgrid assets.

Planned

Prior to the ongoing microgrid study, Memorial Hall did not have any planned microgrid asset installations.

Efficiency Improvements

This section provides information on existing and planned facility efficiency improvements that are currently being considered by the facility independent of the microgrid study. For a discussion regarding proposed efficiency improvements discussed in conjunction with the study, please refer to the New Energy Efficiency Improvements section on Page 81.

Existing

As part of a 2013 AMERESCO investment grade audit, several energy efficiency measures were studied, a subset of which have been implemented including infiltration reduction and lighting upgrades.

Planned

There are currently no planned facility improvements.

LOAD CHARACTERIZATION

The following section provides an in-depth analysis of historic energy consumption collected from monthly utility bills in addition to 15-minute interval data obtained from National Grid's Energy Profiler Online (EPO). Historic energy data, coupled with the project team's knowledge of site equipment and operation, was used to develop a weather normalized 8,760 load profile for each site, including an estimated end-use breakdown.

Prior to microgrid DER asset identification, each building's operation was analyzed to identify opportunities for cost-effective energy reductions. From the end-use data and building walkthroughs, B2Q identified the potential for ECMs and their estimated electrical savings. Please refer the Energy Conservation Measures section for a detailed discussion on measures identified.

The following data is also presented to assist in the identification of what loads may be served, trimmed, or cut in the event of an islanding event. Please refer to the Islanded Operation section for a further discussion on load shedding during islanded events.

OVERVIEW

A summary of energy consumption metrics for the four sites can be found in Table 11. Shaw's Supermarket makes up the majority of the proposed microgrid's energy consumption, accounting for approximately 83% of the total electric energy and 62% of the natural gas.

Table 11: Energy summary for microgrid facilities.

Building	Gross Square Footage	Annual Natural Gas Use	Annual Electricity Use	Peak Demand	Baseload Demand	Load Factor	Energy Use Intensity
-	sq. ft	therms	kWh	kW	kW	%	kBtu/sf
Shaw's Supermarket	36,000	35,891	2,004,403	332	163	69%	289.7
City Hall	30,288	8,419	213,482	84	15	29%	51.8
Memorial Hall	28,477	8,751	103,981	51	8	23%	43.2
Fire Station	11,533	4,462	96,423	24	5	45%	67.2
Total	**106,298**	**57,522**	**2,418,289**				**131.7**

Although the municipal buildings account for only 18% of the total electricity use, City Hall and Memorial Hall have particularly low electric load factors of 24% and 12%, respectively. Electric load factor is defined below.

$$LF = \frac{Annual\ kWh}{Peak\ kW * 8{,}760\ hours}$$

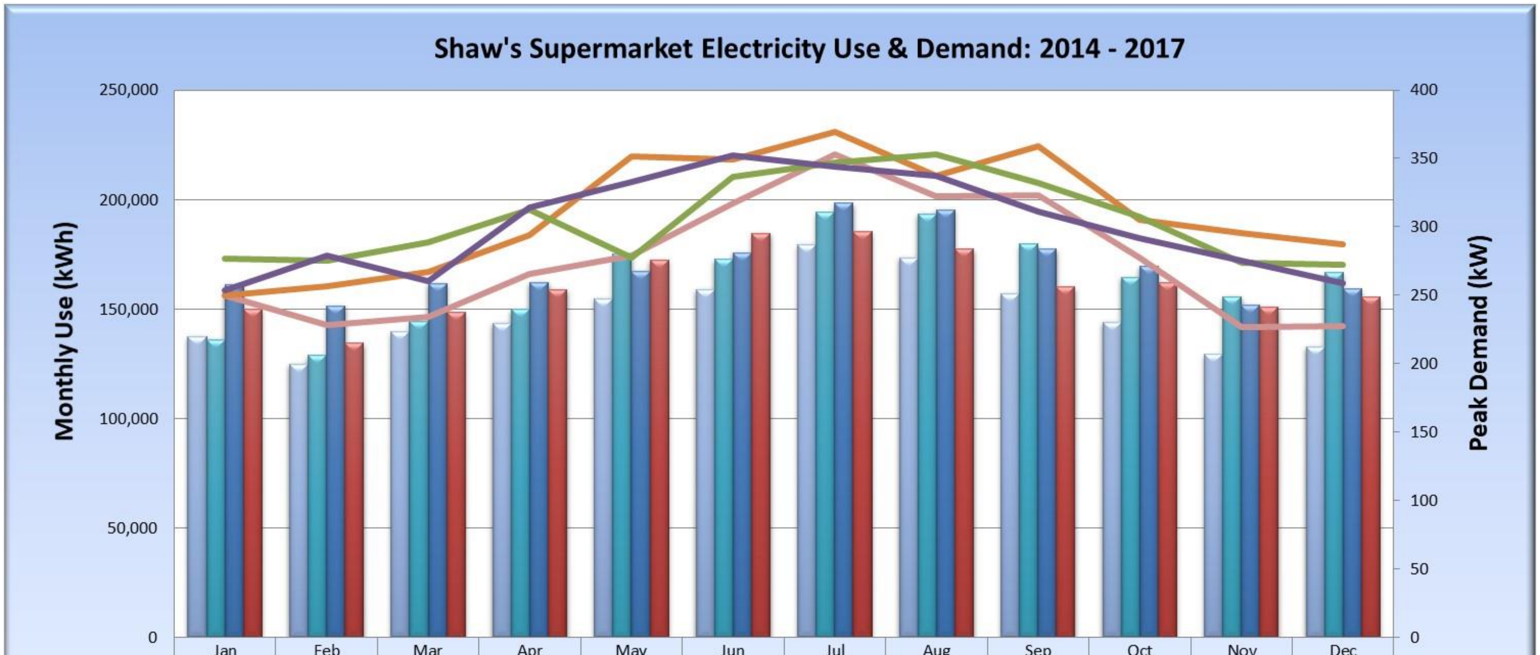
A low load factor is indicative of a peak demand that is high given the demand profile on an average day. City Hall and Memorial Hall's peak demands occur during the summer and are likely a result of mechanical cooling equipment operating at maximum capacity. Shaw's Supermarket's load factor is 69%, indicating that the building's load is less sensitive to time of day and seasonal changes. Understanding each building's peak operating demand and critical demand during an outage event is important for selecting what loads are served by the microgrid and effects microgrid asset consideration and sizing.

HISTORIC ENERGY USE

SHAW'S ENERGY USE

ELECTRIC

The following figure shows both electricity use (kWh) and demand (kW) for the calendar years of 2014 through 2017. It can be seen that the facility's historic peak load is approximately 370 kW and corresponds to the peak cooling periods, when refrigeration equipment is operating at or near maximum capacity. The peak load during the winter months is typically around 270 kW. This graph also displays the seasonal trends associated with cooling in the usage profile, showing an increase in monthly consumption of approximately 50,000 kWh during the summary months compared to use during the winter. Multi-year analysis indicates that the building's energy use is consistent, with some variations due to differing cooling degree days.

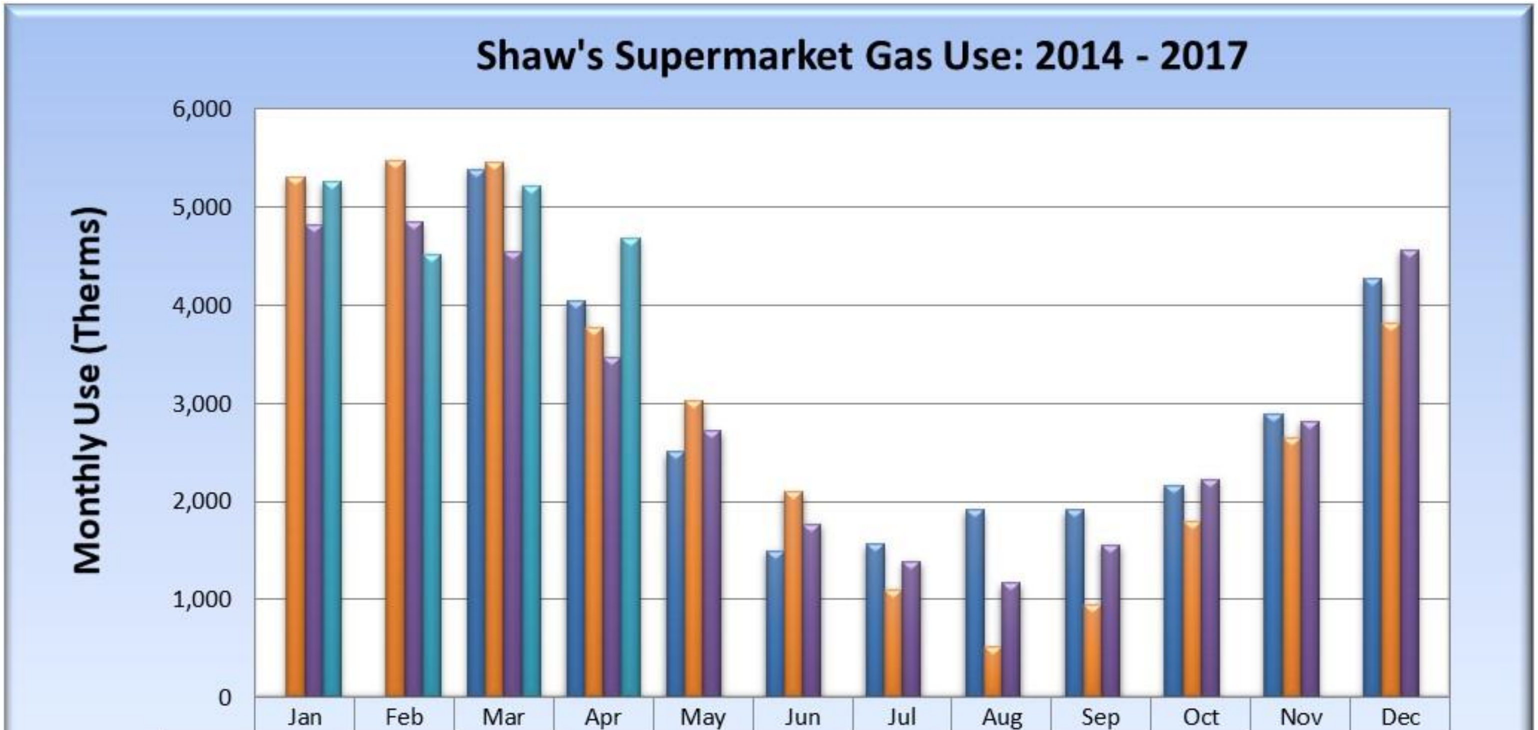


	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2014 kWh	137,512	124,729	139,495	143,557	154,577	158,883	179,493	173,244	156,965	144,059	129,140	132,656
2015 kWh	135,924	128,872	144,413	149,783	174,889	172,684	194,137	193,495	179,671	164,419	155,526	166,491
2016 kWh	161,185	151,426	161,685	162,179	167,389	175,760	198,357	195,365	177,247	169,706	151,830	159,084
2017 kWh	149,937	134,356	148,347	158,799	172,443	184,529	185,150	177,342	160,081	161,827	151,043	155,499
2014 Peak kW	250	228	234	265	279	317	353	322	323	277	227	228
2015 Peak kW	250	256	267	294	351	349	370	337	359	305	296	287
2016 Peak kW	277	275	289	313	278	336	347	353	332	308	274	273
2017 Peak kW	253	279	260	314	333	352	344	337	312	292	276	259

Figure 6: Shaw's Supermarket's electricity use and demand for 2014 through 2017.

GAS

The graph below shows approximately three years of gas data. It can be seen that usage follows a seasonal pattern, reaching approximately 5,000 therms monthly (1,250 therms per week) during the winter. The facility summer load can also be seen, at approximately 1,000 to 2,000 therms per month, or 250 – 500 therms per week. This summer load is a result of domestic hot water needs and potentially the use of gas-fired RTU consumption at night or in the early morning. Average annual consumption is 37,891 therms.



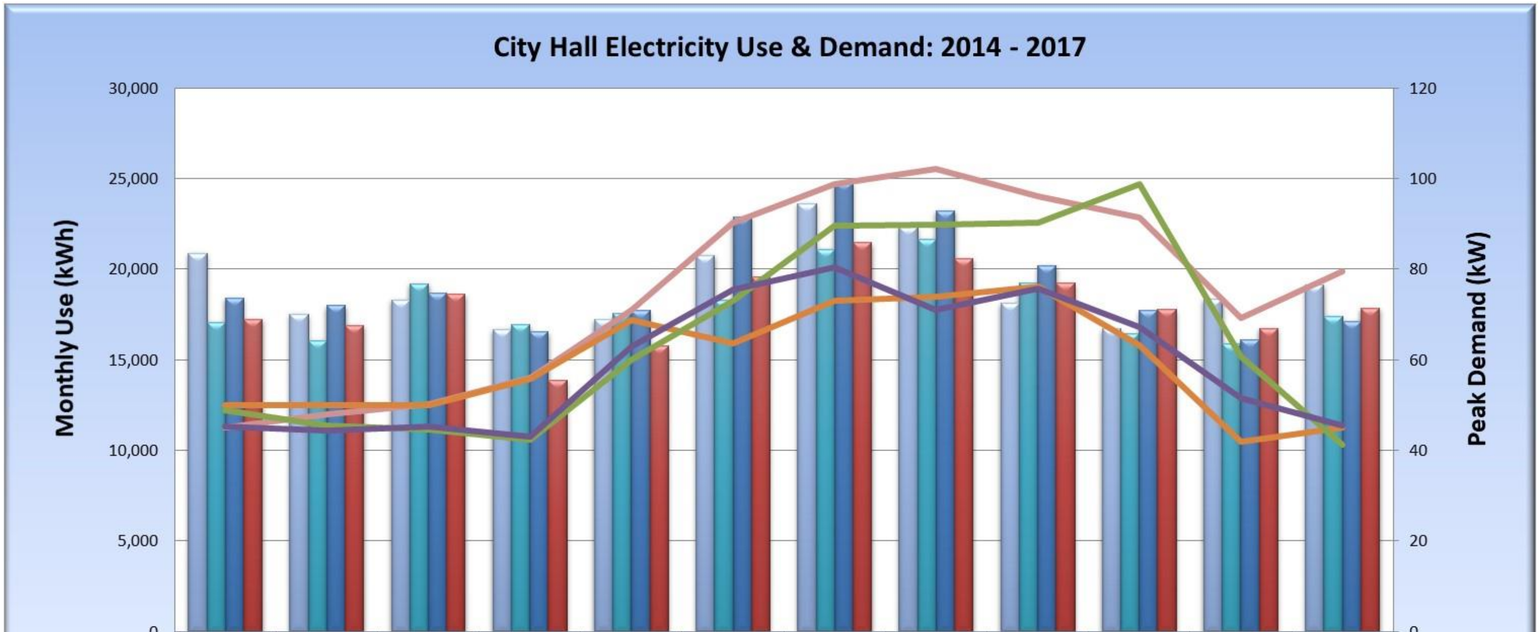
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2014			5,389	4,041	2,504	1,496	1,565	1,916	1,916	2,167	2,895	4,267
2015	5,299	5,481	5,456	3,776	3,025	2,099	1,104	514	950	1,794	2,649	3,823
2016	4,817	4,843	4,546	3,473	2,720	1,768	1,387	1,168	1,558	2,225	2,818	4,568
2017	5,254	4,517	5,222	4,686								

Figure 7: Shaw's Supermarket's gas use for 2014-2017 , displaying seasonal thermal load profiles.

City Hall Energy Use

Electric

The following figure shows both electricity use (kWh) and demand (kW) for the calendar years of 2014 through 2017. It can be seen that the facility's historic peak load is approximately 100 kW and corresponds to the peak cooling periods, when mechanical cooling equipment is operating at or near maximum capacity. This graph also displays the seasonal trends associated with cooling in the usage profile, showing an increase in monthly consumption of approximately 5,000 kWh during the summer months compared to use during the winter. Multi-year analysis indicates that the building's energy use is consistent, with some variations due to differing cooling degree days. Note that erroneous data due to meter communication issues in 2015 has been approximated based on previous years' trends.

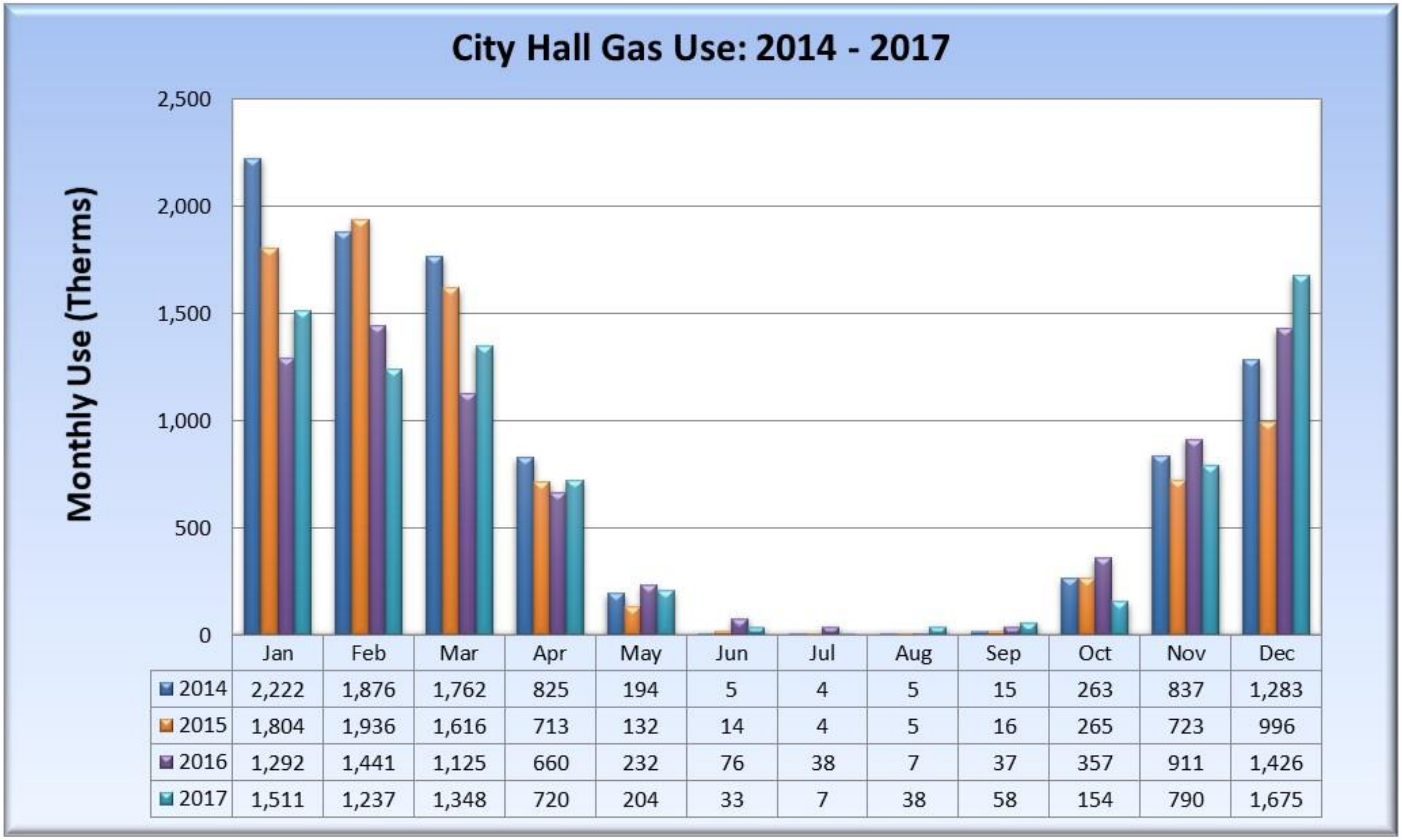


	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2014 kWh	20,889	17,526	18,302	16,668	17,210	20,766	23,623	22,330	18,149	16,720	18,368	19,141
2015 kWh	17,084	16,053	19,209	16,945	17,537	18,292	21,094	21,663	19,238	16,432	15,886	17,399
2016 kWh	18,405	18,002	18,681	16,541	17,707	22,891	24,770	23,236	20,202	17,727	16,103	17,122
2017 kWh	17,246	16,919	18,613	13,842	15,747	19,578	21,464	20,596	19,230	17,776	16,724	17,860
2014 Peak kW	45	48	50	56	71	90	99	102	96	92	69	80
2015 Peak kW	50	50	50	56	69	64	73	74	76	63	42	45
2016 Peak kW	49	46	45	42	60	73	90	90	90	99	61	41
2017 Peak kW	45	44	45	43	63	75	80	71	76	67	52	46

Figure 8: Melrose City Hall's electricity use and demand for 2014 through 2017.

GAS

The graph below shows four years of gas data. It can be seen that usage follows a seasonal pattern, with usage reaching approximately 1,500 to 2,000 therms monthly (350 – 450 therms per week) during the winter. The summer load ranges from 5 to 100 therms per month and is a result of domestic hot water needs and potentially the use of gas-fired RTU consumption at night or in the early morning. Average annual consumption is 7,468 therms.



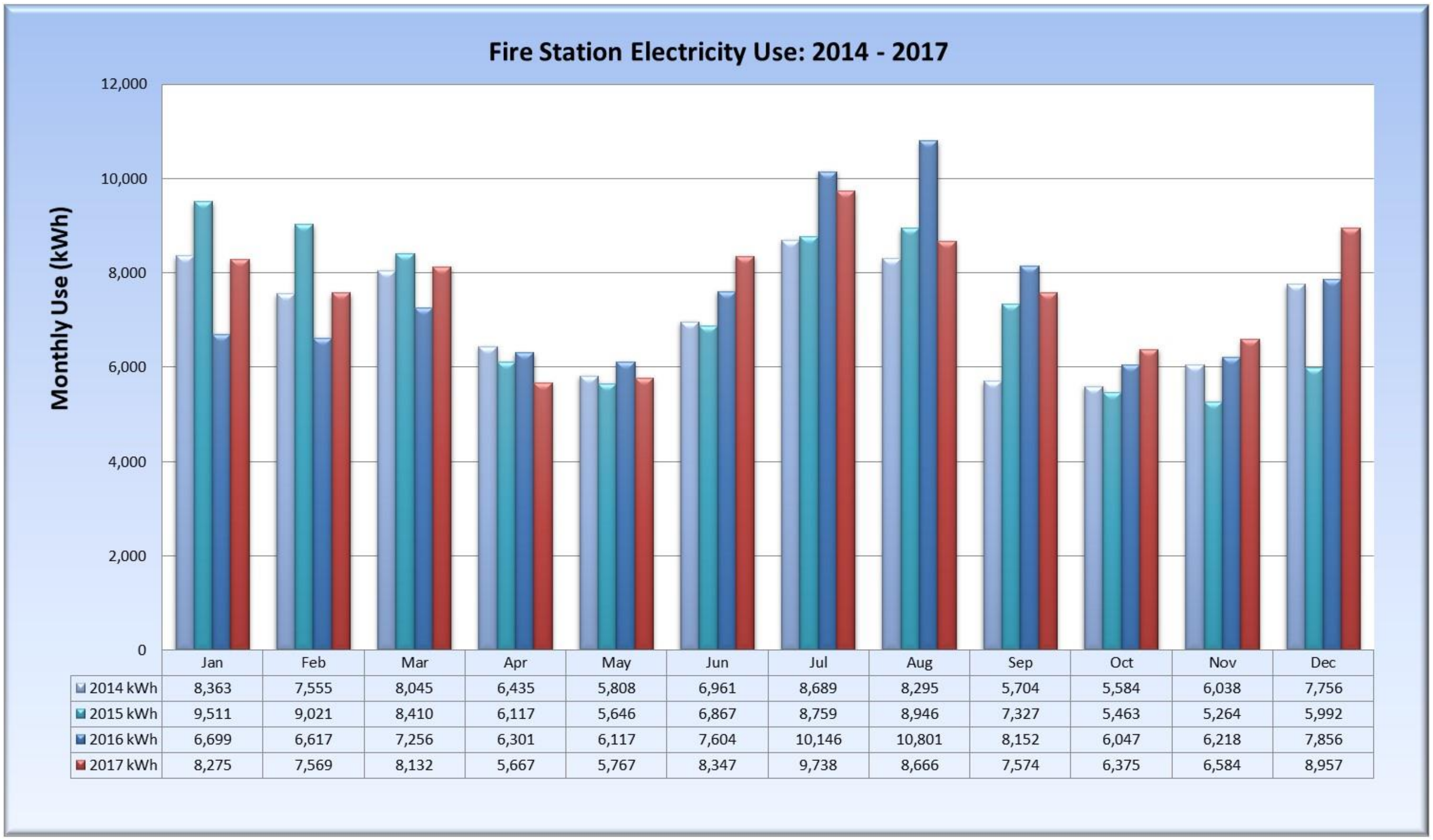
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2014	2,222	1,876	1,762	825	194	5	4	5	15	263	837	1,283
2015	1,804	1,936	1,616	713	132	14	4	5	16	265	723	996
2016	1,292	1,441	1,125	660	232	76	38	7	37	357	911	1,426
2017	1,511	1,237	1,348	720	204	33	7	38	58	154	790	1,675

Figure 9: Melrose City Hall's gas use for 2014–2017 , displaying seasonal thermal load profiles.

FIRE STATION ENERGY USE

ELECTRIC

The following figure shows electricity use (kWh) for the calendar years of 2014 through 2017. It can be seen that the facility displays the seasonal trends associated with cooling and heating energy in the usage profile, showing an increase in monthly consumption of approximately 3,000 kWh in the summer months and 2,000 kWh in the winter months compared to use during the swing season months. The increase in the summer is likely due to the increase in mechanical cooling. The increase in the winter may be due to the electric baseboard in the building as well as the fan energy from the (2) gas-fired unit heaters. Multi-year analysis indicates that the building's energy use is consistent, with some variations due to differing cooling and heating degree days.

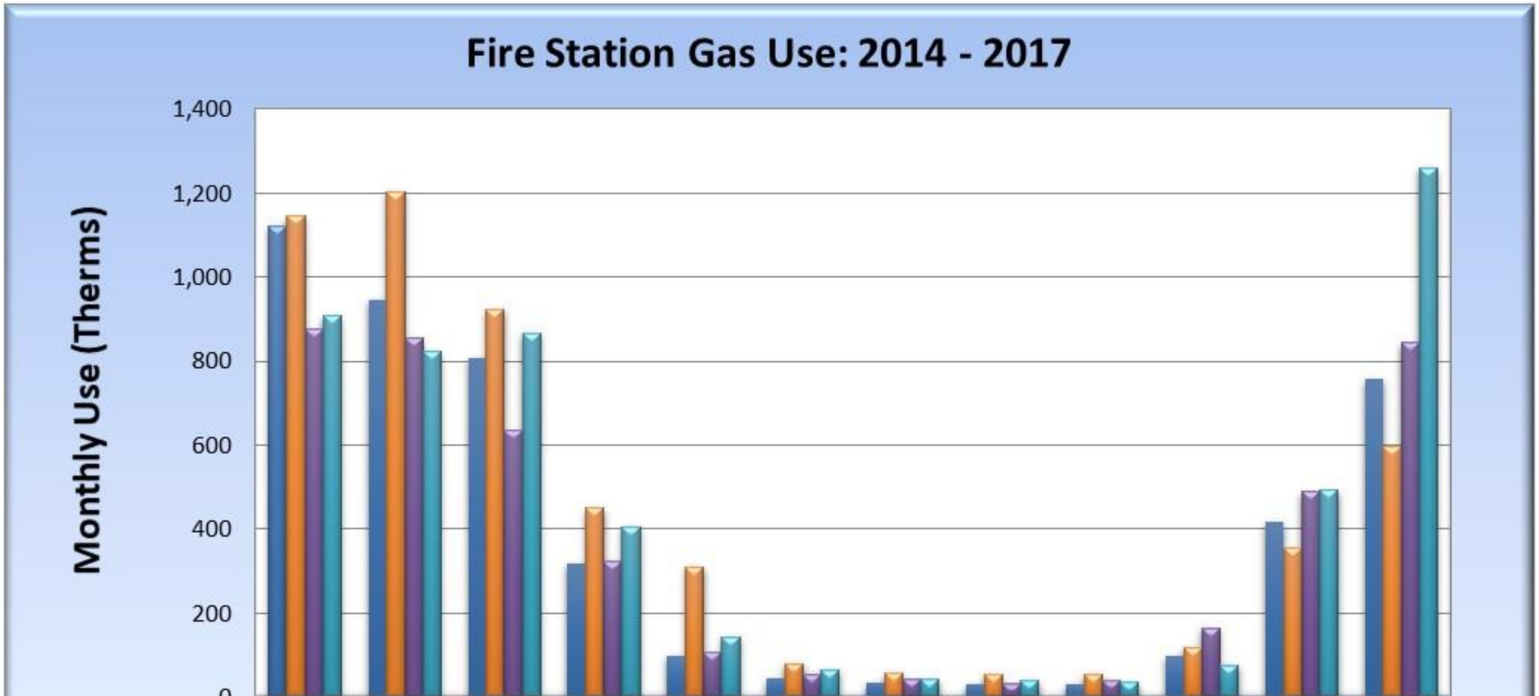


	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2014 kWh	8,363	7,555	8,045	6,435	5,808	6,961	8,689	8,295	5,704	5,584	6,038	7,756
2015 kWh	9,511	9,021	8,410	6,117	5,646	6,867	8,759	8,946	7,327	5,463	5,264	5,992
2016 kWh	6,699	6,617	7,256	6,301	6,117	7,604	10,146	10,801	8,152	6,047	6,218	7,856
2017 kWh	8,275	7,569	8,132	5,667	5,767	8,347	9,738	8,666	7,574	6,375	6,584	8,957

Figure 10: Melrose Central Fire Station's electricity use for 2014 through 2017. Note that peak demand data was not available at the time of this report.

GAS

The graph below shows four years of gas data. It can be seen that usage follows a seasonal pattern, with usage reaching approximately 800 to 1,200 therms monthly (200 – 300 therms per week) during the winter. Note that the 2015 peak in gas use is a result of the unusually cold winter season from January 2015 through March 2015. The summer load ranges from 30 to 100 therms per month and is likely a result of the use of the (2) gas-fired unit heater consumption at night or in the early morning. The table below does not include the gas used for DHW or diesel used for emergency generation. Average annual consumption is 5,351 therms.



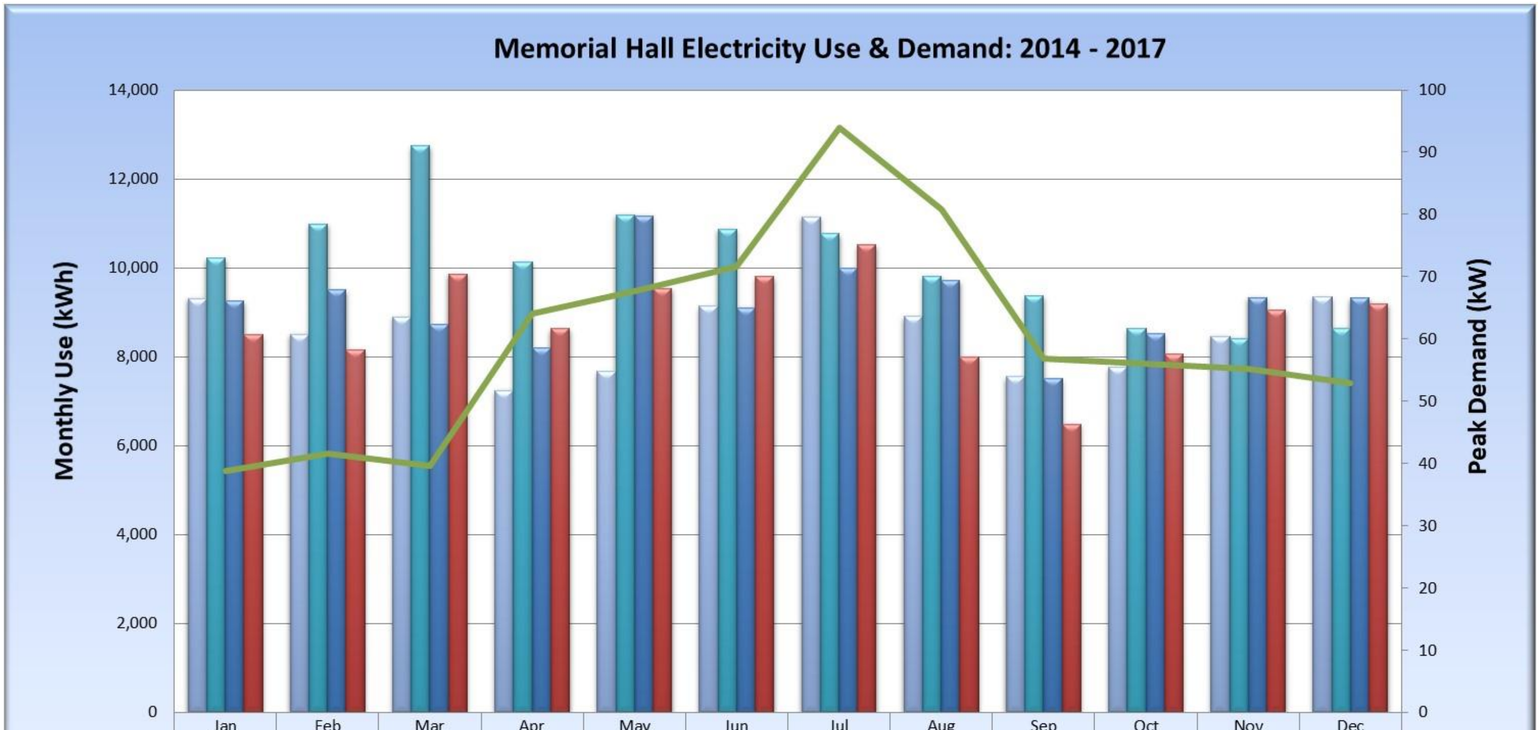
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2014	1,122	947	807	319	97	45	36	29	30	97	419	757
2015	1,145	1,204	923	450	310	80	57	54	55	119	354	596
2016	876	855	635	323	106	55	42	31	41	164	490	843
2017	908	823	866	406	144	66	42	40	36	76	492	1,261

Figure 11: Melrose Central Fire Station's gas use for 2014-2017 , displaying seasonal thermal load profiles.

Memorial Hall Energy Use

Electric

The following figure shows electricity use (kWh) for the calendar years of 2014 through 2017 and demand (kW) for the 2016 calendar year. It can be seen that the facility's historic peak load is approximately 95 kW and corresponds to the peak cooling period, when mechanical cooling equipment is operating at or near maximum capacity. The peak load during the winter months is typically between 40 to 60 kW. Multi-year analysis indicates that the building's energy use has been relatively consistent since April of 2015, which had a particularly high winter energy consumption.

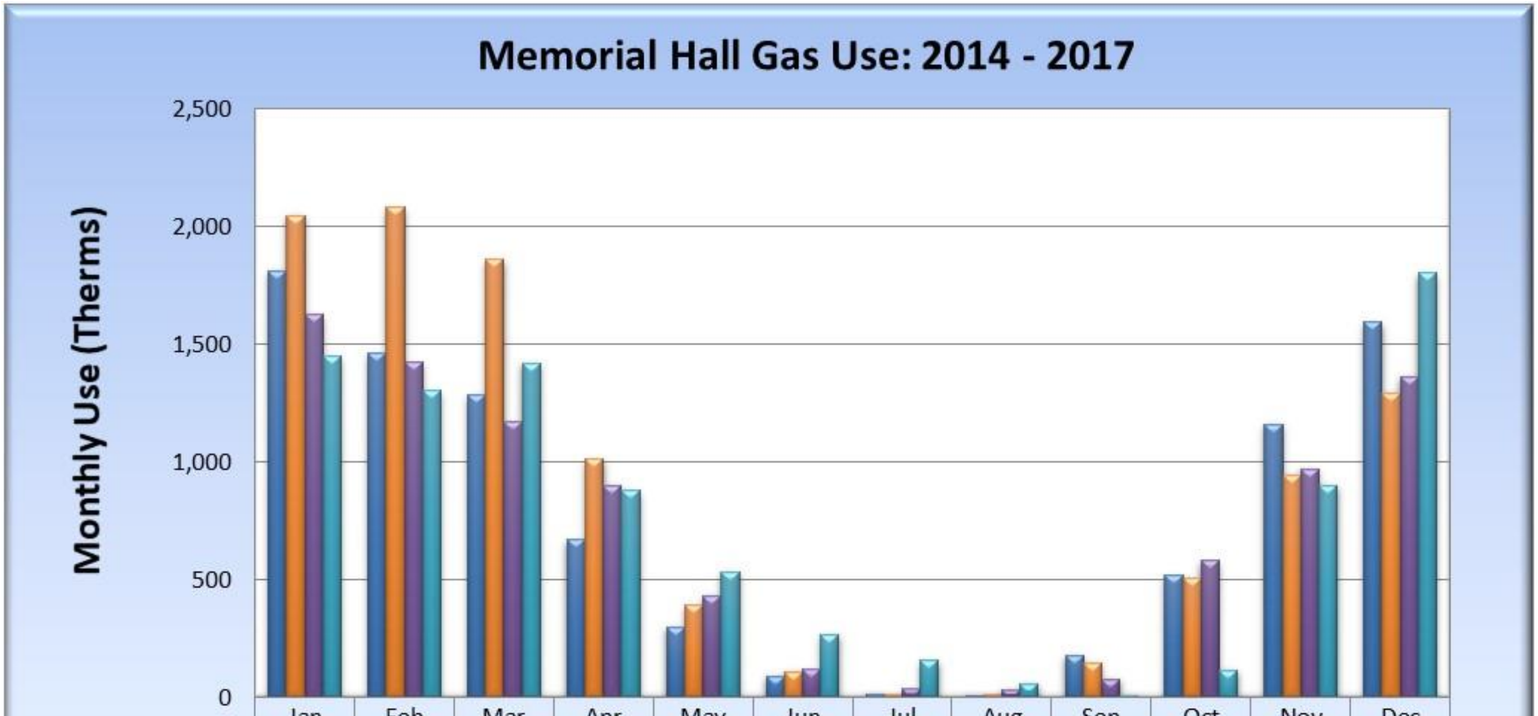


	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2014 kWh	9,304	8,502	8,889	7,232	7,656	9,129	11,139	8,907	7,545	7,759	8,457	9,341
2015 kWh	10,218	10,985	12,738	10,131	11,190	10,864	10,764	9,813	9,363	8,622	8,406	8,635
2016 kWh	9,245	9,496	8,716	8,194	11,171	9,094	9,983	9,705	7,506	8,514	9,324	9,318
2017 kWh	8,484	8,156	9,853	8,631	9,540	9,797	10,517	7,994	6,479	8,049	9,043	9,193
2016 Peak kW	39	42	40	64	68	72	94	81	57	56	55	53

Figure 12: Melrose Memorial Hall's electricity use for 2014 through 2017. Note that peak demand data was only available for 2016 at the time of this report.

GAS

The graph below shows four years of gas data. It can be seen that usage follows a seasonal pattern, with usage reaching approximately 1,300 to 2,000 therms monthly (300 – 450 therms per week) during the winter. Note that the 2015 peak in gas use is a result of the unusually cold winter season from January 2015 through March 2015. The summer load ranges from 10 to 300 therms per month and is likely a result of the use of the HW system enabling at night or in the early morning as well as DHW use. Average annual consumption is 8,836 therms.



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2014	1,814	1,462	1,285	672	300	92	16	8	181	518	1,161	1,594
2015	2,047	2,082	1,860	1,011	392	110	12	11	148	505	948	1,296
2016	1,627	1,424	1,171	901	434	119	38	36	80	582	971	1,366
2017	1,451	1,305	1,421	881	536	268	159	60	10	117	903	1,803

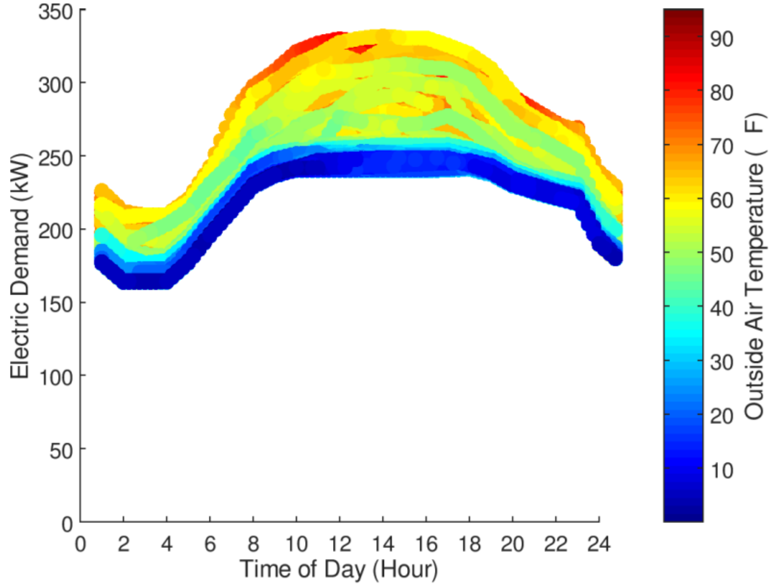
Figure 13: Melrose Memorial Hall's gas use for 2014-2017 , displaying seasonal thermal load profiles.

NORMALIZED ELECTRICAL LOAD PROFILES

The following electric load data was developed from available electric data from 6/1/2017 through 5/31/2018. For Shaw's, the interval demand (kW) data was obtained from National Grid's Energy Profiler Online (EPO). This EPO data is recorded in 15-minute intervals, and is useful for investigating and analyzing the electrical loads at the facility over time. For the Melrose municipal buildings, B2Q utilized monthly electric bills, equipment control sequences, information collected while on site, and B2Q's understanding of typical municipal building operation to interpolate monthly demand data into approximated 8,760 interval demand data. B2Q recommends that for an investment-grade analysis of the proposed microgrid, data logging should be deployed in order to better assess the yearly load profiles of the municipal buildings.

Note that all end-use loads were approximated from equipment information and available control sequences. This data was not developed from sub-metered data.

SHAW'S LOAD (NORMALIZED)



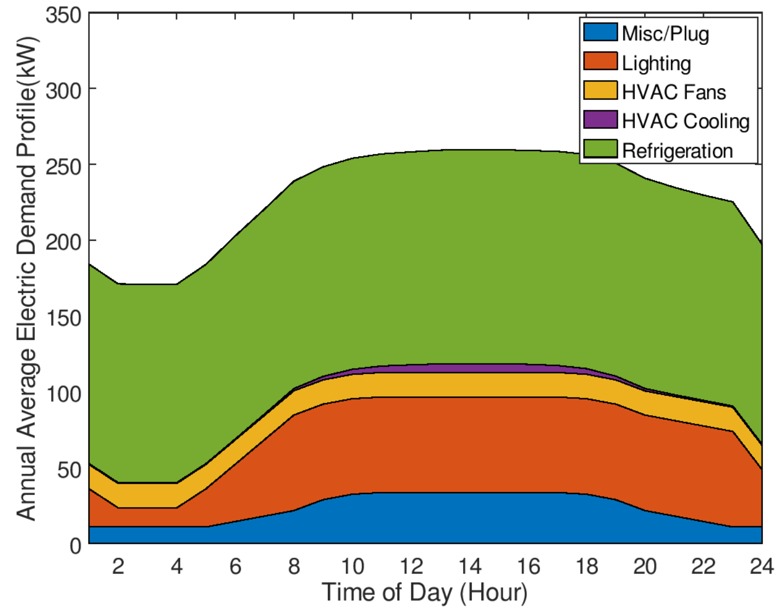


Figure 14: 8,760 (left) and annual average (right) load profiles for Shaw's.

Table 12: Normalized monthly metrics at Shaw's.

Month	Usage	Peak Demand	Average Demand
-	kWh	kW	kW
January	162,767	259.2	218.8
February	147,117	251.5	218.9
March	163,865	277.5	220.2
April	161,125	320.3	223.8
May	171,910	312.7	231.1
June	171,702	308.4	238.5
July	188,106	331.9	252.8
August	180,897	328.0	243.1
September	167,704	304.1	232.9
October	167,091	274.3	224.6
November	158,908	258.6	220.7
December	163,213	257.7	219.4
Total/Avg	**2,004,403**		**228.8**

- Peak demand of 332kW
- Baseload demand of 163kW
- Refrigeration load accounts for between 120kW to 170kW of the electric demand depending on OAT and time of day
- Significant lighting demand during operating hours due to use of T8 fluorescent tubes

CITY HALL LOAD (NORMALIZED)

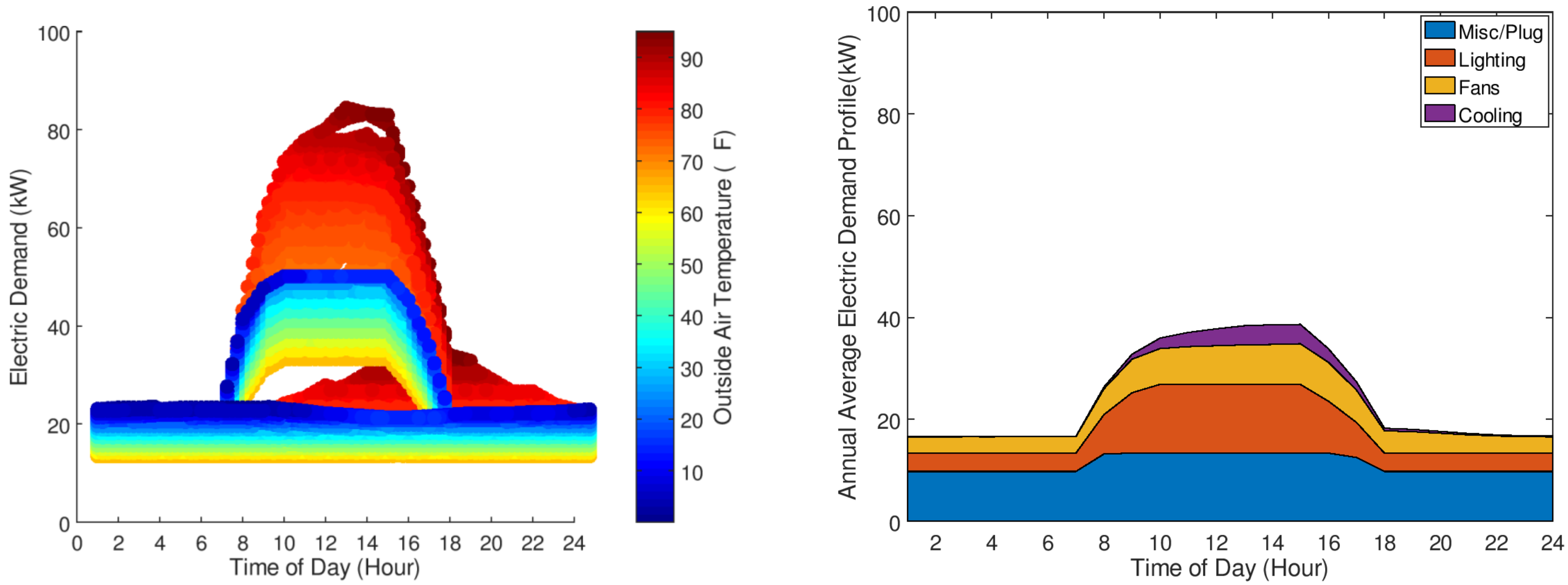


Figure 15: 8,760 (left) and annual average (right) load profiles for City Hall.

Table 13: Normalized monthly metrics at City Hall.

Month	Usage	Peak Demand	Average Demand
-	kWh	kW	kW
January	18,835	50.1	25.3
February	15,833	48.7	23.6
March	18,075	48.7	24.3
April	16,311	45.2	22.7
May	17,131	77.9	23.0
June	18,809	84.4	26.1
July	20,345	79.1	27.3
August	20,540	74.8	27.6
September	16,684	72.7	23.2
October	16,319	69.2	21.9
November	16,085	45.9	22.3
December	18,516	50.1	24.9
Total/Avg	**213,482**		**24.4**

- Peak demand of 84kW
- Baseload demand of 15kW
- Load highly dependent on outside air temperature

Memorial Hall Load (Normalized)

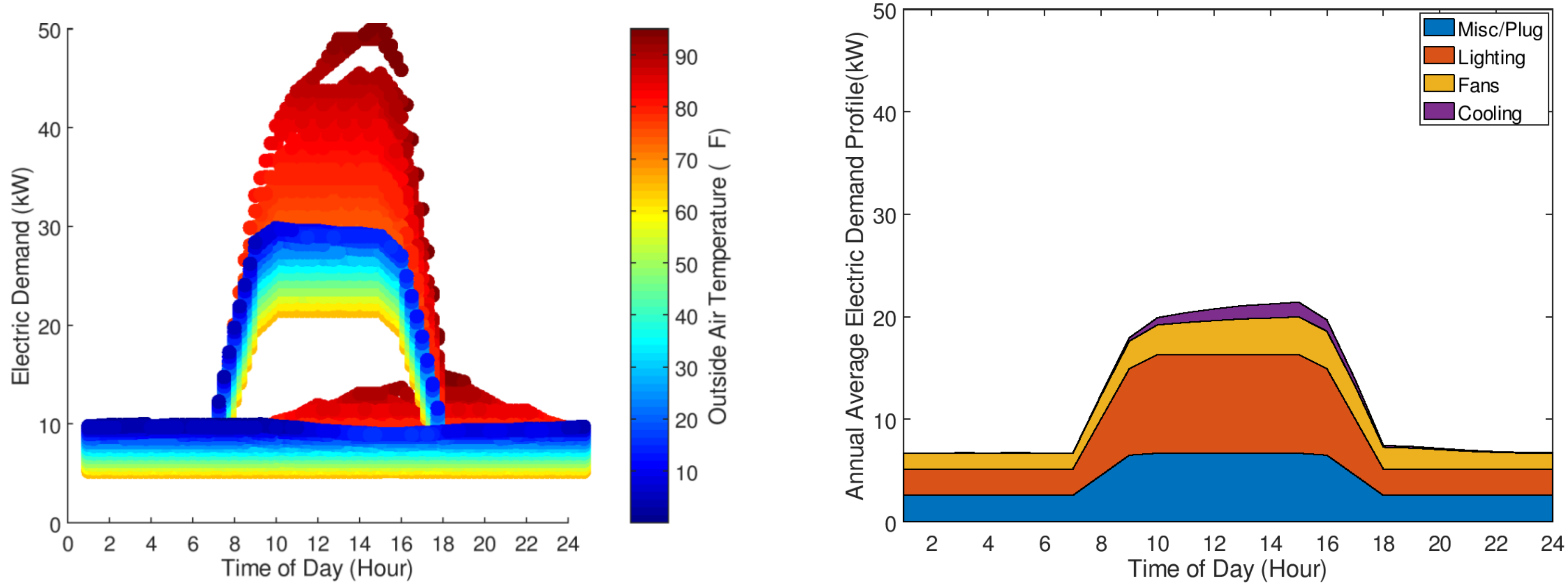


Figure 16: 8,760 (left) and annual average (right) load profiles for Memorial Hall.

Table 14: Normalized monthly metrics at Memorial Hall.

Month	Usage	Peak Demand	Average Demand
-	kWh	kW	kW
January	9,141	29.8	12.3
February	7,720	27.4	11.5
March	8,840	27.4	11.9
April	8,020	26.1	11.1
May	8,474	45.5	11.4
June	9,179	50.8	12.7
July	9,815	45.5	13.2
August	9,954	41.9	13.4
September	7,984	40.2	11.1
October	8,037	38.4	10.8
November	7,866	26.3	10.9
December	8,948	29.8	12.0
Total/Avg	**103,981**		**11.9**

- Peak demand of 51kW
- Baseload demand of 5kW
- Load highly dependent on outside air temperature

FIRE STATION LOAD (NORMALIZED)

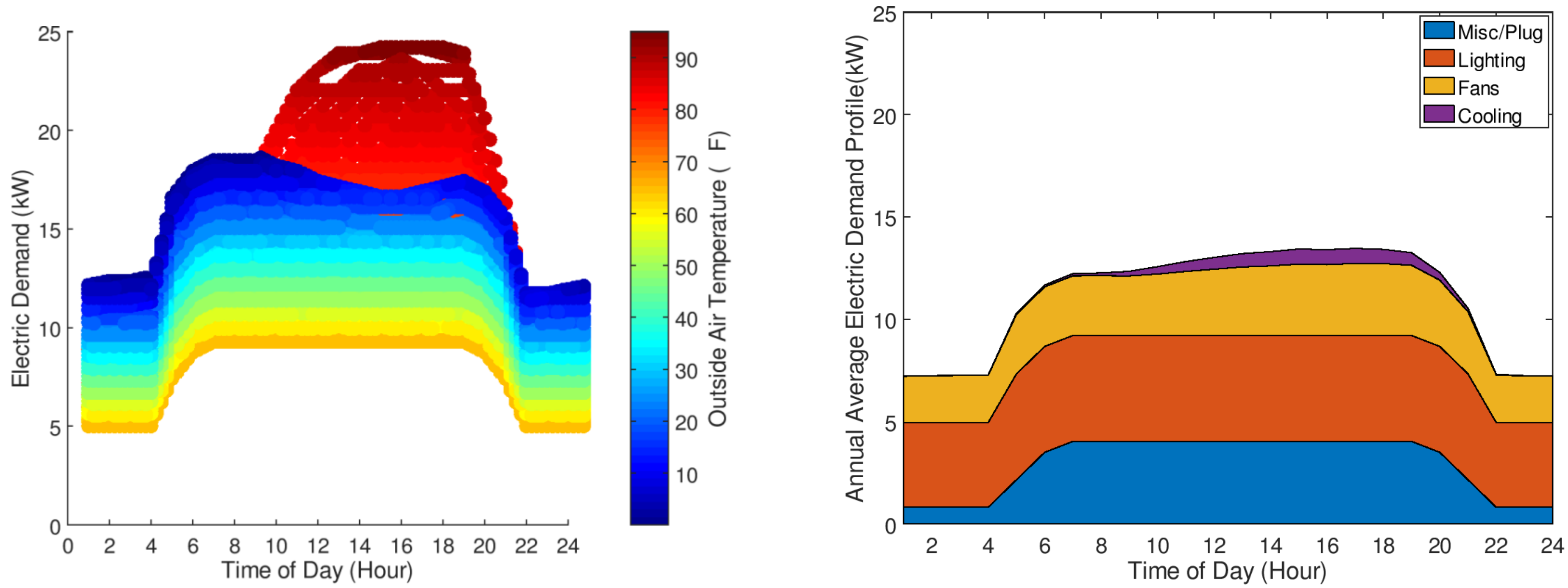


Figure 17: 8,760 (left) and annual average (right) load profiles for the Fire Station.

Table 15: Normalized monthly metrics at the Fire Station.

Month	Usage	Peak Demand	Average Demand
-	kWh	kW	kW
January	9,265	19.0	12.5
February	7,575	17.4	11.3
March	8,576	16.4	11.5
April	7,583	14.8	10.5
May	7,458	23.6	10.0
June	7,970	24.2	11.1
July	8,663	23.6	11.6
August	8,382	22.0	11.3
September	7,068	20.0	9.8
October	7,055	19.0	9.5
November	7,611	15.3	10.6
December	9,219	18.0	12.4
Total/Avg	**96,423**		**11.0**

- Peak demand of 24kW
- Baseload demand of 5kW

ENERGY CONSERVATION MEASURES

The following figures represent estimated electrical savings from the implementation of identified ECMs at each site and their combined impact on the normal operating load of the microgrid. Table 16 provides an overview of all ECMs identified. Note that all ECM energy savings are anticipated to be electrical savings, therefore no thermal savings or post-ECM load profiles are included in the subsequent analysis.

Table 16: Identified ECMs and associated savings. Note that the total does not include interactive effects of the measures; however, the interactive effects are captured in Figure 21 and Table 19.

Measure	Annual Electric Savings	Maximum Peak Savings
-	kWh	kW
LED Lighting Retrofit - Shaw's	127,458	18.0
LED Lighting Retrofit - City Hall	30,677	9.0
LED Lighting Retrofit - Memorial Hall	19,715	5.7
LED Lighting Retrofit - Fire Station	15,111	1.7
Shaw's Case Door Retrofits	151,152	17.7
Shaw's RTU-2 Replacement	135,377	23.5
TOTAL	**479,491**	

SHAW'S

LED LIGHTING RETROFIT

B2Q estimates that 950, 4', 32 W T8s light the main storefront area which accounts for approximately 28.5 kW of the building's baseload. This measure would be to replace all existing 32 W T8 lights and ballasts with LED tube and drivers to reduce the lighting demand by approximately 14.7 kW.

CASE DOOR RETROFIT

B2Q identified several refrigerated cases that are not equipped with doors to reduce infiltration and cooling demand. This measure would be to retrofit doors on all non-produce cases. Depending on the application, case door retrofits can reduce cooling load by between 40 – 60%.

RTU-2 REPLACEMENT

RTU-2 is a Seasons-4 variable volume unit that provides dehumidification via the refrigeration loop and utilizes the loop's hot gas for reheat. The unit was installed in November of 1993. While on site, B2Q identified that the VFD on RTU-2 had failed, resulting in constant volume operation. The proposed case for this measure would be to replace the 25+ year old unit with a variable volume unit that utilizes desiccant dehumidification. Desiccant dehumidification is the process of absorbing moisture from the airstream into a desiccant material. Unlike traditional dehumidification, desiccant dehumidification does not require the airstream to reach dewpoint in order to condense water, resulting in reduced mechanical cooling energy and reheat energy.

City Hall

LED Lighting Retrofit

B2Q estimates that lighting demand accounts for approximately 21.2 kW of the building's baseload. Lighting fixtures within City Hall consist primarily of fluorescent fixtures, including T8 and T12 tubes as well as CFLs. The proposed case of this measure would be to retrofit all fluorescent lights and fixtures with LED lights and drivers. B2Q estimates this could reduce the lighting demand by approximately 7.6 kW.

Fire Station

LED Lighting Retrofit

B2Q estimates that lighting demand accounts for approximately 8.1 kW of the building's baseload. The fire station's lighting is mostly fluorescent, with a mixture of T8, T12 and CFLs. Some areas utilize incandescent fixtures as well. The proposed case of this measure would be to retrofit all existing lights and fixtures with LED lights and drivers. B2Q estimates this could reduce the lighting demand by approximately 3.5 kW.

Memorial Hall

LED Lighting Retrofit

Memorial Hall contains a mixture of incandescent and fluorescent lighting. B2Q estimates that lighting demand accounts for approximately 19.9 kW of the building's baseload. The proposed case of this measure would be to retrofit all existing lights and fixtures with LED lights and drivers. B2Q estimates this could reduce the lighting demand by approximately 8.5 kW.

LIGHTING

All four buildings considered in this study utilize primarily fluorescent lighting. The proposed case of this measure would be to replace existing fluorescent tubes and bulbs with more efficient LEDs. Figure 18 shows the average hourly lighting demand profiles before and after the proposed LED lighting retrofits. Note that for the purposes of analysis these profiles only show lighting demand profiles and exclude all other electric load.

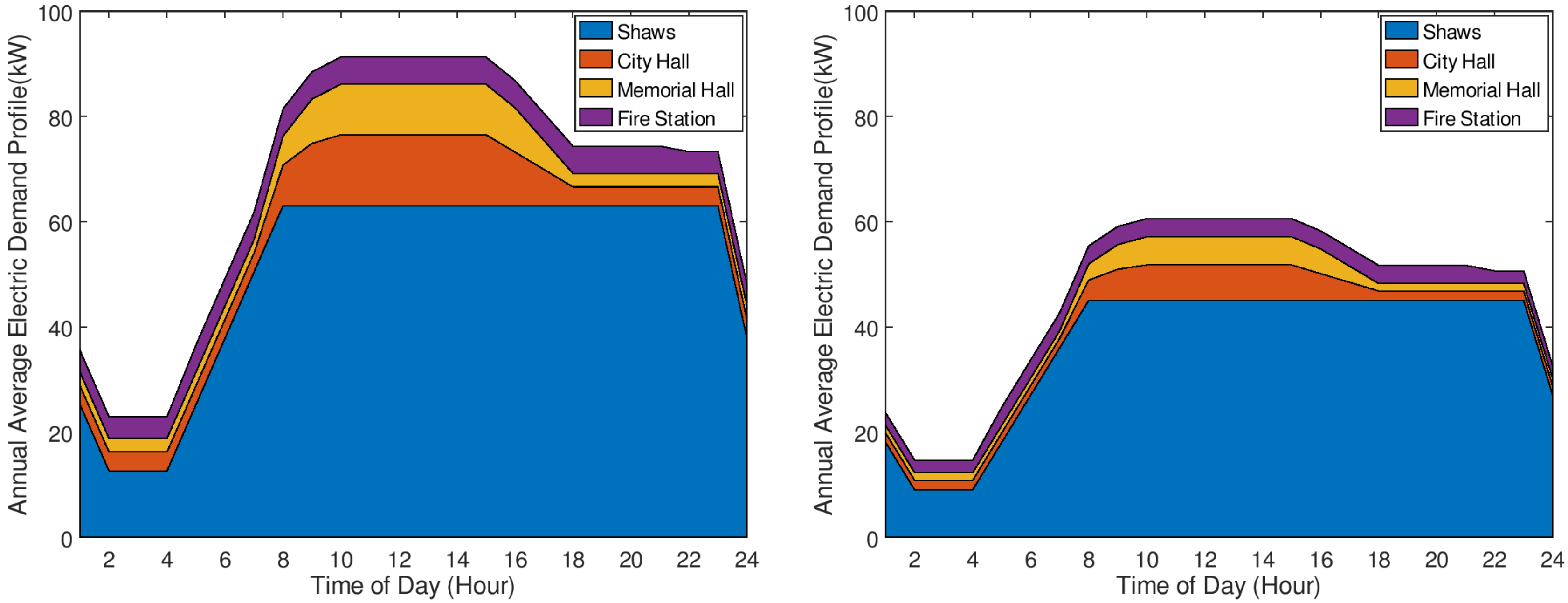


Figure 18: Base (left) and proposed (right) average hourly lighting demand profiles.

SHAW'S CASE DOOR RETROFITS

Following review of the refrigerated cases in Shaw's and discussions with Shaw's staff, B2Q identified the opportunity for 406 feet of refrigerated cases to be retrofitted with case doors. Case doors reduce the spillover of refrigerated air from the cases into the surrounding store area, reducing the refrigeration load. B2Q estimates that the existing design load of 543 MBH can be reduced to 326 MBH by the addition of case doors on all non-produce cases. Refrigerated produce cases were not considered for case door retrofits based on discussions with Shaw's staff. Figure 19 (left) shows the existing building electrical load and Figure 19 (right) shows the proposed building electrical load following the case door retrofit. As can be seen in Table 17, the refrigerated case doors result in consistent energy savings year-round, totaling approximately 150,000kWh. However, the peak demand reductions are most impactful during colder weather. During the summer months, the existing spillover refrigeration helps reduce the cooling and dehumidification load met by HVAC. By retrofitting case doors, the existing HVAC equipment must meet a greater mechanical cooling/dehumidification load. Therefore, while there is reduced load on the refrigeration system, there is a slightly increased load on the HVAC. In total, however, the refrigeration savings outweigh the increases in HVAC use.

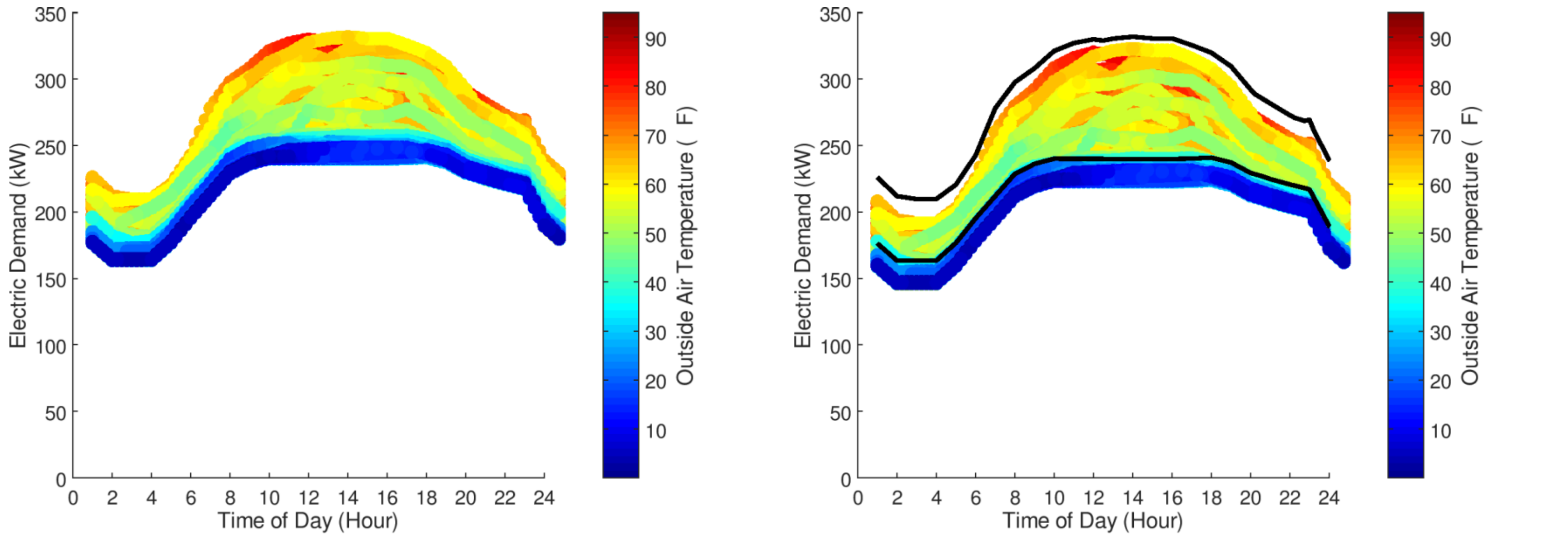


Figure 19: Shaw's base (left) and proposed (right) total building demand mapped by the outside air temperature. Note that the black lines on the proposed demand indicate the existing minimum and maximum demand profiles for comparison.

Table 17: Shaw's base and proposed demand after implementing the case door retrofit ECM.

Month	Base		Proposed		Savings	
	Use	Peak	Use	Peak	Use	Peak
-	kWh	kW	kWh	kW	kWh	kW
January	162,767	259.2	149,953	242.1	12,814	17.0
February	147,117	251.5	135,549	234.4	11,568	17.1
March	163,865	277.5	151,050	259.7	12,815	17.7
April	161,125	320.3	148,816	313.3	12,309	7.0
May	171,910	312.7	159,037	302.7	12,873	10.0
June	171,702	308.4	159,158	296.9	12,544	11.6
July	188,106	331.9	175,384	322.9	12,722	9.0
August	180,897	328.0	167,923	318.1	12,973	10.0
September	167,704	304.1	155,188	289.9	12,516	14.2
October	167,091	274.3	154,250	256.7	12,841	17.6
November	158,908	258.6	146,531	241.2	12,377	17.4
December	163,213	257.7	150,411	240.7	12,801	17.0
Total	**2,004,403**		**1,853,251**		**151,152**	

SHAW'S RTU-2 REPLACEMENT

RTU-2 is a Seasons-4 variable volume unit that provides dehumidification, cooling, and heating to the main store area. The unit uses a dedicated low temperature circuit from the refrigeration system to provide mechanical cooling and dehumidification. The refrigeration hot gas is also used for preheat and dehumidification reheat. The unit was installed in November of 1993 and serves as the primary heating, cooling, and dehumidification unit for the store area. While on site, B2Q observed that the VFD on RTU-2 appeared to have failed and was in bypass, resulting in constant volume operation. The proposed case for this measure would be to replace the 25+ year old unit with a variable volume unit that utilizes desiccant dehumidification. Desiccant dehumidification is the process of absorbing moisture from the airstream into a desiccant material. Unlike traditional dehumidification, desiccant dehumidification does not require the airstream to reach dewpoint in order to condense water out of the airstream, resulting in reduced mechanical cooling energy and saved reheat energy.

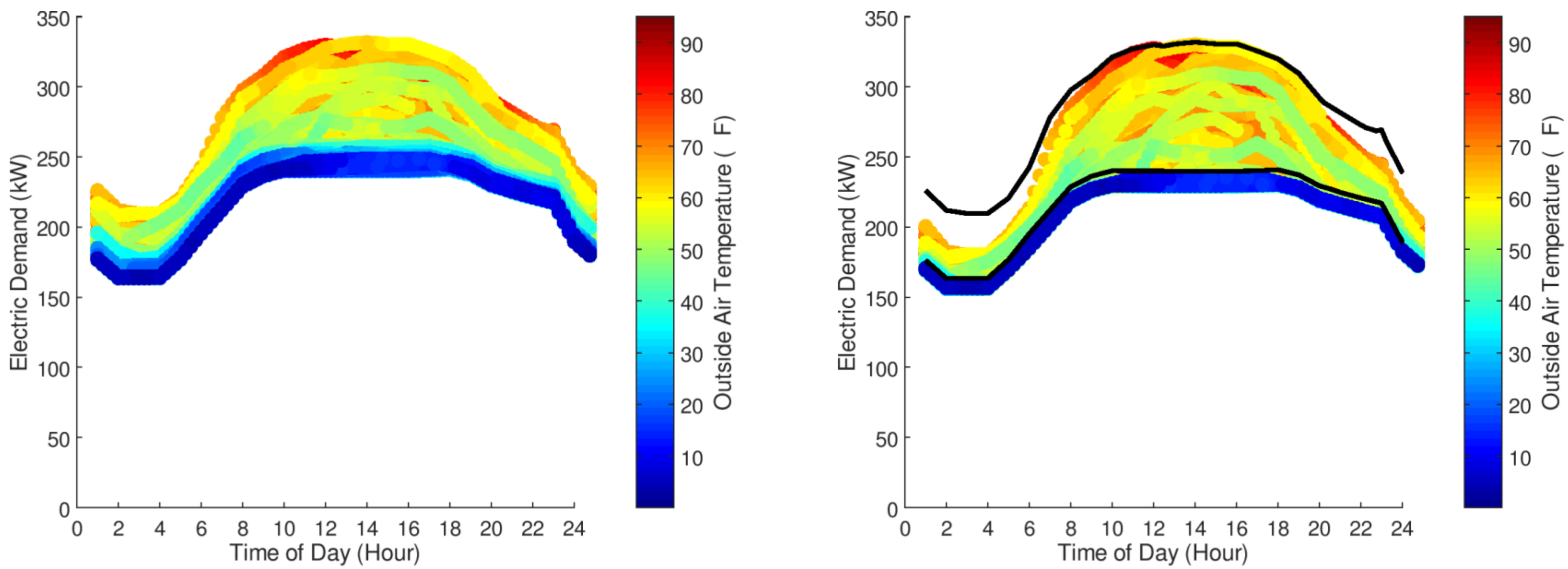


Figure 20: Base (left) and proposed (right) total building demand mapped by the outside air temperature at Shaw's. Note that the black lines on the proposed demand indicate the existing minimum and maximum demand profiles for comparison.

Table 18: Shaw's base and proposed demand after implementing the RTU-2 replacement ECM.

Month	Base		Proposed		Savings	
	Use	Peak	Use	Peak	Use	Peak
-	kWh	kW	kWh	kW	kWh	kW
January	162,767	259.2	154,856	235.6	7,910	23.5
February	147,117	251.5	139,710	235.4	7,407	16.1
March	163,865	277.5	154,735	259.8	9,130	17.7
April	161,125	320.3	150,943	319.3	10,182	1.0
May	171,910	312.7	158,603	309.6	13,307	3.1
June	171,702	308.4	157,517	304.1	14,185	4.4
July	188,106	331.9	174,420	330.2	13,685	1.7
August	180,897	328.0	166,100	330.2	14,796	-2.2
September	167,704	304.1	153,177	297.6	14,527	6.5
October	167,091	274.3	154,961	255.1	12,131	19.2
November	158,908	258.6	149,418	237.4	9,489	21.2
December	163,213	257.7	154,585	235.3	8,627	22.4
Total	**2,004,403**		**1,869,027**		**135,377**	

COMBINED SAVINGS

The implementation of all above ECMs results in the demand profile shown in Figure 21 and associated use and demand savings shown in Table 19. Combined, the measures result in a maximum peak demand reduction of 64.5kW (14%) and savings of approximately 460,000kWh (19%).

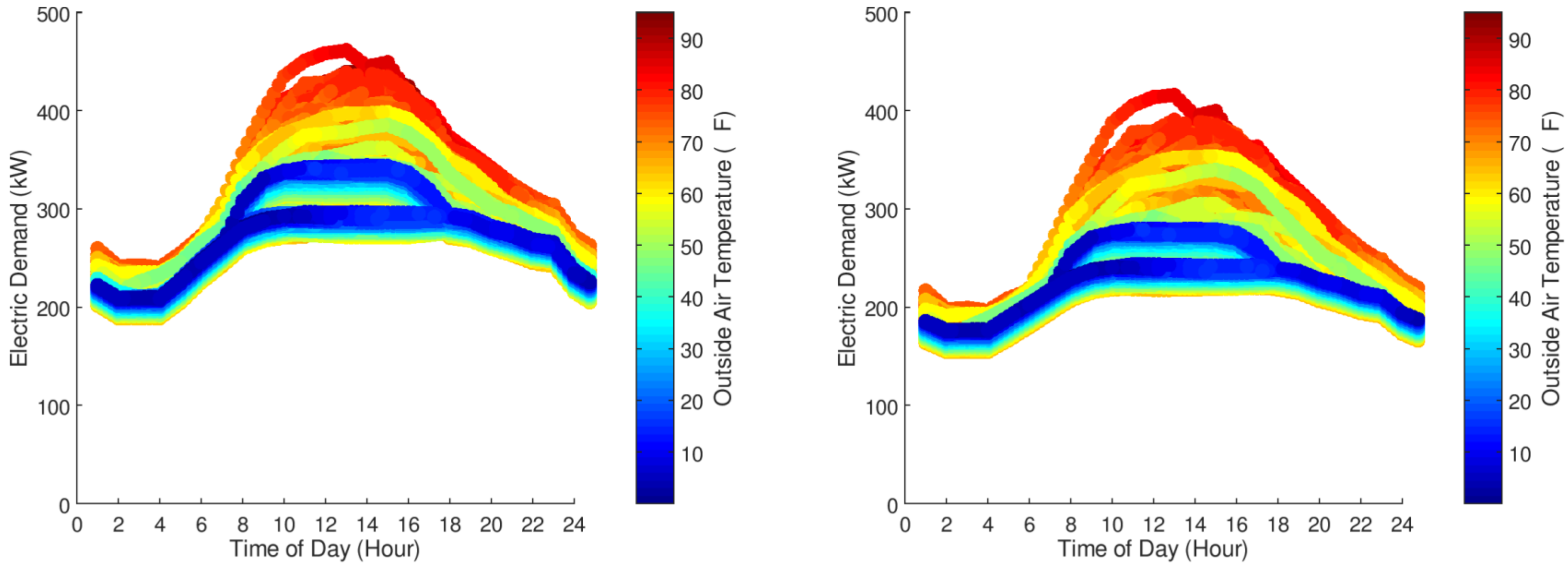


Figure 21: Base (left) and proposed (right) total microgrid demand mapped by the outside air temperature.

Table 19: Combined microgrid's base and proposed energy use and demand.

Month	Base		Proposed		Savings	
	Use	Peak	Use	Peak	Use	Peak
-	kWh	kW	kWh	kW	kWh	kW
January	200,008	342.6	162,836	279.0	37,172	63.6
February	178,245	335.9	144,382	272.2	33,863	63.7
March	199,356	352.8	160,964	291.7	38,391	61.1
April	193,039	385.4	154,801	339.6	38,239	45.7
May	204,973	428.9	164,243	375.7	40,730	53.1
June	207,659	439.4	168,229	379.4	39,431	59.9
July	226,929	461.4	188,912	415.9	38,017	45.5
August	219,773	435.6	179,601	387.7	40,172	47.9
September	199,440	422.8	159,153	373.7	40,287	49.1
October	198,503	381.5	157,680	317.5	40,822	63.9
November	190,470	340.9	152,721	276.8	37,749	64.1
December	199,895	344.2	161,911	279.6	37,984	64.5
Total	**2,418,290**		**1,955,433**		**462,857**	

NORMAL OPERATION WITH ECMs

The following figures illustrate the individual loads at each site during normal microgrid operation.

SHAW'S LOAD (NORMAL OPERATION WITH ECMS)

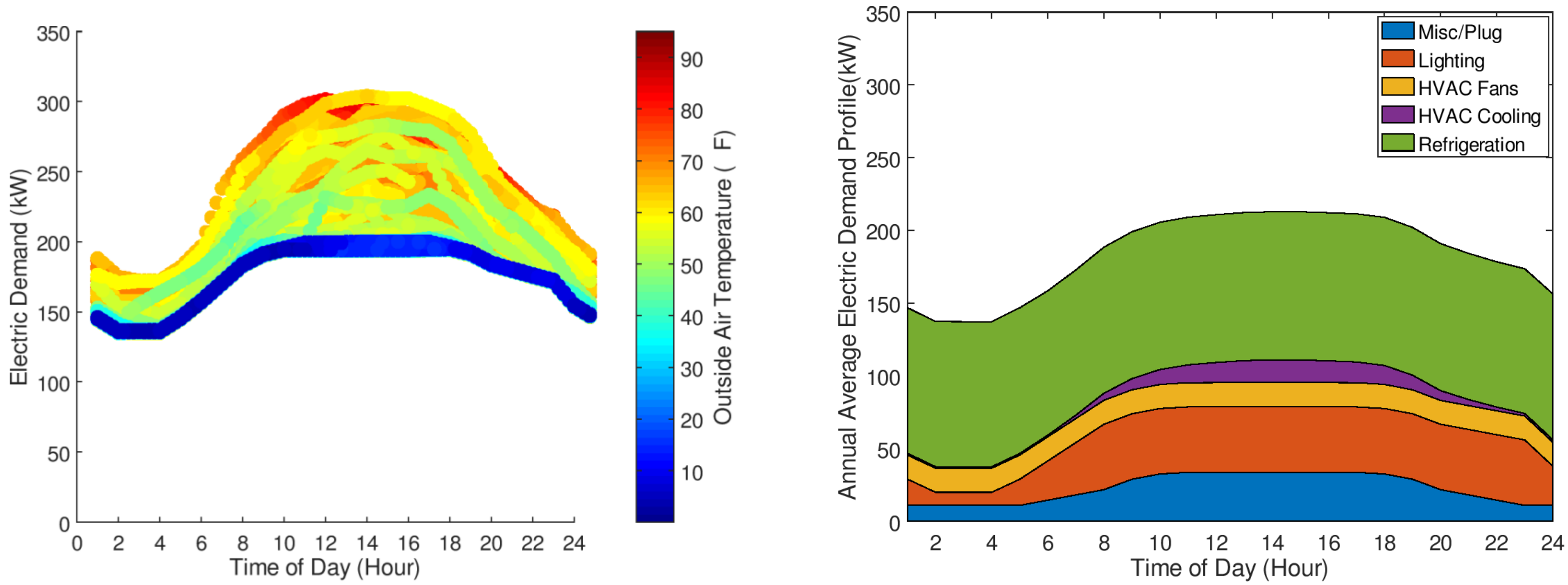


Figure 22: Shaw's proposed 8,760 (left) and annual average (right) load profiles during normal operation.

Table 20: Proposed monthly metrics at Shaw's during normal operation.

Month	Usage	Peak Demand	Average Demand
-	kWh	kW	kW
January	131,127	205.0	176.2
February	118,254	200.0	176.0
March	131,104	233.6	176.2
April	128,306	293.1	178.2
May	136,811	283.4	183.9
June	137,691	277.9	191.2
July	155,621	304.0	209.2
August	146,453	304.0	196.8
September	132,640	271.4	184.2
October	131,899	228.9	177.3
November	126,481	211.2	175.7
December	130,702	202.4	175.9
Total/Avg	**1,607,089**		**183.5**

- Peak demand of 304kW
- Baseload demand of 135kW
- Refrigeration load accounts for approximately 100kW of the load and does not vary drastically with outside air temperature

CITY HALL LOAD (NORMAL OPERATION WITH ECMS)

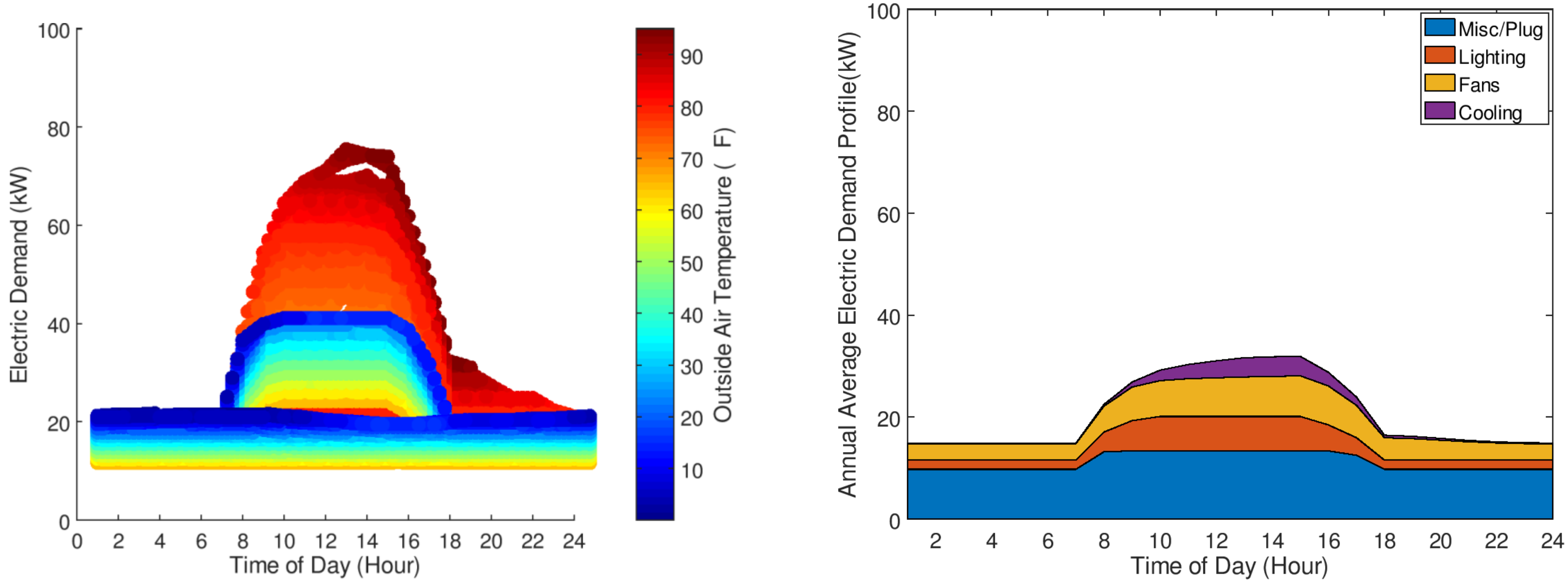


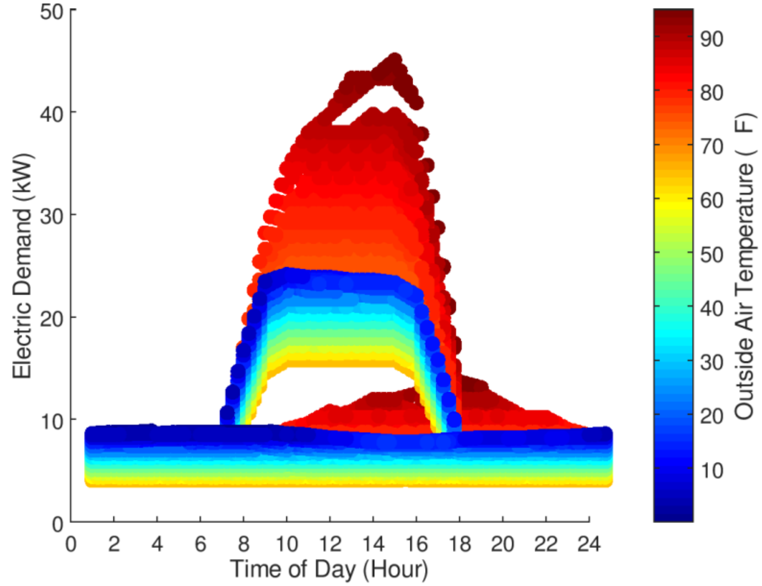
Figure 23: City Hall proposed 8,760 (left) and annual average (right) load profiles during normal operation.

Table 21: Proposed monthly metrics at City Hall during normal operation.

Month	Usage	Peak Demand	Average Demand
-	kWh	kW	kW
January	16,249	41.1	21.8
February	13,495	39.7	20.1
March	15,429	39.7	20.7
April	13,767	36.2	19.1
May	14,485	68.9	19.5
June	16,265	75.4	22.6
July	17,758	70.1	23.9
August	17,835	65.8	24.0
September	14,260	63.7	19.8
October	13,673	60.2	18.4
November	13,601	37.8	18.9
December	15,968	41.1	21.5
Total/Avg	**182,784**		**20.9**

- Peak demand of 75kW
- Baseload demand of approximately 12kW
- Load is highly temperature dependent due to chiller operation
- Computers, plug loads, servers, and miscellaneous loads make up a significant portion of the baseload

MEMORIAL HALL LOAD (NORMAL OPERATION WITH ECMS)



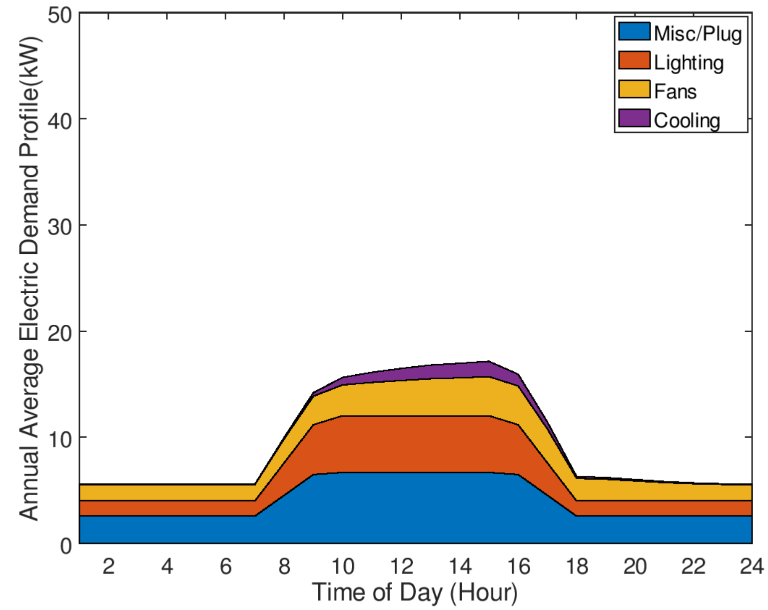


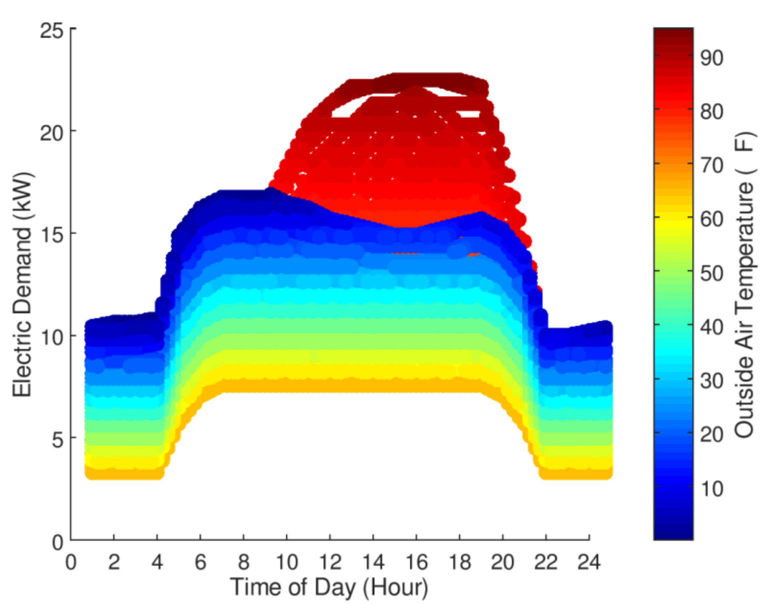
Figure 24: Memorial Hall proposed 8,760 (left) and annual average (right) load profiles during normal operation.

Table 22: Proposed monthly metrics at Memorial Hall during normal operation.

Month	Usage	Peak Demand	Average Demand
-	kWh	kW	kW
January	7,479	24.1	10.1
February	6,218	21.7	9.3
March	7,140	21.7	9.6
April	6,386	20.4	8.9
May	6,773	39.8	9.1
June	7,545	45.1	10.5
July	8,153	39.8	11.0
August	8,215	36.2	11.0
September	6,427	34.5	8.9
October	6,336	32.7	8.5
November	6,270	20.6	8.7
December	7,316	24.1	9.8
Total/Avg	**84,258**		**9.6**

- Peak demand of 45kW
- Baseload demand of approximately 4kW
- Load highly dependent on outside air temperature

Fire Station Load (Normal Operation with ECMs)



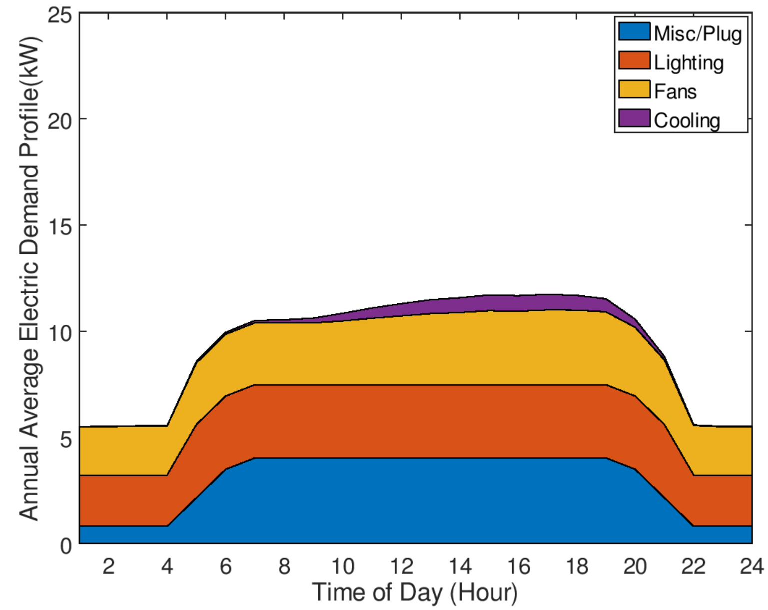


Figure 25: Fire Station proposed 8,760 (left) and annual average (right) load profiles during normal operation.

Table 23: Proposed metrics at the Fire Station during normal operation.

Month	Usage	Peak Demand	Average Demand
-	kWh	kW	kW
January	7,981	17.3	10.7
February	6,415	15.7	9.5
March	7,292	14.7	9.8
April	6,341	13.1	8.8
May	6,174	21.9	8.3
June	6,728	22.5	9.3
July	7,380	21.9	9.9
August	7,098	20.3	9.5
September	5,826	18.3	8.1
October	5,772	17.3	7.8
November	6,369	13.6	8.8
December	7,926	16.2	10.7
Total/Avg	**81,302**		**9.3**

- Peak demand of 23kW
- Baseload demand of approximately 4kW

Islanded Operation

Critical Loads and Redundancy

While all facilities served by this microgrid are considered critical during an islanded event, the most critical loads to be met are the City Hall's data center and the entire load of the fire station. The continuous operation of these assets is vital for the dispatch of emergency services in the City of Melrose. During an islanded event, priority would be given to both of these assets. However, in the event of a microgrid failure, both assets are equipped with existing backup power systems to enable continuous operation. City Hall's data center is equipped with a UPS system that can maintain data center operation for approximately two hours and the Fire Station is equipped with a 33kW diesel generator which can operate for approximately 12 hours before refueling is required. Furthermore, the microgrid concept includes a redundant ATS provision to allow the CHP to be dedicated for continuous service to the IT server loads. The SSC would prioritize operation to first support level 1 critical loads, followed by level 2 and level 3.

- Level 1 Critical loads: Fire Station and the IT servers in City Hall
- Level 2 Critical loads: Memorial Hall Shelter and City Hall
- Level 3 Critical loads: Shaw's Refrigeration, HVAC, and lighting Systems

Load Shedding

Load shedding strategies can be utilized during an islanding event to reduce the load served by the microgrid and extend the duration of islanded operation. The following section identifies building-level load shedding strategies that could be implemented during islanded operation.

Shaw's

Emergency Lighting

As part of the lighting upgrade energy efficiency measure, controls can be added to enable an emergency lighting mode. In the event of an islanding event, the proposed LED light fixtures could be dimmed to 50% output. This strategy could reduce the building's base demand by 7-10 kW in addition to the 14.7 kW reduction from the LED upgrade.

City Hall

Emergency Lighting

As part of the lighting and controls energy efficiency measure, an emergency lighting mode can be utilized to dim lights to 50% output. Another control strategy is to turn every other light fixture off in emergency lighting mode. Either strategy could reduce the building's base demand by approximately 6.8-10.2 kW in addition to the 13.6 kW reduction from the LED upgrade.

Cooling Setbacks

City Hall features a dual temperature loop that provides HW and CHW to (69) fan coil units that condition recirculated air. The CHW loop is served by a 70 ton Daikin chiller with an 80 ton Daikin condenser located on the roof. During an islanding event, zone temperature cooling setpoints could be setback, allowing the zones to be maintained at higher temperatures thus reducing the load on the chiller, condenser, and fan coil units. Alternatively, during an islanding event, the primary mechanical cooling equipment could be shut down to reduce the building's peak demand by a maximum of approximately 92 kW.

Fire Station

Cooling Setbacks

Ventilation air for the 2nd and 3rd floors is provided by (2) Carrier AHUs. The AHUs are each equipped with a set of DX coils that have dedicated condensing units located on the first floor call center roof. During an islanding event, zone temperature cooling setpoints could be setback, allowing the zones to be maintained at higher temperatures thus reducing the load on the condensing units. During moderate cooling events, the mechanical equipment could be shut down to reduce the building's peak demand by a maximum of approximately 22 kW.

Memorial Hall

Emergency Lighting

As part of the lighting and controls energy efficiency measure, an emergency lighting mode can be utilized to dim lights to 50% output. Another control strategy is to turn every other light fixture off. Either strategy could reduce the building's base demand by approximately 5.7-8.5 kW in addition to the 8.5 kW reduction from the LED upgrade.

Cooling Setbacks

Memorial Hall's cooling load is met by a 70 ton air-cooled chiller located on the ground outside the building and a 3 ton condensing unit located on the roof. The air-cooled chiller provides CHW to the building and flow is circulated by a set of (2) 3 hp CHW pumps. During an islanding event, zone temperature cooling setpoints could be setback, allowing the zones to be maintained at higher temperatures thus reducing the load on the chiller and condenser. During moderate cooling events, the mechanical equipment could be shut down to reduce the building's peak demand by a maximum of approximately 79 kW.

COMBINED SAVINGS

As can be seen in Figure 26 (left), the electric demand of the combined microgrid peaks during the highest outside air temperatures. This is the result of increased mechanical comfort cooling in Shaw's and the municipal buildings. By implementing temperature setbacks during an islanding event, the mechanical cooling load can be significantly reduced or entirely removed. This load shedding strategy is represented in Figure 26 from the reduced peak demand during higher outside air temperatures (red). Additionally, with LED lighting and associated controls, lighting can be dimmed to approximately 50% design output, resulting in a reduction of the building's demand during all operating hours. This is represented in Figure 26 as the downward shift of the entire demand profile. Note that Figure 26 (right) reflects the anticipated load and savings associated with the microgrid operating in an islanded state 8,760. While this is not the intent of the microgrid strategy to continuously operate with deep load shedding, the data is presented to illustrate the effect of the implementation of load shedding given an islanded event at any hour of the year.

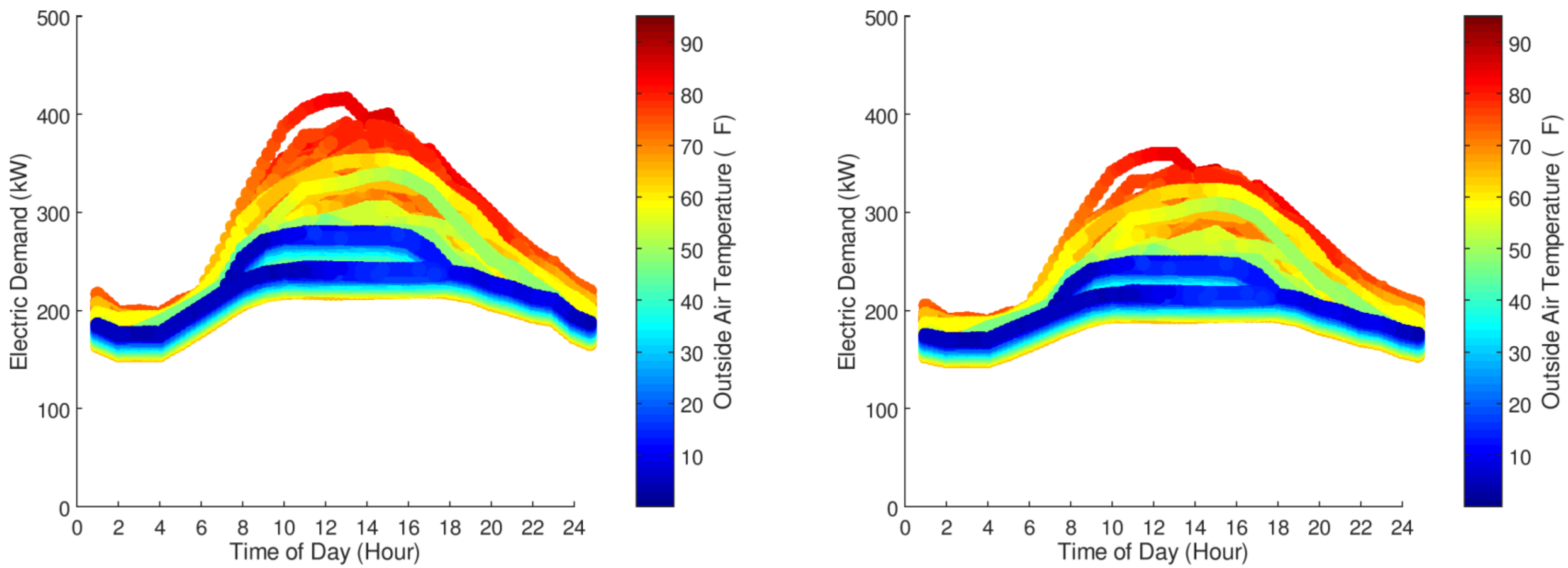


Figure 26: Normal (left) and load shed (right) combined microgrid operating load mapped by the outside air temperature.

CRITICAL FACILITIES

All sites included in the proposed microgrid serve as a critical facility either in normal operation or during extreme events and power outages. City Hall, Memorial Hall, and the Fire Station are all municipal buildings that service the near 28,000 residents of the City of Melrose. Shaw's, based on square footage, has been estimated to serve approximately 15,000 people. Each facility provides a service to the population it serves, and its ability to maintain those services during a loss of power varies. The percentage of its normal service that is capable of being provided during the loss of power without the proposed microgrid has been estimated in Table 24.

Table 24: Services provided by each facility in the proposed microgrid and current ability to maintain service during loss of power.

Building	Service	Population Served	Percent of Service Maintained During Power Outage
City Hall	Emergency Dispatch	28,000	60%
	City Services	28,000	10%
Memorial Hall	Community Gatherings	1,000	10%
	Emergency Shelter	1,000	0%
	Supplies	3,000	60%
Fire Station	Fire & Rescue, EMS	28,000	95%
Shaw's Supermarket	Groceries and supplies	15,000	5%

SHAW'S – TIER 2

Shaw's Supermarket provides groceries and supplies to an estimated 15,000 residents. Shaw's is the only supermarket in the local area and one of only two in the City of Melrose. It is also the preferred supermarket for seniors who reside nearby in senior housing apartment buildings and live on fixed incomes with limited travel resources.

The facility is equipped with a 20kW backup generator that is used for emergency lighting. During a loss of power, the building would be unable to maintain refrigerated and frozen produce at safe temperatures. Additionally, registers would not be operational and the sale of any product would present a challenge. The project team estimates that the store would be able to provide 5% of its services during a power outage. The emergency lighting would allow customers to safely exit the store and would also allow staff to relocate frozen and refrigerated produce, as needed. Additionally, in an extreme emergency event, the emergency lighting could allow the store to open to the public; although transactions would need to be manually calculated and would need to be paid for by either cash or check.

CITY HALL – TIER 1

The primary function of City Hall is to provide public access to several city services, including the City Clerk's office, the Assessor's office, paying bills, and several other boards and services. During an emergency event the City Hall becomes a 24/7 operations center. The Emergency Management Operations Center at City Hall is the home base for the Mystic Region Emergency

Planning Council. They house all of the Tier 2 Hazardous waste information for the 19 member communities.

Due to a lack of existing backup power, City Hall would not be open to the public during a loss of power. The project team estimates that approximately 10% of the existing services could be maintained in the event of a power outage. While many services can be done remotely, such as calling animal control and paying bills, many of the services cannot be achieved without an operating building.

City Hall also plays a crucial role in emergency dispatch via the local IT server. Without power, City Hall's servers can remain operational for approximately 2 hours through a local UPS. During an extended outage, the server would go down. In this event, phone and internet communications are lost between public safety officials, including all police and fire locations and six of the eight schools. Without power, calls to police, fire, ambulance, and schools are unable to be made. All communication within City Hall and the school systems are not functional, including the school's security systems. Lastly, the Police Department would be unable to retrieve criminal information and track public safety data through their existing software. Historically, the City of Melrose has resorted to communicating via cell phones or walkie-talkies to dispatch emergency services as needed.

Fire Station – Tier 1

The fire station on Main Street operates 24/7 based on the critical nature of the services it provides: it is the central fire station and the primary ambulance service for the area, a service provided by the City and not an outside agency. Additionally, Melrose shares Mobile Data Terminals on fire apparatus functions with Chelsea, Wakefield, Saugus, Malden and Lynn through mutual aid agreements.

Although equipped with a backup generator, the generator is only tied in to a subset of the facility's electrical circuits. Additionally, the diesel generator requires staff to monitor the fuel levels to ensure continuous power generation. In the event that City Hall has also lost power, the Fire Station's emergency response time would suffer due to inefficient emergency dispatch. During a power outage, the fire department staff would maintain operation of the site's backup diesel generator, providing power to the facility's critical loads. The project team estimates that the fire station could achieve 95% of its normal services during a loss of power.

Memorial Hall – Tier 1

Memorial Hall serves as a community meeting facility during normal operation. The facility includes an auditorium that has a capacity of 800 occupants. The building also contains a hall that is equipped with a kitchen and can seat up to 100 occupants. Use of the building has increased by 300% since FY2009 (City of Melrose 2017). Without power, the project team estimates that the facility can achieve 10% of its normal operation. The facility would be unable to provide heating, cooling, or lighting during a loss of power. In addition, the facility's kitchen would not be usable. Given sufficient weather and sunlight, the facility would be capable of hosting gatherings during the daytime, if needed.

During an emergency event, Memorial Hall serves as an emergency shelter, with an estimated capacity of 1,000 occupants. The facility is also used to store food and emergency supplies. Memorial Hall currently does not have any backup power options in the event of an outage. During a grid outage, the project team estimates that the facility would be unable to act as an emergency shelter, but would remain capable of providing an estimated 60% of its normal ability to store food and emergency supplies. Without power, the building would be unable to provide comfortable temperatures, and kitchen equipment and refrigerated storage would not be operational. During an outage event, Memorial Hall could still be a suitable place to store non-perishable items and certain emergency supplies.

Required and Preferable Microgrid Characteristics

Overview

Through analysis and discussion of each facility's normal and intended emergency operation goals, the project team has identified required and preferable characteristics of the microgrid. Required characteristics identified are:

- Each facility in the microgrid serves as a critical facility in either normal operation or during extreme events.
- The microgrid anticipates a combination of renewable and traditional generation capacity including solar, battery storage, cogeneration, and existing diesel and gas generators.
- Previously planned and newly studied energy conservation measures will be implemented to reduce new microgrid generation requirements. Furthermore, load shedding strategies during islanded mode will be utilized to ensure critical loads are met first.
- The proposed microgrid and its assets will be resilient to typical electrical power outages that pose the highest risk to downtown Melrose and each facilities operation.
- The anticipated microgrid controls and assets would enable black start capability, load shedding strategies, and demand response strategies.

Preferred characteristics identified are:

- The proposed microgrid could utilize Massachusetts based companies for energy storage and cogeneration equipment.
- The proposed microgrid leverages significant third-party investment.

These characteristics are discussed in the sections which follow.

Required Characteristics

Facilities

All sites serve as a critical facility either in normal operation or during extreme events and power outages. See above in the Critical Facilities section for a more detailed description of critical operations at each site.

Microgrid Capabilities and Resiliency

It is required that the DERs selected are resilient to the typical power outages that pose the highest risk of disrupting the critical operations of the facilities. Melrose's electrical infrastructure has historically been prone to extended electrical outages from winter storms.

Warm summer days typical strain the grid due to high peak demands. As discussed further in Microgrid Control, it is required that the proposed microgrid be capable of providing demand response. This will allow the microgrid to reduce its load on the grid through a variety of control strategies such as load shedding, pre-cooling zones, zone temperature setbacks, and bringing on additional microgrid assets. See below for a discussion of each potential asset's resiliency to the typical power outages that pose the highest risk to the facilities.

Cogeneration

Cogeneration units typically require a constant supply of medium pressure natural gas. The natural gas infrastructure of Melrose has proven resilient to major events that have historically caused power outages leading to the disruption of critical operations of the proposed Melrose microgrid facilities.

Solar and Battery Storage

Solar, when sized properly and combined with battery storage, acts a resilient generation asset for the microgrid. Although PV generation fluctuates according to the time of year and time of day, in the event of a power outage a PV and battery storage system can operate to bring on additional generation resources as needed to meet the microgrid's load.

As part of the study, Zapotec Energy conducted on-site analysis of each building's rooftop to determine their solar capacity. The maximum capacity and energy production from each site are shown below in Table 25. Note that the rooftops of City Hall, Memorial Hall, and Shaw's Supermarket would require an exploratory structural analysis study to confirm that the roof can handle the extra weight of the PV system. Similarly, the City Hall Plaza Parking lot would require boring soil samples to better understand what foundation types would be needed to construct the solar canopy. The results of the soil samples can heavily influence construction costs. The Fire Station's rooftop was not considered to host a solar array because of shading obstructions and roof orientation and design.

Table 25: Maximum solar capacity and annual production by site.

Site	Aprroximate System Capacity (Max)	Estimated Annual Energy Production
-	kW	kWh
City Hall	21	24,000
Memorial Hall	73	92,000
City Hall Plaza Parking Lot	560	619,000
Shaw's Rooftop	186	236,000

New Energy Efficiency Improvements

As part of the proposed microgrid, it is required that energy efficiency upgrades be leveraged to minimize new microgrid asset generation requirements. The preliminary energy efficiency measures for each building, discussed earlier in the report, are summarized in Table 26. Note that all energy demand calculations are approximations based on information available at the time of this report.

Table 26: Energy efficiency improvements and their estimated maximum demand savings.

Measure	Annual Electric Savings	Maximum Peak Savings
-	kWh	kW
LED Lighting Retrofit - Shaw's	127,458	18.0
LED Lighting Retrofit - City Hall	30,677	9.0
LED Lighting Retrofit - Memorial Hall	19,715	5.7
LED Lighting Retrofit - Fire Station	15,111	1.7
Shaw's Case Door Retrofits	151,152	17.7
Shaw's RTU-2 Replacement	135,377	23.5
TOTAL	**479,491**	

LOAD SHEDDING STRATEGIES

During an outage event when the proposed microgrid is islanded, non-critical loads can be shed to further reduce the microgrid generation requirements. Potential strategies, discussed earlier in the report, are summarized in Table 27. Note that all energy demand calculations are approximations based on information available at the time of this report.

Table 27: Load shedding strategies and their estimated maximum demand savings.

Building	Strategy	Maximum Demand Reduction (kW)
Shaw's	Emergency Lighting	10
City Hall	Emergency Lighting	10.2
	Cooling Setbacks	91.7
Fire Department	Cooling Setbacks	22.0
Memorial Hall	Emergency Lighting	8.5
	Cooling Setbacks	78.8

MICROGRID CONTROL

It is required that the proposed microgrid utilize a SSC to provide system control and monitoring. In the event that a single microgrid interconnection cannot be formed, as discussed in Task 3: Technical Feasibility, two separate SSC's would be required. The SSC would communicate with all potential microgrid assets, such as the battery energy storage systems (BESS), cogeneration units, standby generators, and solar PV inverter systems. During an islanding event, the SSC, powered by the BESS, would bring on additional assets to maintain islanded operation of the microgrid. The SSC would also communicate with each site's BAS, allowing for the implementation of load shedding strategies and demand response.

PREFERRED MICROGRID CHARACTERISTICS

MICROGRID ASSET SOURCING AND FUNDING

It is preferable that the proposed microgrid leverages significant third-party investment to reduce capital costs. Developing a power purchase agreement (PPA) or a MaaS through a third-party would be preferred.

Massachusetts based companies for energy storage and cogeneration equipment would also be preferred.

TASK 3: TECHNICAL FEASIBILITY

This section explores and presents:

- Microgrid interconnection strategies
- Proposed DER sizing and selection
- Evaluation of existing and proposed electrical, thermal, control, and IT infrastructure and their role in the proposed microgrid
- Various microgrid services and control strategies

According to the required and preferred microgrid characteristics identified in Task 2, the project team identified a preliminary design concept for the proposed microgrid. As discussed in the Microgrid Interconnection section, three solutions were identified to interconnect the four facilities and all DERs with the electric utility. To align with the goals of this study, it was ultimately decided that all facilities would be connected via a common microgrid bus connection, which includes a private, buried duct bank that crosses Essex Street. Asset selection and sizing was driven by electric and thermal loads of the selected facilities, the requirements set forth by the project team, and the goals of the study to promote renewable energy technologies. The identified solution includes:

- A 500kW/3300kWh BESS located in the Plaza Parking Lot
- (3) rooftop PV arrays and (1) canopy PV array totaling 819kW of capacity
- A 10kW micro-CHP at City Hall

Preliminary infrastructure upgrades at both the distribution and facility levels are identified. Lastly, a discussion of the various services and control capabilities of the proposed microgrid is provided.

It should be noted that DER and microgrid control strategies identified in this report have been selected based on a high-level review of existing electrical infrastructure. DER and control strategies have not yet been vetted by National Grid in the system impact study required to obtain an interconnection agreement. All required utility upgrades would be determined during the system impact study based on the selected DERs. Additionally, National Grid has discussed the planned demolition of the substation currently serving all locations included in this microgrid, which could impact future design and infrastructure considerations.

MICROGRID INTERCONNECTION

OVERVIEW

The following section below provides a discussion of microgrid interconnection options. The proposed microgrid configuration is comprised of a public-private partnership between three critical municipal facilities in the City of Melrose and one private business, Shaw's Supermarket. The facilities considered are located in Downtown Melrose on Main Street and Essex Street approximately 800 feet from each other. Figure 1 is duplicated below. Electrical and gas service are provided by National Grid for all four sites. B2Q has developed three alternative interconnection options, discussed below.

ELECTRICAL

The preferred interconnection option, Option 1, is to utilize the existing pathway through Essex Street to develop a microgrid bus connection between the municipal buildings and Shaw's. After review of this option, National Grid's safety team and legal team determined that the microgrid cannot be interconnected via the existing pathway unless the infrastructure is owned by the utility. As such, Option 2 presents an identical interconnection layout, however the microgrid bus would connect the sites via a private, street crossing. An alternative option to maintain an independently operated microgrid without the added construction cost of a private street crossing is present in Option 3, in which Shaw's would operate as a separate microgrid with no connection to the municipal building loads or microgrid assets. A disadvantage of Option 3 is that microgrid infrastructure and equipment would be required at two separate sites. To align with the goals of this study and the preferred characteristics identified by the stakeholders, interconnection Option 2 was selected for further study.

Option 1 and Option 2 – One Microgrid

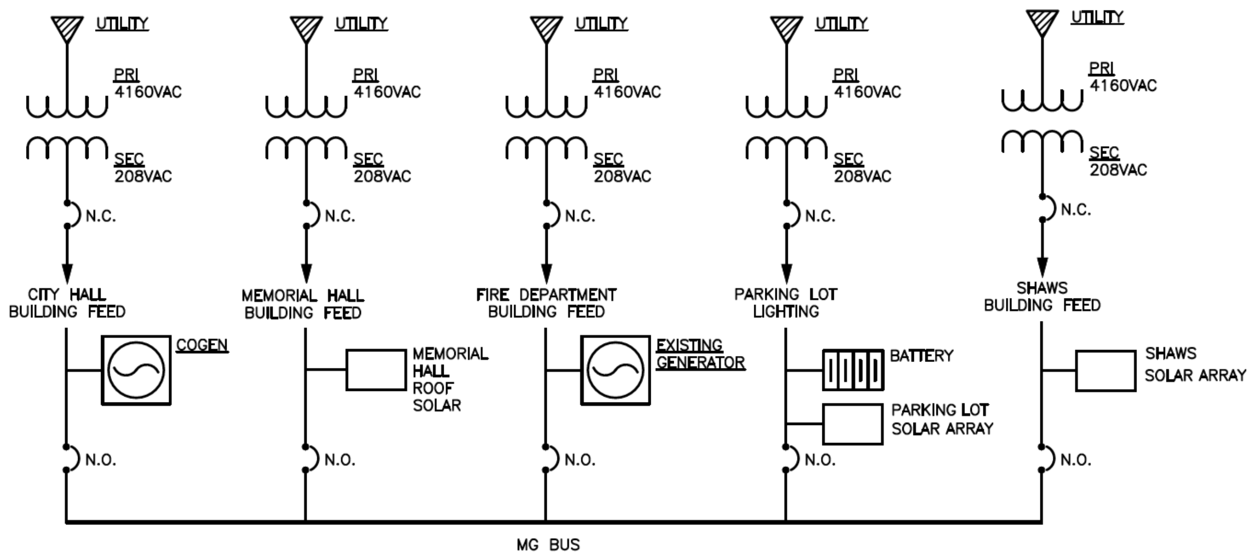


Figure 27: Electric interconnection Option 1 and Option 2.

Option 3 – Two Microgrids

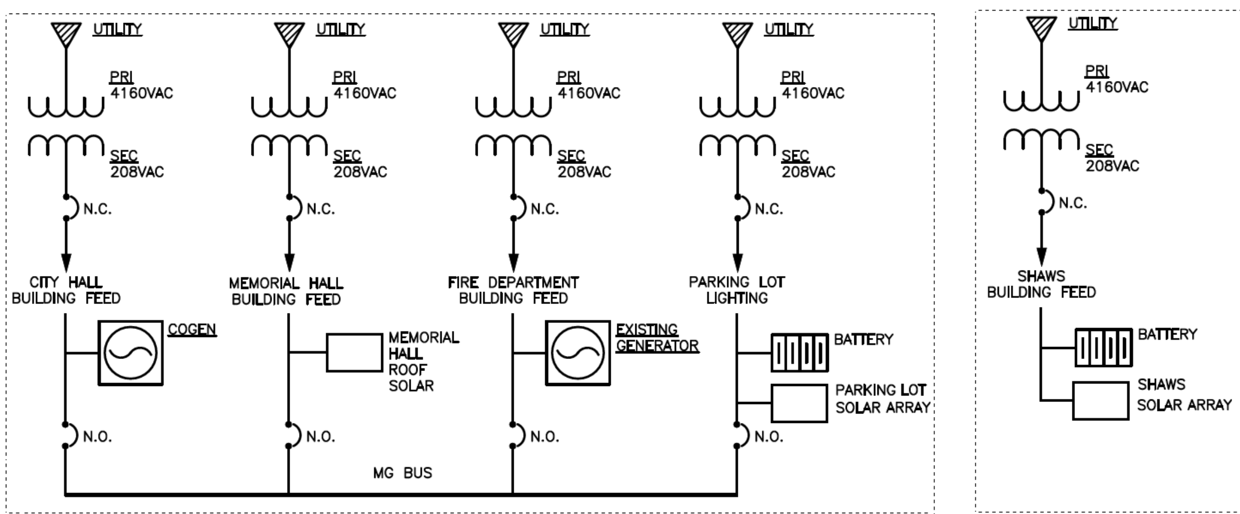


Figure 28: Electric interconnection Option 3.

Natural Gas and Heating

The annual natural gas consumption of the combined microgrid is just under 60,000 therms. Given the size of the microgrid's heating load and that the existing natural gas infrastructure is highly reliable, no interconnection between any of the facilities for heating is considered in this study. Any DER considered that generates heat, such as a cogeneration unit, will be used locally at the site where it is installed.

DISTRIBUTED ENERGY RESOURCES

ASSET SIZING AND SELECTION

A wide variety of DERs were analyzed for their practicality in the proposed microgrid. To align with stakeholder needs in addition to economic and technical feasibility, the assets shown in Table 28 were selected. DERs that were considered but not selected can be found below in the Other Evaluated DERs section.

Table 28: Selected DERs for the proposed microgrid.

Location	Asset Type	New/Existing	Fuel Source	Electric Capacity	Thermal Capacity
Fire Station Basement	Diesel Generator	Existing	Diesel	33 kW	--
City Hall Exterior	NG Micro-CHP	New	NG	10 kW	57.3 kBtu/h
Shaw's Rooftop	PV	New	--	186 kW	--
Memorial Hall Rooftop	PV	New	--	73 kW	--
Plaza Parking Lot	PV	New	--	560 kW	--
Plaza Parking Lot	BESS	New	--	500kW/3300kWh	--

The electrical and thermal load at Shaw's is a primary driver in the DER selection and sizing methodology. Meeting Shaw's nighttime demand is a critical hurdle that is addressed by the addition of increased battery energy storage capacity and inverter sizing in the Plaza Parking Lot.

The assets selected are designed to meet all four building's islanded electric load for a total of 24 hours, carried by the solar PV during the day and by the BESS during the night. During an extended outage event, it is expected that the electric load at Shaw's would be supplemented by a portable diesel generator that would be transported to the site during the allotted 24-hour window. Dispatchable generator services should be readily available within 24 hours (with a contract in place) and often much sooner under non-severe weather conditions. Therefore, in an effort to manage battery costs and container size, we have assumed in this analysis that the microgrid battery and solar PV assets would need to be sized to meet the microgrid load for 24 hours to give the dispatchable generator time to arrive on site. After the dispatchable generator arrives on site, the Shaw's load would be disconnected from the microgrid, and Shaw's would operate independently in islanded mode. Following the removal of the electric load at Shaw's, the remaining municipal and parking lot DER assets could maintain the three municipal building's electric loads for at least 5 days, provided that good solar access remains.

It is important to note that although the natural gas generator at Shaw's is existing, the generator control package is limited in functionality and is not able to be integrated into an SSC. Further, this existing generator is circuited for emergency lighting only and would require additional recircuiting to be usable during islanding.

As shown in Figure 32, the proposed microgrid is located outside of the 0.2% annual flood zone. To ensure resiliency, the BESS and CHP systems will be installed on a concrete pad 1' above grade. In addition, all control systems will be contained in a weather-proof enclosure. None of the assets are capable of ride-through voltage.

NATURAL GAS-POWERED SYSTEMS

CITY HALL COMBINED HEAT AND POWER

City Hall's proposed electrical and thermal load as well as potential electrical and thermal tie-ins indicate that the building could benefit from a 10kW micro combined heat and power (micro-CHP) system. The micro-CHP system would run at maximum capacity during normal operation. This CHP would be capable of black start, allowing the unit to maintain voltage and frequency without requiring an external electric service. However, the system would likely operate simultaneously with either the utility connection or the MG bus connection. The CHP could also operate independently to serve the City Hall critical IT server load when isolated from the rest of the loads via an automatic transfer switch.

The ideal location for electrical and thermal interconnection is between the parking lot entrance and the City Hall building but the final location would need to be evaluated in order to meet code requirements. This system would be capable of meeting interconnection standards in grid-connected mode.

SHAW'S BACKUP GENERATOR

Shaw's has an existing 20kW natural gas emergency generator which can power emergency lighting but is not sized to meet normal lighting power, HVAC, or refrigeration loads. The generator is currently located on the Shaw's rooftop and is connected to the utility's natural gas line. The backup generator considered in this study is capable of black start, allowing the unit to maintain voltage and frequency without requiring an external electric service; however, the controls for this generator cannot be incorporated into the SSC without completely replacing the equipment. This generator would not typically operate during islanded mode unless the DER asset generation could not meet the building load.

DIESEL GENERATORS

Diesel generators, although similar in functional resiliency to natural gas generators, can be considered to require more manual intervention due to the need for refueling, although more resilient in the sense that they are supplied by an energy source that is not tied to the utility electric or gas infrastructure. Without adequate fuel storage and proper staffing and surveillance, diesel generators may run out of fuel and be unable to serve the microgrid during certain outage events. This can be mitigated through the use of tank level monitors that are tied into control infrastructure to notify facility personnel that the tank is low.

FIRE STATION BACKUP GENERATOR

The fire station has an existing 33kW diesel generator which can meet a portion of the facility's electric loads (based on circuits connected to the ATS) for approximately 12 hours before refueling. The generator is currently located in the basement of the fire station. The existing generator does not have the controls necessary to regulate frequency and voltage precisely enough to participate in the microgrid as a controllable asset. Therefore, this generator would likely operate only when with both the utility connection or the MG bus had no power available.

Shaw's Dispatchable Generator

The proposed microgrid anticipates the electric load at Shaw's to be met by a dispatchable diesel generator within 24 hours of the microgrid entering an islanded mode. The generator would be connected to the main electrical switchgear to power the entire building. The dispatchable generator is unlikely to have controls which are readily compatible to be integrated to the SSC so that it could be incorporated into the microgrid. Therefore, prior to connecting the generator, the SSC would disconnect Shaw's load from the MG bus. The SSC would also curtail the solar PV output so that solar production does not result in adverse impacts on the dispatchable generator. The dispatchable generator would be black start capable, be provided with a sufficient amount of fuel to support the facility, and would be capable of load following.

Photovoltaic Systems

Photovoltaic systems would act as the primary source of electrical generation for the proposed microgrid in both normal and islanded operation. In this study, only passive PV systems are considered. The PV would require a grid to follow in order to maintain system voltage and frequency. The system(s) would therefore not be capable of black start. The PV would rely on the utility or MG bus to form the grid to allow passive generation. With periodic maintenance, PV systems act as a reliable source of generation; however, the electrical output is highly variable according to the time of day, season, and cloud/snow coverage. These PV systems would be capable of meeting interconnection standards in grid-connected mode.

SHAW'S SOLAR

Shaw's Supermarket's rooftop, pending structural analysis, may be capable of hosting a solar PV system with a maximum capacity, given space constraints, of approximately 186kW. Due to the electric demand, Shaw's could utilize all 186kW during normal operation and islanded operation. An initial layout of the proposed solar array is shown below in Figure 29. The system shown would be posted up from the building's existing structural members, making the asset more resistant to wind damage than ballasted PV systems.

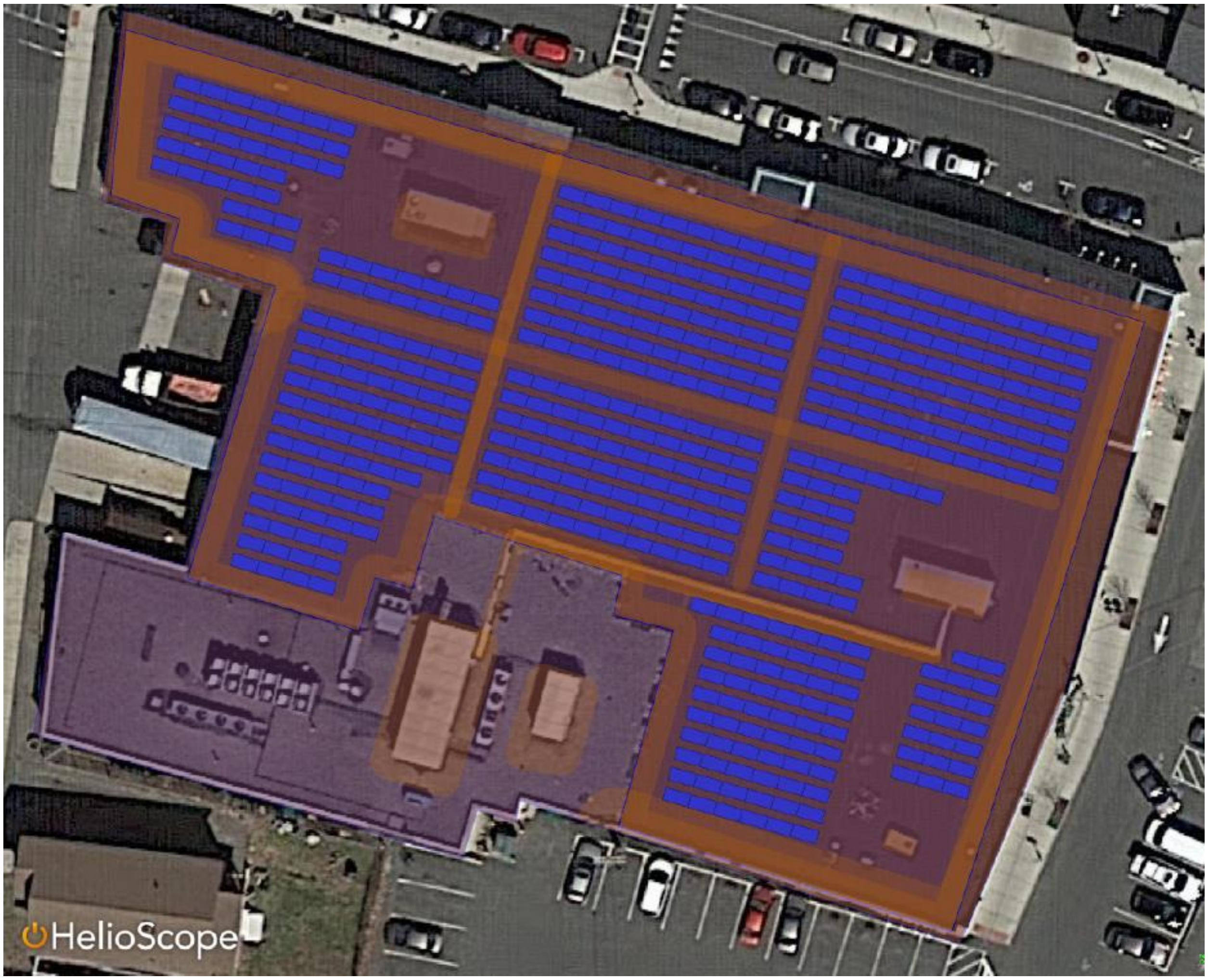


Figure 29: Proposed solar array arrangement on Shaw's rooftop within the Helioscope software.

MEMORIAL HALL SOLAR

Memorial Hall's rooftop, pending structural analysis, may be capable of hosting a solar PV system with a maximum capacity, given space constraints, of approximately 73kW. Although the peak demand of Memorial Hall is estimated to be 45kW, the building's annual energy consumption is within 10% of the annual electric output of the proposed 73kW solar array. An initial layout of the proposed solar array is shown below in Figure 30. Regarding the resiliency of the system, there is the potential of wind damage as the proposed construction would be a ballasted system. However, this risk could be mitigated though a robust anchor design strategy that exceeds standard ballasted PV array designs.

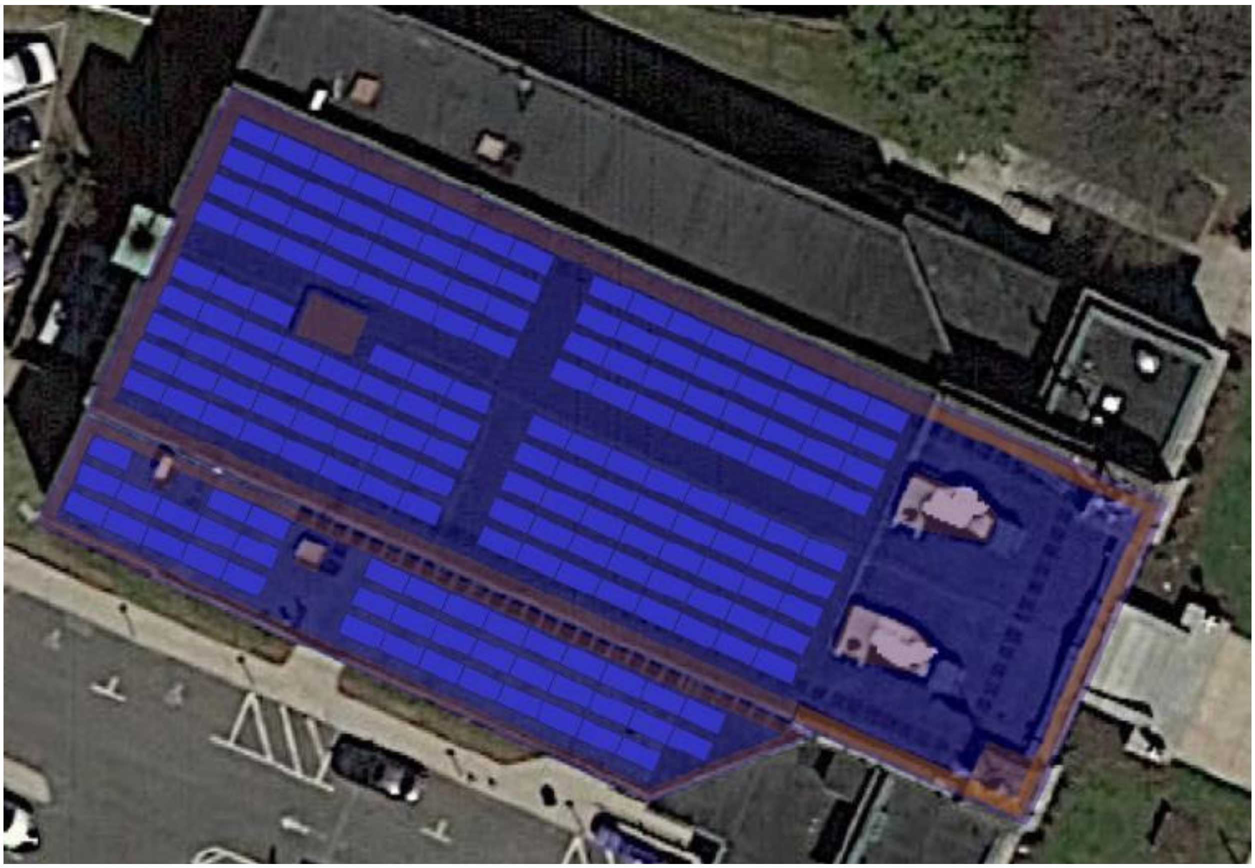


Figure 30: Proposed solar array arrangement on Memorial Hall's rooftop within the Helioscope software.

PLAZA PARKING LOT SOLAR

The plaza parking lot, located behind the (3) municipal buildings included in this study, may be capable of hosting a 560kW solar canopy array. This capacity solar array would maximize the available space in the parking lot for solar PV canopy generation. An initial layout of the proposed solar array is shown below in Figure 31. In terms of resiliency to extreme weather, there are trees within the vicinity of the proposed site that could strike the system in severe weather, however only a small portion of the system is exposed to this threat and regular tree trimming could significantly mitigate risk.

Figure 31: Proposed solar array arrangement on Plaza Parking Lot solar canopy within the Helioscope software.

BATTERY SYSTEMS

BESSs can play an important role in quickly and efficiently matching the microgrid's electric demand. When sized properly, BESSs can integrate PV, generators, and CHP systems and help regulate the voltage, frequency and electric demand of the microgrid. The housing of BESSs in a safe and isolated location also ensures that the system is not subject to weather events that could result in damage and/or system downtime.

PLAZA PARKING LOT BATTERY

The BESS would be sized to provide a minimum of 24 hours of energy to the entire microgrid. The intent of the current battery sizing is to enable Shaw's sufficient time to connect a portable electric generator on site to meet the building's electric demand. Following the removal of the Shaw's electric demand, the remaining DERs would enable the municipal buildings to operate in an islanded mode for an extended period. The BESS selected for this microgrid would be Lithium Ion (LI-ion). This system would be capable of meeting interconnection standards in grid-connected mode.

This microgrid concept assumes that a single BESS would be installed to serve the (4) buildings included in this study due to the impact on economies of scale. The battery would be enclosed in a new weather-proof, secure enclosure located in the Plaza Parking Lot. Modeling results indicate that the battery size required to serve the microgrid for 24 hours is 500kW/3300kWh, assuming that the battery starts in a fully-charged state. The BESS inverter has been selected at a typical inverter capacity of 500kW to meet the peak islanded load of 425kW. A customized inverter system could be right sized, however spare capacity would be required to mitigate the possibility of the BESS tripping offline when islanded. If the dispatchable diesel generator could be dispatched to the site and brought online within 12 hours rather than the assumed 24 hours, the required battery capacity could be significantly reduced to approximately 1,700kWh. The responsibilities and technical duties of the BESS could also be accomplished by installing a second battery at Shaw's to reduce overall energy storage capacity and inverter sizing of the Plaza Parking Lot battery. However, this alternative approach is not evaluated in this study.

Scenarios exist that solar PV and BESS modeling using typical meteorological data cannot account for, such as a winter snow storm with full snow cover or significant hot, cloudy days directly following a hurricane. In the event that no solar PV generation was available due to snow cover, the BESS could meet cold-weather islanded microgrid loads for 6 to 8 hours, starting from a full charge. Similarly, if solar production was reduced to 25% of modeled generation output due to summer storm clouds, the BESS and limited solar PV could meet peak islanded microgrid loads for approximately 8 hours.

OTHER EVALUATED DERS

Initial microgrid concepts for this feasibility study incorporated a traditional CHP making hot water at Shaw's to meet nighttime demand, and utilizing the CHP thermal output dedicated to the desiccant reactivation energy in a new dehumidifier RTU. However, as the feasibility study progressed into deeper review of loads and identification of specific equipment modifications required to utilize the CHP thermal energy, it was determined that a CHP was not the best solution to address Shaw's nighttime demand. Energy modeling revealed that the thermal reactivation energy requirement for the desiccant dehumidifier RTU throughout the year was lower than originally estimated and that this load could be met more efficiently and cost effectively using a refrigerant hot gas heating coil loop to the RTU desiccant wheel section.

If the CHP was selected for a lower output (e.g. < 75kW) to meet the RTU desiccant reactivation energy loads, the complexity and cost of the associated electrical upgrades would make the CHP not economically viable. Shaw's also indicated that there was no appetite to convert all heating systems within the facility to hot water systems as it would require significant capital equipment replacements and extensive piping distribution throughout the building, with limited energy benefits on replacement projects. A summary of other evaluated DERs is presented in Table 29.

Table 29: Summary Table of Other Evaluated DERs.

Building	DER	Benefits	Drawbacks
Shaw's	Traditional CHP	• Baseload electric demand during islanded operation • Reduces capacity required for battery storage assets • Can be used year-round to baseload electric demand and reduce electric demand charges	• Minimal thermal recovery load without high capital cost for RTU and UH replacements/retrofits to convert to HW systems for recovering heat from cogen • Significant amount of glycol would be required for conversion to HW due to outdoor piping • Poor economics due to conversions required to utilize heat recovery.
Shaw's	In-Case Thermal Storage	• Reduces thermal load during islanded operation • Minimal controls or system integration required • Can be used during normal operation for peak demand reduction • Low capital cost relative to other solutions	• Requires space within existing refrigerated area for installation • High payback • Only an option for walk-in coolers and freezers
Shaw's	CHP with Ammonia Absorption Chiller	• Single source of heating, cooling, and electrical generation • Reduces electric generation requirements by reducing refrigeration loads • Can be used year-round to baseload electric demand	• High capital cost • Significant design, operation, maintenance, and safety considerations • Very disruptive installation

Microgrid Infrastructure

Summary

Table 30: Summary of new and existing microgrid assets and infrastructure evaluated in this concept.

	New	Existing
General Infrastructure	• System supervisory controller • Buried electrical and communications cabling and conduit	• (1) National Grid transformer serving Shaw's • (1) National Grid transformer serving City Hall • (1) National Grid transformer serving Fire Station • (1) National Grid transformer serving Memorial Hall • (1) National Grid transformer serving the Plaza Parking Lot
Shaw's	• Two new automatic breakers • Optimized electrical switchgear • 186kW PV rooftop array	• Main disconnect: 3,000A, 480VAC • Fully populated 3000A, 3 phase, 4 wire, 208Y/120VAC service entrance switchboard • 20kW natural gas generator
City Hall	• Two new automatic breakers • Optimized electrical switchgear • 10kWe micro-CHP with hot water heat recovery	• Main disconnect: 1,200A, 480VAC • Fully populated 1,200A, 3 phase, 4 wire, 208Y/120VAC service entrance switchboard
Plaza Parking Lot	• 500kW/3300kWh BESS • 560kW PV canopy array • EV charging station(s)	• EV charging stations
Fire Station	• Two new automatic breakers	• Main disconnect: 200A, 208Y/120VAC • Fully populated 200A, 1 phase, 3 wire, 208Y/120VAC service entrance switchboard • 33kW diesel generator
Memorial Hall	• Two new automatic breakers • 73kW PV rooftop array	• Main disconnect: 1,000A, 208VAC • 1,000A, 3 phase, 4 wire, 208Y/120VAC service entrance switchboard

ELECTRICAL INFRASTRUCTURE

The proposed microgrid concept requires a new electrical service that would connect all of the municipal buildings, the Plaza Parking Lot, and Shaw's, referred to as the MG bus. The one-line electrical diagrams attached in Appendix B show the MG bus as an extension of the Plaza Parking Lot. The MG bus would connect to each building load behind the meter and the general routing of the cabling would be underground along the border between the Plaza Parking Lot and the municipal buildings, and buried under Essex Street (right of way) to interconnect with Shaw's. B2Q and E3i reviewed with National Grid whether the MG bus conceptually could be located within existing manholes to make use of existing utility infrastructure. However, National Grid felt that this presents a significant safety concern for their line workers because during a grid outage the utility cabling would be de-energized while the MG bus would be energized within the same duct bank or manhole. For this reason, we have assumed that new buried duct banks would be required for the MG bus connection between the municipal facilities and Shaw's. The existing utility transformers would remain, with the exception of the transformer serving the Plaza Parking Lot, which may need to be upsized to accommodate the new solar and battery energy storage system.

The MG bus would be separated by Normally Open (NO) automatic breakers between each load. A Normally Closed (NC) automatic breaker would be installed between the utility transformer and the main switch board of every building load. These automatic breakers would sense the utility voltage via potential transformers located between the breaker and the utility transformer. In addition to the electrical interlock of all automatic breakers together, they would also be electrically interlocked with the SSC for status verification. The NO automatic breakers for each load on the MG bus would only be allowed to close and interconnect the loads and generation assets to the MG bus when all of the NC automatic breakers between the load and the utility grid are reporting their status as open (de-energized) to the SSC via the electrical interlock relays. The relay interconnect to the SSC is identified on the one-line diagrams with the (e) symbol.

New current and potential transformers would be installed at each site for smart metering, as well as for protective relaying (shown on the one-line diagrams as Multi-Function Relays). The potential and current transformers for the smart metering would reference the load potential and line current, respectively. Conversely, the potential and current transformers for the protective relaying would reference line potential and load current for safety control.

The electrical infrastructure, in general, would be resilient to typical storms and other forces of nature since the MG bus and interconnecting cabling would be buried, and the breakers, relays, and transformers would be located within each facility's electrical room. The exception to this is the infrastructure for the Plaza Parking Lot, which would be housed in a weather proof, secure enclosure. Since this microgrid is located outside of the 0.2% annual chance flood hazard as shown in Figure 32, risks of flooding are minimal. However, as the electrical equipment would be located within each buildings' electrical room in the basement level of the municipal buildings and on grade at Shaw's, the microgrid would not be able to function if flooding compromised any of the buildings. There is currently no adequate space to relocate any of the municipal building electrical rooms to be at or above grade.

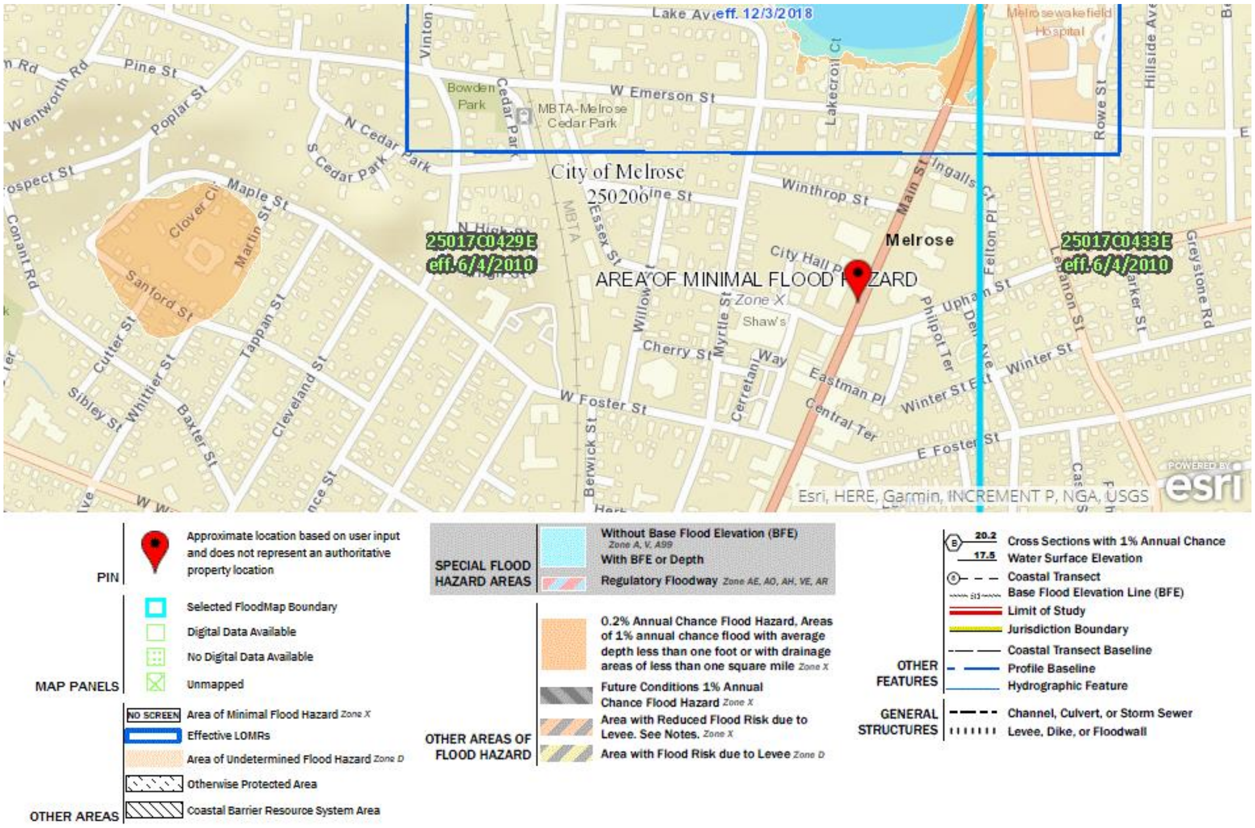


Figure 32: 0.2% annual flood plain (FEMA Flood Map Service Center 2019).

THERMAL INFRASTRUCTURE

The existing thermal infrastructure of Memorial Hall and the Fire Station, as described in Task 2: Site Overview would not be modified in the proposed microgrid. Each building would maintain current operation of its independent heating and cooling equipment with no central microgrid infrastructure.

City Hall, as discussed in the Distributed Energy Resources section, would be equipped with a micro-CHP system. The proposed CHP system would utilize excess heat produced from the engine to offset the hot water load at City Hall. The CHP's heat recovery system would be tied into the existing hot water system through a new runaround hot water loop. The heat recovery loop would be tied into the existing hot water system on the return hot water header before the boilers.

Shaw's Supermarket's central thermal infrastructure would not be modified in the proposed microgrid; however, walk-in freezers and coolers could be retrofitted with thermal storage for added resiliency as discussed in the Other Evaluated DERs section. Thermal storage systems can act as a passive energy storage system through the use of phase-change materials engineered to have a melting point at or just above the design operating temperature of the environment. In the event of a loss of mechanical cooling, the walk-in temperature would begin to rise beyond the design temperature. As the temperature rises, the thermal storage would begin to change phases, maintaining the space at its design melting point until the system has been completely discharged. Thermal storage systems can be installed in variable capacities as space allows to increase resiliency.

City Hall, Memorial Hall, and the Fire Station's most critical thermal loads are heating applications. All three municipal heating loads are met by a variety of hot water or gas-fired equipment served by utility natural gas connections. Historically, the natural gas infrastructure of Melrose has proven resilient to major events that have previously caused power outages. Other end-use devices, such as boilers, air handling units, cabinet unit heaters, and fan coil units are indoor devices not exposed to the typical environmental risks that threaten the microgrid's operation. All rooftop equipment is outdoor duty and time-proven to be resilient to the forces of nature. In addition, all rooftop equipment on the four buildings is above nearby tree lines, reducing the risk of damage from falling objects.

The most critical thermal load at Shaw's is the refrigeration load. The refrigeration load provides cooling for the refrigerated cases, walk-in coolers, and walk-in freezers. The refrigeration hot gas also provides reheat energy to the building's primary roof top unit. The refrigeration loops' compressors are located in a mechanical doghouse on the roof of Shaw's. The doghouse limits exposure to the outside elements.

CONTROLS INFRASTRUCTURE

A new SSC, also referred to as a microgrid controller, would perform supervisory control of the microgrid and would have the capability to communicate with all new DERs, utility and microgrid automatic breakers, meters, and the utility. The SSC would be a Programmable Logic Controller (PLC) similar to those offered by Eaton, Raytheon, Schneider Electric, EnergyIQ etc. This concept assumes that the SSC would be installed in the City Hall mechanical room, although alternatively it could be located in any of the buildings or in a weather-rated, secure enclosure adjacent to the DER assets in the plaza parking lot. The SSC and all remote gateways will be utility grade according to IEEE C37.90 and other codes and requirements set forth by the utility and other authorities. Refer to the Microgrid Control section below for additional discussion.

IT/TELECOMMUNICATIONS INFRASTRUCTURE

The SSC will communicate over a dedicated local area network. The network will be added to the existing City Hall IT server room, where ethernet switches would tie into all microgrid equipment (breakers, equipment controllers, energy meters, etc.). CAT7 communication cables would be wired to each asset in buried, shielded conduit with the new MG bus infrastructure. Note that the electrical cabling and communications cabling will not be located within the same conduit, but will likely utilize the same trench for installation. If the capacity is available and it is identified to be an owner's project requirement, a redundant ethernet communication network could be wired to the SSC. The SSC would also have a cellular port for emergency remote diagnostics and control. To ensure ride through communication during an outage event, both the SSC and associated Local Area Network (LAN) components would have small, dedicated UPS systems.

Upon a loss in communications from the utility and after repeated failed attempts to re-establish communication, it may be necessary for the microgrid to disconnect from the utility grid. However, microgrid stakeholders should evaluate the risk management and identify if automatically disconnecting from the grid is necessary in the event of a loss of communication.

IT Security

IT security would be maintained and managed by the microgrid service provider/vendor and should be evaluated with an IT security consultant. In a worst-case scenario, a security compromise could allow an attacker to use a microgrid device to endanger human safety, damage or destroy equipment and facilities, or cause major operational disruptions (National Institute of Standards and Technology 2019). Therefore, the beginning of any IT security plan should include stakeholder risk assessment to identify vulnerabilities as they relate to critical infrastructure, stakeholder risk management strategy is in place and managed, and a response and recovery plan in place in the event of an incident or disaster.

Since the SSC would be connected to the internet via LAN, conventional IT security measures should be evaluated and included as appropriate, such as network firewall, antimalware service, and intrusion prevention. In addition, a minimum of 3 password-protected user-levels, such as:

- System Administrator – full access to system controls programming, security software, and system settings. May require two-factor authentication.
- Network Administrator – full access to network configuration settings. May require two-factor authentication.
- Equipment Technician – limited access to modify setpoints and manage connected equipment basic configuration settings, troubleshoot, microgrid system settings are read-only, no access to programming.
- Read-only User – read-only access restricted to certain areas of the graphics and monitored system points, trends, and data exporting (e.g. For Measurement and Verification (M&V) and Commissioning (Cx)).

Cloud-based data acquisition and Monitoring-Based Commissioning (MBCx) software would be configured to be export-only from the SSC (e.g. outbound only on IP port) so that there is no inbound access via the MBCx software. Only non-critical data would be supplied to the user-accessible area of the software (e.g. BESS state of charge, solar output/production, microgrid/DR status, HVAC/lighting operation and setpoints etc.). Critical data such as system configuration settings, DER controller settings, communication settings, etc. would not be made available.

The automatic/remote demand response signal would be protected by upstream hardware firewall (e.g. signal receiver/controller). Network communications with the curtailment service provider would be secured by conventional means.

IT Resiliency

The proposed IT/Telecommunication infrastructure for the proposed microgrid would be buried or contained within the microgrid buildings. Baring extreme events, such as a construction project breaking ground without DigSafe consultation and damaging underground communication networks, the proposed infrastructure is highly resilient to the forces of nature. In the event of a loss of power to the IT infrastructure (including the UPS and BESS), IT communications would utilize emergency cellular ports to signal an alarm. However, this remote requires a local mesh cellular network and that the existing service provider infrastructure is operational.

FACILITY INFRASTRUCTURE

SHAW'S SUPERMARKET

ELECTRICAL INFRASTRUCTURE

EXISTING

Shaw's existing electrical service is provided via a National Grid 500kVa, 4160VAC primary, 208VAC secondary, pad mount utility transformer located in the rear parking lot of Shaw's. Shaw's main service entry gear is located on the main floor. The existing service entrance switchboard is 3,000A, 3 phase, 4 wire, 208Y/120VAC and is fully utilized with no spare positions. The switchboard was installed circa 1989. The electric room is fully populated with no space for additional electric panels. The main disconnect is a 3,000A, 480VAC rated, fused pringle switch.

NEW

Two new automatic breakers would be installed in the existing electrical room. One automatic breaker would connect the building load to the utility, and the other would connect the building load to the MG bus. The utility automatic breaker would be electrically interlocked via a 52 contact with all other utility breakers. The automatic breaker connecting the building load to the MG bus would be controlled via the new SSC. Electrical connections to the PV and MG bus would be made in the electrical room. Additionally, the existing electrical switchgear would need to be upgraded to increase capacity for the connection to the MG bus and the solar PV.

MICROGRID ASSETS

EXISTING

This facility has a 20kW natural gas emergency generator which can power emergency lighting but is not sized to meet normal lighting power, HVAC, or refrigeration loads.

NEW

The proposed microgrid includes a 186kW solar PV system installed on the rooftop of Shaw's. The passive solar PV system would be supported from posts connected to the building structural supports. Please note that this assumes the structure is capable of supporting a solar array, structural capacity should be verified.

CITY HALL

ELECTRICAL INFRASTRUCTURE

EXISTING

City Hall's existing electrical service is provided via a National Grid 150kVa, 4160VAC primary, 208VAC secondary, pad mount utility transformer located directly outside Melrose City Hall at the corner of the Essex Street entrance into the parking lot. City Hall's main service entry gear is located in the basement level, referred to as the ground level on building documentation. The existing service entrance switchboard is 1,200A, 3 phase, 4 wire, 208Y/120VAC and was installed circa 1989. The existing distribution panel has an available spare position. Circuit relocation within the distribution panel may be necessary to utilize the spare position. The basement electric room is fully populated with no space for additional electric panels. The main disconnect is a 1,200A, 480VAC rated, fused pringle switch. The fused protection is shown on building drawings and should be verified.

NEW

Two new automatic breakers would be installed in the existing basement electrical room. One automatic breaker would connect the building load to the utility, and the other would connect the building load to the MG bus. The utility automatic breaker would be electrically interlocked via a 52 contact with all other utility breakers. The automatic breaker connecting the building load to the MG bus would be controlled via the new SSC. Electrical connections to the CHP and MG bus would be made in the basement electrical room. The existing electrical room circuitry would need to be modified to increase/optimize switchboard capacity for the connection to the MG bus and the CHP. The circuits powering the IT servers would be intercepted and would connect to a new automatic transfer switch to allow the CHP to support the critical IT server communication functions in the event that the solar-battery microgrid DERs were not able to meet the system loads.

MICROGRID ASSETS

EXISTING

The IT servers are currently backed up by a UPS which can provide power for data servers and emergency telephone services for approximately one hour following a power interruption. Data servers are cooled via (2) window AC units, but can be removed in the winter to allow outside air to cool the room as needed.

NEW

The proposed microgrid includes a new 10kWe micro-CHP system would be installed on the exterior of City Hall. The IT servers would provide the baseload for the small CHP system year-round and the intent of the CHP system in addition to supplementing the building heat is to provide backup power to the IT servers when other microgrid DERs are unavailable. The CHP will produce hot water and be tied into the existing building HW loop.

PLAZA PARKING LOT

The Plaza Parking Lot which is located behind City Hall, Memorial Hall, and the Fire Station would be equipped with a 560kW PV canopy system as part of the proposed microgrid. Additionally, a 500kW/3300kWh BESS would be installed within the existing parking lot. The microgrid concept also includes the installation of additional EV chargers, including a blend of both DC fast chargers and Level 2 chargers, although location and quantity would need to be identified through a detailed survey. The utility transformer serving the plaza parking lot EV charging stations and lights would need to be upgraded to accommodate the solar PV and BESS interconnection during normal operation.

This microgrid concept assumes that a single BESS would be installed to serve the (4) buildings included in this study. The availability of a dispatchable generator to serve Shaw's is a key driver in the BESS capacity sizing. This study assumes that 24 hours is adequate time for a service provider to dispatch a generator to the site to support Shaw's loads, since this asset dispatch can typically be performed in significantly less time under ideal conditions. Modeling results indicate that the battery size required to serve the microgrid for 24 hours is 500kW/3300kWh, assuming that the battery starts in a fully-charged state.

FIRE STATION

ELECTRICAL INFRASTRUCTURE

EXISTING

The Fire Station's existing electrical service is provided via a National Grid 4160VAC primary, 208VAC secondary utility transformer. The existing service entrance is a single phase, 208VAC service connected via a fused disconnect switch panel rated for 200 Amp, 1 phase, 3 wire, 208Y/120VAC. The basement main electric room is fully populated, so there is no room for additional electrical panels within the room; however, the area outside the room is free of any installations.

NEW

Two new automatic breakers would be installed in the existing basement electrical room. One automatic breaker would connect the building load to the utility, and the other would connect the building load to the MG bus. The utility automatic breaker would be electrically interlocked via a 52 contact with all other utility breakers. The automatic breaker connecting the building load to the MG bus would be controlled via the new SSC. Electrical connections to the MG bus would be made in the available area outside the basement electrical room.

MICROGRID ASSETS

EXISTING

The fire station has an existing 33kW diesel generator which can meet a portion of the facility's electric load for approximately 12 hours before refueling. This is connected to the building by an existing automatic transfer switch.

NEW

The proposed microgrid does not require that the Fire Station be equipped with any additional microgrid assets.

MEMORIAL HALL

ELECTRICAL INFRASTRUCTURE

EXISTING

Memorial Hall's existing electrical service is provided via a National Grid 4160VAC primary, 208VAC secondary utility transformer. Memorial Hall's main service entry gear is located in the lower level electric room. The existing service entrance switchboard is 1,000A, 3 phase, 4 wire, 208Y/120VAC. The existing distribution panel has available spare positions. The basement electric room has some remaining wall space for expansion panels. The main disconnect is a 1,000A, 208VAC rated circuit breaker.

New

Two new automatic breakers would be installed in the existing basement electrical room. One automatic breaker would connect the building load to the utility, and the other would connect the building load to the MG bus. The utility automatic breaker would be electrically interlocked via a 52 contact with all other utility breakers. The automatic breaker connecting the building load to the MG bus would be controlled via the new SSC. Electrical connections to the solar PV and MG bus would be made in the basement electrical room.

Microgrid Assets

Existing

Memorial Hall has no existing microgrid assets.

New

The proposed microgrid includes a 73kW solar PV system. The passive solar PV system would be installed on the rooftop of Memorial Hall with ballasted supports. Please note that this assumes the structure is capable of supporting a solar array, structural capacity should be verified.

MICROGRID CONTROL

The SSC, also known as a microgrid controller, would be a PLC controller similar to those offered by Eaton, Raytheon, Schneider Electric, EnergyIQ etc. The SSC would directly communicate with all of the building energy meters, DER asset controllers, and automatic utility and MG bus breakers. The SSC would have hardwired ethernet connections via a JACE controller to communicate with the BAS within both the City Hall and Memorial Hall, the refrigeration control system at Shaw's (which also controls HVAC equipment) and the lighting control systems within each facility. The SSC would also have cloud-based connections through the City Hall LAN and backup cellular communication port. Table 31 below displays the connections required for the SSC.

Table 31: Communication connections in the proposed microgrid. Note that the system supervisory controller is architecture level 1.

Item	SSC Communication	Communication Medium	Communcation Protocol	Physical Location	Architecture Level	New/Existing
1	Utility-Load Automatic Breakers	2-wire (electrical interlock) Ethernet (monitoring/control)	24V (electrical interlock) DNP3 (monitoring/control)	CH, MH, FD, Shaws, Parking Lot	2	New
2	MG Bus-Load Automatic Breakers	Ethernet	DNP3	CH, MH, FD, Shaws, Parking Lot	2	New
3	BESS Automatic Breaker	Ethernet	DNP3	Parking Lot	2	New
4	Battery Management System Controller	Ethernet	Modbus	Parking Lot	2	New
5	Battery Inverter System Controller	Network via Battery Management System	Modbus	Parking Lot	3	New
6	Solar PV Inverter System Controller	Ethernet	Modbus	MH, Shaws, Parking Lot	2	New
7	Solar PV Micro Inverters	Network via Solar PV Inverter System Controller	Modbus	MH, Shaws, Parking Lot	3	New
8	Solar Energy Meters	Network via Solar PV Inverter System Controller	Modbus	MH, Shaws, Parking Lot	3	New
9	Solar PV Automatic Breaker	Ethernet	DNP3	MH, Shaws, Parking Lot	2	New
10	Building Controls JACE	Ethernet	BACnet/IP	MH, CH, Shaws	2	New
11	Building Automation System	Network via Building Controls JACE	BACnet/IP	MH, CH	3	Existing
12	Refrigeration Control System	Network via Building Controls JACE	Modbus/DNP3	Shaw's	3	Existing
13	Lighting Control System	Network via Building Controls JACE	BACnet/IP	MH, CH, Shaws	3	New
14	CHP Controller	Ethernet	BACnet/Modbus/DNP3	CH	2	New
15	Energy Meters - loads	Ethernet	BACnet/Modbus	CH, MH, FD, Shaws, Parking Lot	2	New
16	Local Area Network	Ethernet	BACnet/Modbus/DNP3	City Hall	2	Existing
17	System Data Acquisition and MBCx	Cloud via LAN	BACnet/Modbus/DNP3	Cloud	3	New
18	Demand Response Link to CSP	Cloud via LAN	BACnet/Modbus/DNP3	Cloud	3	New
19	MG Vendor Remote Diagnostics and Service	Cloud via LAN (cellular emergency backup)	BACnet/Modbus/DNP3	Cloud	3	New
20	Utility Remote Disconnect	Cloud via LAN (cellular emergency backup)	Modbus/DNP3	Cloud	3	New

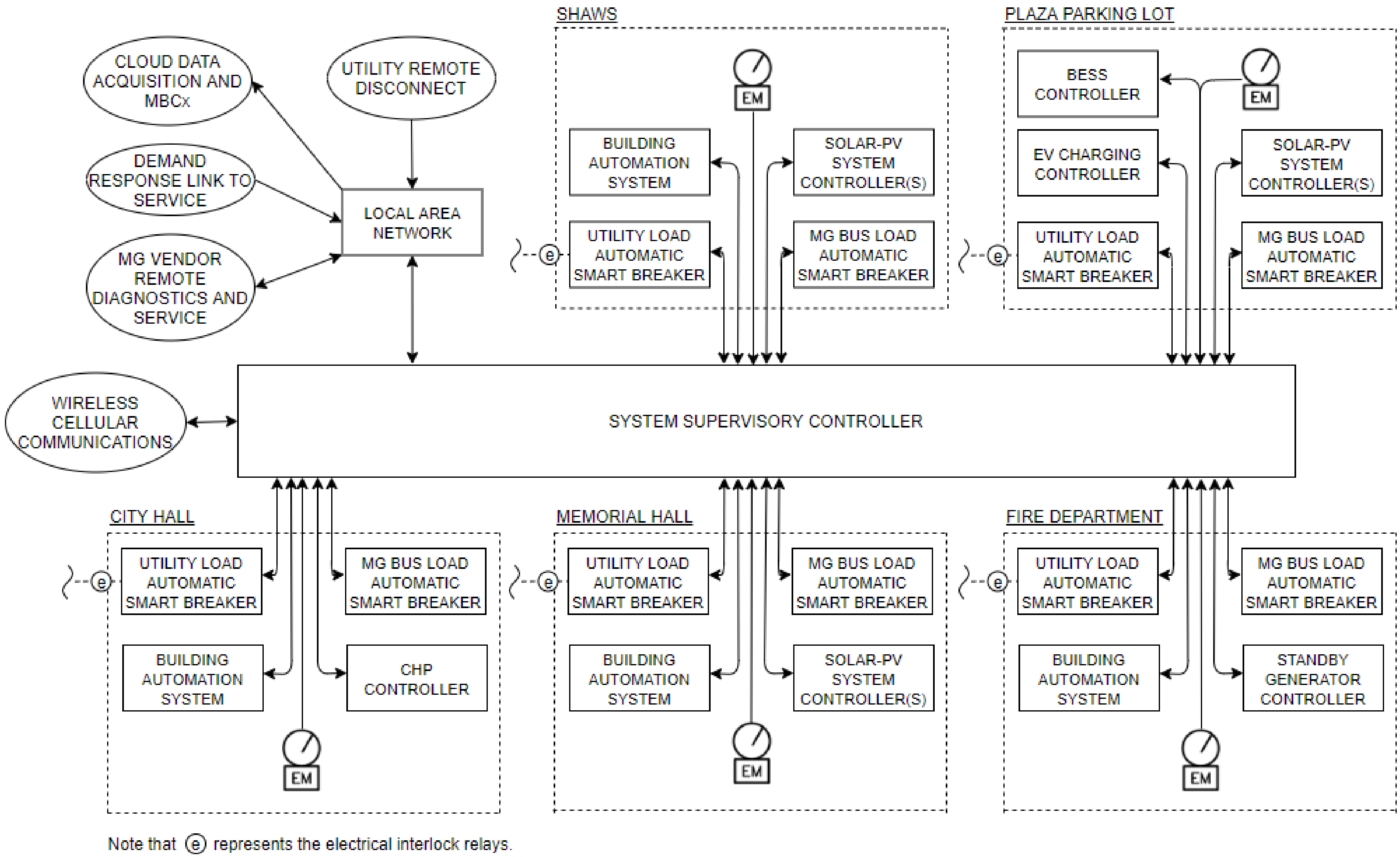


Figure 33: Microgrid controls conceptual diagram. Rectangular objects refer to controllers connected physically at the site, while circular objects refer to remote/cloud/internet communications

Operating Modes

Normal Power Mode

The buildings within the microgrid will operate individually during normal power operation, and all MG bus-load breakers will be open. Each building will utilize the DER generation on-site or with utility grid-export in a “typical” (non-microgrid) approach, as described below.

Shaw’s Solar

During normal operation, Shaw’s Supermarket would utilize the proposed 186kW solar array to offset the building’s daytime electric demand. The demand from Shaw’s building loads is always greater than the design output of the solar array, so all electricity generated by the solar array would be used at the site. Note that PV inverter specifications would need to be identified prior to submitting an interconnection agreement.

City Hall CHP

During normal operation, City Hall would utilize the proposed CHP system to meet the base load of the IT Servers and would operate to offset electric and thermal demand. The CHP system would electric load follow, and operate as the first stage of heating for the building hot water loop. The existing boilers would be sequenced to operate whenever the CHP thermal production could not meet the building load. The CHP would reject excess thermal energy as required via an integral radiator. The proposed CHP would likely operate to maintain a minimum utility import threshold; however, the exact control and threshold would need to be determined by National Grid during a system impact study.

Memorial Hall Solar

Memorial Hall will utilize the 73kW rooftop solar array to offset the building’s proposed electric demand. Since the solar array is sized to maximize capacity for islanding, modeling shows there will be times when the system power generation exceeds Memorial Hall’s electric load under normal conditions. Memorial Hall would not be able to distribute excess energy generation to other sites within the microgrid during normal operation due to both state regulations and the MG bus connection concept; therefore, Memorial Hall would export the excess solar energy to the utility grid. Note that although the daytime production of the solar array exceeds the daytime demand, the models predict the estimated total annual production would be nearly equivalent to the annual energy use of the building. Current regulations regarding net metering are discussed in Task 5: Financial Feasibility in relation to their impact on project economics. Note that PV inverter specifications would need to be identified prior to submitting an interconnection agreement.

Plaza Parking Lot Solar and BESS

The energy generated by the plaza parking lot solar canopy must be solely utilized on the same parcel of land it is installed or sold back to the grid. Accordingly, all energy generated during normal operation would either be used on-site by the two existing EV car charging stations, the newly installed EV car charging stations, be stored in the BESS, or be exported to the utility grid. Depending on the BESS state of charge, the BESS can be discharged to serve parking lot lighting and EV charging loads after dark when there is no solar PV generation available. Since this system is lightly loaded, additional EV car charging stations may be installed within the parcel to provide an opportunity to reduce utility grid-export, assuming current EV charging market demand trends continue. Note that the BESS inverter specifications would need to be identified prior to submitting an interconnection agreement.

The BESS can also be utilized to participate in DR programs during normal operation, such as the Daily Dispatch Program offered by National Grid. Since the battery storage system capacity and inverter is sized for the entire microgrid during an outage event, the battery would have the ability to discharge more energy from the battery than the Plaza Parking Lot's demand, exporting stored energy to offset loads on the utility grid. During each DR event, a remote signal originating from the Curtailment Service Provider (CSP) would be communicated to the SSC. The SSC would calculate the constant discharge power to be provided based on the BESS remaining charge and the duration of the DR event and signal the BESS to discharge for the duration of the event. This would enable a consistent load shed threshold throughout the DR event. During a DR event, the EV charging stations would be limited to a reduced rate of charge. New V2G charging station technology may soon be available, enabling electric vehicle batteries to be utilized during demand response. If these are added to the system, the SSC would need to manage any additional mobile demand response assets available.

Standby Generators

During normal operation, the existing diesel generator at the Fire Station and the existing natural gas generator at Shaw's would not operate.

Microgrid Islanding Mode (Emergency Operation)

The SSC shall utilize DER and storage assets to perform load following at the microgrid distribution level upon a loss of grid power for an extended period of time. The SSC will control the BESS to "form the grid" during black start conditions, supplying the PV passive inverters in the Plaza Parking Lot with a frequency and voltage to follow in order to operate without a connected utility grid. During black start conditions to initiate islanding, the SSC would perform load and DER asset addition while controlling the solar output at the Plaza Parking Lot, Memorial Hall, and Shaw's and BESS output (or charging) to perform load following to meet variable building loads, including current inrush to support motor starts. The City Hall CHP would run continuously to provide base load. In the event the microgrid DER assets cannot meet the microgrid demand, the ATS in the City Hall would switch to allow the CHP to provide dedicated load following service to the critical IT servers, and, similarly, the ATS in the Fire Station would switch to allow the existing standby generator to provide backup fossil-fuel power to support critical operations.

The microgrid would never parallel the utility grid, and the connections between the DER assets, the loads and the MG Bus would only be closed to form the microgrid when there is an extended utility outage or request from the utility to disconnect from the utility grid. This requires protection controls via electrical relay interlocks between the automatic breakers, as well as hardwire interlock connections to the SSC. Each microgrid load-utility breaker will verify open status and that it is disconnected from the utility grid before the MG bus breakers can be closed by the SSC to island the facilities together as a Microgrid. This can also be seen schematically in the single line diagram and control concept in Appendix B.

MICROGRID CONTROL SERVICES

The services that the SSC and microgrid controls can provide are numerous. Key services are described below.

ISLANDING CONTROL

The SSC has the capability to initiate islanding to form the microgrid, regardless of the utility grid status by commanding the utility-load automatic breakers to open. The SSC would monitor and control all automatic breakers that are a part of the microgrid. Hardwire electrical relay interlocks to the utility-load breakers must prove open in order to energize the microgrid. The SSC can transition the microgrid into an islanded state in several ways. The transition can occur manually as initiated via command by an administrator level user to the SSC if the utility grid was operational. This method would likely be used for testing, maintenance, and commissioning purposes. The transition can also occur from a remote signal initiated via command from utility grid to the SSC. Due to the size of DER assets, this method of islanding any generation assets from the grid will enable the utility to disconnect from the assets to protect the utility grid if there are any problems and/or improve stability. Lastly, the SSC would automatically transition the microgrid to an islanded state upon a loss of utility grid power.

The SSC would not have the capability to automatically reconnect to the utility grid. Based on feedback received from National Grid, reconnection to the utility grid after islanding would need to be coordinated with the local utility. The is due to the size of the loads and generation capacity which would be reconnected.

LOAD SHEDDING

During an islanding event, the SSC could initiate load shedding schemes for load management. Load shedding would be performed via the Building Controls JACE and communicated to HVAC and lighting system controls. The need for load shedding strategies would be identified by the SSC based on BESS charge state, DER outputs, and building demand.

DEMAND RESPONSE

During normal operation, the BESS would be utilized for demand response, such as in the Daily Dispatch program. Upon receiving a DR signal from the CSP, the SSC would calculate the discharge power based on the BESS remaining charge and the duration of the demand response event. This would enable a consistent load shed threshold throughout the DR event. During a DR event, the EV charging stations would be limited to a smaller rate of charge. In addition, new V2G charging station technology may soon be widely deployed, enabling electric vehicle batteries to be utilized during demand response. If these are added to the system, the SSC could manage any additional mobile demand response assets available.

Blackstart and Load Addition

The SSC and BESS would perform the duties of DER asset blackstart and load addition. The general sequence of operation for load addition would be as follows:

1. Prove electrical interlocks from utility load breakers
2. Verify all MG bus-load breakers are open
3. Confirm BESS status and PV systems status as ready, and PV inverters are curtailed.
4. Signal to BESS to establish grid voltage and frequency.
5. Close Shaw's MG Bus-load breaker (anchor load). Shaw's refrigeration controls shall utilize existing sequences for staggered startup (delays) of refrigeration and HVAC loads.
6. The BESS inverter system shall meet the initial inrush current of adding refrigeration and HVAC loads, and the SSC shall slowly enable strings of solar PV to generate as load increases.
7. The SSC shall enable or curtail solar PV output as needed to load follow. The BESS shall alternate between charging and discharging to trim the solar PV production.
8. Sequentially close the MG bus-load breakers for the City Hall, Fire Station, and Memorial Hall.
9. Enable CHP to start.
10. EV charging shall only be enabled for load addition if there is a surplus of solar PV generation available.

DER Asset Control Interface

The Battery Management System Controls would manage internal battery controls, including environmental controls. Similarly, the CHP controller would manage internal CHP operation, including load following. In both cases, the SSC would have supervisory control over the equipment to enable, disable, change setpoints, etc.

Remote Control and Cloud Services

BESS storage optimization may be cloud-controlled by a service provider. Similarly, solar PV data could be used for observability and forecasting through cloud services. The SSC would have the capability to store system data and information, and would utilize MBCx software, such as FacilityConneX, for cloud data acquisition to aggregate, archive, and present useful data sets. The analytics provided by the MBCx software would be used to detect problems and energy waste to maintain the building load systems in optimized operation. The data collected by the MBCx system would include building load energy meters, CHP and Solar PV production meters, BESS energy meter, CHP/BESS/Solar PV equipment key performance indicators, building automation system operational data, refrigeration system operational data, lighting control system operational data, DR events and status, and microgrid key performance indicators/operational data. The SSC would also be configured for remote access by vendors and authenticated users for configuration, diagnostics, and testing.

Selling Energy

The SSC is connected to all meters associated with the microgrids from loads as well as DER assets. The SSC could be used to quantify energy sold from any of the DER assets, using other system meters for verification calculations.

Load Management Plan

If the electric demand on buildings during an islanding event exceeds the available microgrid capacity, either due to failed DERs or unpredictable events, the SSC would communicate with each BAS to initiate load shedding strategies as discussed in the Load Shedding section. Specifically, HVAC cooling would be the first load shed upon reaching critical threshold. Upon a request for additional load shedding, emergency lighting would be dimmed to 50% capacity. In the event of a critical system emergency response, all loads would be shed except for the Fire Station and the circuit(s) feeding the City Hall data center. Prior to the implementation of load shedding strategies, the SSC would signal a warning alarm to all identified personnel.

Resiliency of Microgrid Controls

The two most critical assets to the microgrid control infrastructure are the BESS and SSC. The planned location for the SSC is in the basement mechanical room at City Hall, protected from the outside environment. The BESS will be located on the perimeter of the Plaza Parking Lot, outdoors. The unit shall be housed in application specific enclosures, limiting direct exposure to the harsh climate and mitigating weather risks. The BESS will also be surrounded by bollards, protecting the system from potential vehicular collision.

TASK 4: COMMERCIAL FEASIBILITY

This section explores and presents:

- The importance of these sites to the community and the value they add through the services they provide.
- The proposed microgrid's business model, examining the potential microgrid customers, value proposition, project team, creation and delivery of value.
- The commercial hurdles which this microgrid and other similar microgrids would encounter.
- The value and challenges associated with the selected DERs and control strategies.

CUSTOMERS

AFFECTED INDIVIDUALS

In the event of an electrical outage, the population that would be affected if the critical loads of the buildings included in this microgrid were to go unserved is shown in Table 32, below. Note that due to the Fire Station's existing diesel generator, fire and rescue services would be minimally impacted; however, it is estimated that two employees would be needed for refueling and to ensure continuous operation.

Table 32: Affected individuals. Note that all numbers are estimates based on available census information, information provided by the town, and industry averages (Melrose Massachusetts 2020).

Building	Service	Affected Individuals
City Hall	Emergency Dispatch	28,000
	City Services	28,000
	Employment	75
Memorial Hall	Emergency Shelter	1,000
Fire Station	Fire & Rescue	--
	Generator Service	2
Shaw's Supermarket	Groceries	15,000
	Employment	65

It is important to note that there is overlap in the affected individuals in each category, so totaling the affected individuals identified in the table above would not be an accurate representation and is therefore not provided. However, this data indicates the potential number of individuals who would be affected by a grid outage at just these four sites could represent 0.5-1.0% or more of the 4.8 million Greater Boston residents (Wikipedia contributors 2020). This figure also does not account for individuals who would be indirectly impacted, such as those who may be doing business in or at these facilities or families of those who are directly impacted (such as those who may have relatives living in the elderly care facilities).

SERVICES AND BENEFITS

UTILITY

The proposed microgrid would participate in National Grid's ConnectedSolutions program through the use of the Plaza Parking Lot BESS. Through the ConnectedSolutions Daily Dispatch Program, the battery would be remotely dispatched by the utility either directly or via a DR CSP to discharge during the electrical grid's peak load events, reducing grid stress. The proposed microgrid also includes the installation of several EV charging stations in the Plaza Parking Lot that would be served by the local PV system and BESS. Future areas of study for the proposed microgrid should include the analysis of the EV charging stations with V2G demand response capability.

The proposed microgrid should be reviewed as to its potential for consideration as a NWA to the currently planned capital infrastructure upgrades on the local 4.16kV distribution and/or transformer serving Shaw's Supermarket. In addition to the demand response capabilities of the BESS, the proposed energy conservation measures, rooftop array, and CHP would reduce the net load on the existing distribution system. It is possible that an NWA review could identify an alternative location within their local distribution system that results in greater benefit to the utility to tie in the BESS, parking lot solar PV, and EV charging stations. Together as presently configured, or in another formulation, the technologies involved in this microgrid may have a cost-benefit to the utility to augment or defer the planned capital infrastructure project.

City Hall

City Hall contains the IT hub that supports many city services and operations, handling all phone services for City Hall, six of the eight schools, and all police and fire stations, including emergency dispatch. Although the data center is equipped with a small UPS, without the proposed microgrid, a loss of grid electricity for an hour or more threatens to delay response time and/or impede critical communication for emergency dispatch. This would affect the near 28,000 residents served by the emergency services which are coordinated through City Hall. Additionally, schools will utilize communication and security equipment. The proposed microgrid would ensure a redundant, continuous power supply to the data servers at City Hall. Beyond electrical outages, in the event of a disaster or emergency, the microgrid would allow City Hall to continue to conduct emergency response operations.

The installation of new EV charging stations at the Plaza Parking Lot would provide new charging options if the city were to expand upon their existing EV fleet, which is currently comprised of a few electric vehicles. The city currently has three EVs but has no plans in their current budget to expand the fleet, however the installation of near-by EV charging stations would enable the city to continue the electrification of their fleet more comfortably.

Memorial Hall

During an emergency scenario, Memorial Hall serves as the community's emergency shelter, with a seating capacity of approximately 1,000 residents. Without any existing backup power, Memorial Hall would be unable to provide shelter to residents in need. The ability for Memorial Hall to remain operational during an extended outage would allow the city to use the space to host community meetings and forums and to provide shelter, warmth, or a place to charge mobile devices during disaster scenarios.

Fire Station

The fire station at 576 Main Street is the headquarters for the Melrose's fire department. In the event of an electrical outage, the fire station utilizes an existing diesel generator to remain operational. Due to fuel storage limitations, the generator must be re-fueled approximately every 12 hours to maintain continuous power. This requires at least one staff member of the 58-member department to monitor and maintain the diesel generator during an outage event (Fire Department 2020). The added benefit of the microgrid would allow all members of the fire department to maintain focus on their primary goal of providing fire protection and emergency medical services to the City of Melrose.

SHAW'S SUPERMARKET

Shaw's Supermarket is one of two supermarkets in the City of Melrose and is the closest supermarket for seniors who reside in the nearby senior housing facilities. The ability to remain open during an extended outage event would prevent the scenario of limited access to food and other household supplies for the 28,000 residents of Melrose.

Food access is defined as "access to supermarkets, supercenters, grocery stores, or other sources of healthy and affordable food" (United States Department of Agriculture 2020). Nearby grocery stores that meet the definition of food access have been summarized below in Table 33. The population served by each supermarket has been estimated based on industry rules of thumb including grocery sales per square foot, median household income, and persons per household. In the event that Shaw's is unable to operate during an electrical outage, the Whole Foods in Melrose would likely be unable to meet the food demand for the remainder of Melrose's population. This means that for the approximately 4,600 Melrose residents that are 65 years or older, they would potentially have to travel an additional 2+ miles to access another grocery store (Melrose Massachusetts 2020). For those with limited mobility and/or limited access to a vehicle, and those who lack the funds for regular grocery deliveries, this can create significant challenges.

Table 33: Nearby supermarkets to Melrose Center.

Supermarket	Distance from Melrose Center	Building Area	Population Served
-	Miles	sf	#
Shaw's, Melrose	0.4	36,000	15,000
Whole Foods, Melrose	0.6	31,000	13,000
Stop & Shop, Saugus	2.6	53,000	21,000
Stop & Shop, Malden	2.9	75,000	30,000
Stop & Shop, Stoneham	3.1	46,000	18,000
Total		**241,000**	**97,000**

CONTRACTUAL AGREEMENTS

CITY OF MELROSE AND SHAW'S

The City of Melrose and Shaw's would need to enter into a public-private partnership agreement to initiate the microgrid development. The city and Shaw's would also independently contract with the Owner's Project Representative (OPR), legal advisors, and any other supporting consultants. Key elements of this partnership and project roles are described in more detail later in the Project Team section.

MAAS PROVIDER

The MaaS provider would be selected through a procurement process developed as a part of the public-private partnership agreement between the City of Melrose and Shaw's. The MaaS provider that is ultimately chosen through the procurement process would contract individually with the City of Melrose and Shaw's for their respective PPAs. The PPA would legally establish the energy rate and payment structures, project ownership, and establish that the MaaS provider is responsible to maintain all microgrid DERs including the BESS, SSC, PV systems, and EV charging stations. This type of PPA would also include language describing the MaaS provider's roles and responsibilities during an extended grid outage when the microgrid is formed to island the four facilities, as well as the roles and responsibilities of the City of Melrose and Shaw's.

The proposed configuration includes a dedicated microgrid bus connection between all sites included in the microgrid. In order to construct the microgrid as currently configured, an agreement between the MaaS provider and the utility would need to be created regarding the ownership, use, and service of the microgrid bus crossing Essex Street and protection and lockout controls of the microgrid.

Potential to Expand the Microgrid

The proposed microgrid, as currently configured, would only include the four critical facilities studied as a part of this project, in addition to the Plaza Parking Lot. The potential to expand the microgrid to surrounding businesses in Downtown Melrose was not explored within the scope of this study due to the large quantity of smaller local businesses directly in this area and the effort associated with surveying the mechanical and electrical infrastructure of the buildings for technical feasibility as well as communicating the microgrid's goals with the necessary parties. If the microgrid development is pursued further, additional consideration should be given to the technical, social, and economic impacts of incorporating surrounding buildings and businesses into the microgrid, and it should be explored in conjunction with the utility and community stakeholders whether there are other local businesses or facilities that could be included in the microgrid to provide a critical service when grid power is not available.

Energy Commodities

Due to the location and magnitude of thermal loads included in this microgrid, no district commodities such as steam, hot water, or chilled water, were included in this feasibility study. An interesting energy commodity with increased market share is EV charging stations. The paid EV charging station model could leverage the large solar and battery capacity in the Plaza Parking Lot. The proposed DERs include a CHP system at City Hall. The CHP would utilize a heat recovery hot water loop to capture waste heat from the engine to offset the thermal load at City Hall. The CHP's hot water loop would be tied in to City Hall's existing hot water system through a heat exchanger on the return hot water header before the boilers. Excess waste heat produced from the CHP would be rejected via an integrated radiator. Future considerations for another commodity that could be included in a future revision of the proposed microgrid are EV charging stations with the capability for V2G demand response.

VALUE PROPOSITION

PURPOSE OF THE MICROGRID

The design intent for the proposed microgrid is to increase resiliency for the City of Melrose's emergency services, emergency shelter, and local grocery store to be able to continue to serve the community during an extended outage. The motivation for the microgrid comes from previous winter outages. The longest outage occurred in March of 2018 and lasted for almost 24 hours. Due to the lack of an existing backup power source, the emergency dispatch had to resort to non-traditional methods in order to coordinate emergency services. A secondary motivation is that Memorial Hall could be more fully utilized in the event of an extended utility outage, as a shelter or warming facility, if backup power were available. At the time of this study, no outage data was available for the utility distribution circuit serving Shaw's, however anecdotal information from Shaw's employees indicated that the store experiences occasional outages. Maintaining operation at Shaw's in the event of a grid outage means that even if there is no power at home, local residents can purchase food and supplies nearby. The proposed microgrid concept was intended to maintain operation for all (4) buildings for 24 hours when there is no grid power available.

COMMUNITY BENEFITS AND COSTS

In addition to the benefits described earlier in the report, the microgrid could create resiliency benefits, energy-related benefits, and indirect benefits. The key community resiliency benefits the project would create during extended outage are:

- Increased reliability of emergency dispatch communications and maintaining normal emergency response times from the emergency dispatch systems at City Hall and the emergency services based at the fire station.
- Increased capability to utilize City Hall as an operations center in the event of an emergency.
- The ability to operate a community shelter in Memorial Hall. The shelter may be able to be used by the public to warm up and charge phones or as a gathering space during an emergency to provide services to the public.
- Increased availability of food and supplies to the community. This benefits the community who have access during an emergency, as well as Shaw's, who could benefit from additional sales.

The key energy benefits this project would create are:

- Installation of renewable energy sources offsets building system and EV charging loads.
- Implementation of energy conservation measures reduces building loads.
- Generation of energy related revenue through participation in demand response programs and paid EV charging stations.

- Opportunities for energy-related incentives, rebates, and grants.

The project would also create indirect benefits, such as:

- Furthering the City of Melrose and Shaw's energy and sustainability goals through energy conservation and renewable energy generation.
- Supporting local market growth of various business sectors that would be involved in the implementation of a microgrid project: consulting, design engineering, finance, equipment manufacturing, installation contractors and subcontractors.
- Supporting market penetration and promote adoption of battery energy storage and EV chargers.

The average daily revenue at a Shaw's Supermarket could be used as a metric to estimate the potential added direct benefits to Shaw's if the supermarket is able to remain open for business during an extended grid outage. This number reflects potential revenue which could be gained from additional operating hours during a loss of grid power and does not account for the cost of lost product due to lack of refrigeration which could be avoided if this project were installed. Keeping one of the two grocery stores in Melrose open during a power outage provides a great benefit to the residents of Melrose while also providing an economic benefit to Shaw's.

Unlike traditional infrastructure improvements, a benefit of a MaaS model is it removes the capital cost burden from the microgrid participants and the community. As described previously, the MaaS provider would carry the costs required to implement the microgrid and the participants would purchase electricity through the MaaS provider. This business model could be used to overcome some of the common barriers of implementation for large capital improvements.

The construction of this project would interfere with normal operation of all facilities included in the microgrid, as well as other local businesses, drivers and pedestrians. While the impact of these disruptions is limited to the duration of the construction timeline and can be reduced through careful planning, it is important to note that there is an associated cost. These disruptions likely include, but are not limited to:

- Closing the Plaza Parking Lot to install the solar canopy. If customers cannot park nearby, sales at local businesses may decrease. While there are other local options for parking, this is a heavily-frequented parking lot. The cost-impact on local businesses is very difficult to quantify, however it is directly correlated to the duration of the parking lot closure needed to complete construction.
- Shutting down Essex Street one lane at a time to install the new duct bank. The direct cost of this is traffic detail during construction and loss of any parking meter revenue for paid spots which are inaccessible during this construction. Indirect and difficult to quantify costs in the scope of this study include traffic delays resulting from the construction.
- Installing LED lights in all four (4) buildings, likely during normal business hours. This results in reduced occupant working efficiency when the installation is taking place at the

municipal facilities. At Shaw's, the cost of this will be reflected added labor cost resulting from the requirement to perform the work after-hours, during 3rd shift.

- Planned electric shutdowns for infrastructure upgrades to install and commission upgraded service to the Plaza Parking Lot in support of the canopy solar PV, BESS, and EV charging stations. This could also include demonstration tests of the microgrid protection systems entering and exiting islanding mode.

The costs associated directly to the microgrid participants include, but are not limited to:

- Permanent loss of parking spots in the Plaza Parking Lot to house the BESS
- Capital expense for the City of Melrose to implement the identified ECMs
- Capital expense for Shaw's to implement the identified ECMs
- Capital expense for the City of Melrose and Shaw's to contract the services of an Owner's Project Manager (OPM)
- Capital expense for both the City of Melrose and Shaw's to contract legal services in the development of the microgrid
- Indirect costs of city/staff employee training for the new equipment and controls implemented as part of the microgrid

UTILITY BENEFITS AND COSTS

As mentioned previously, the microgrid may present the opportunity for National Grid to pursue NWAs for the Shaw's distribution system upgrades. The costs associated with the planned capital upgrades should be weighed against the costs associated with achieving the proposed microgrid's design intent, which may include the replacement of transformer(s), communication wiring to the SSC, and metering upgrades to all parcel's served the microgrid. In this way, the utility can take a holistic approach and choose the most economical long-term solution to their capital infrastructure upgrades and potentially reduce ratepayer charges. Refer to the Capacity Impacts and Ancillary Services section for additional discussion on transmission and distribution impacts at the utility level.

The proposed microgrid would also benefit the electrical distribution system through participation in the ConnectedSolutions Daily Dispatch battery demand response program. The BESS located in the Plaza Parking Lot would have the capability of achieving up to 500kW of peak demand reduction during typical high-load hours on the grid. Similarly, although not currently included in the proposed microgrid, the EV charging stations in the Plaza Parking Lot could be implemented with V2G demand response capability.

VALUE OF RESILIENCY

The value of the proposed microgrid extends beyond the quantifiable costs savings and revenue streams. "The standard benefit-cost analysis approach is challenged by attributes of resilience planning" (U.S. Department of Commerce 2020). The value added is not catered towards the standard cost-benefit approach used in investment decision making processes. The current microgrid arrangement is presented so all revenue streams would be channeled through the MaaS provider, while the purchaser of power would achieve energy cost savings and avoided costs. The life cycle cost analysis (LCCA), shown in the appendices for each party, only quantifies the energy cost savings at this time, and does not include the potential value of resiliency.

Quantifying the value of resiliency should include estimates of the added sales and the avoided cost of throwing away spoiled product that Shaw's could realize should they be able to remain open for business during an extended grid outage. Consideration should also be given to resiliency benefits and costs which are not as easily quantified, such as but not limited to:

- The direct and indirect costs if normal emergency dispatch communication and response times are not maintained during periods of extended grid outages.
- The direct and indirect costs if the local community has limited access to food and supplies during an extended outage.
- The microgrid's construction and implementation offers Massachusetts-based companies the opportunity to be awarded contracts for necessary construction, controls, and maintenance, including long-term service agreements (LTSAs).
- Maintaining building operation will boost downtown foot traffic, ultimately increasing sales for non-microgrid facilities that remain open during power outages.
- Implementation of the microgrid may trigger the development of a more formalized resiliency plan in Melrose and surrounding communities.

Refer to the Quantifying the Value of Resiliency in a Short-Term Outage section for quantifiable value added through the proposed microgrid.

SWOT

The strengths, weaknesses, opportunities, and threats (SWOT) for the proposed microgrid arrangement are shown below in Table 34.

Table 34: Proposed microgrid's SWOT analysis.

Strengths	Weaknesses
• No system maintenance and staffing for microgrid participants • Capital cost for microgrid participants to implement energy resiliency is limited to their consultants and advisors • Cost-effective energy conservation component also reduces facility baseloads • Reduces carbon emissions through the use of renewable energy and furthers microgrid customer's climate goals	• Utility cost to complete required infrastructure upgrades • Poor return on investment • Costs do not fit into the traditional investment return analysis because the threats are difficult to monetize • Non-monetary benefits are not considered by microgrid participants • High % of solar in the DER portfolio results in cost challenges for equipment sized to meet MG electric baseload without utilizing fossil fuel generators at night. • Lack of community engagement and support • Poor financial and commercial viability needed to attract the MaaS provider
Opportunities	**Threats**
• Seek NWAs to utility capital infrastructure upgrades through microgrid implementation • Provide guidelines for future state/utility programs and legislature to improve project payback • Develop metrics for value of resiliency and cost of not being resilient that can be used to generate community support	• No action is taken following this study and the lack of resiliency results in a catastrophic event • High first cost and poor ROI for developer and financier • Complicated and constantly evolving incentive programs • Utility will not allow easement of existing duct bank across Essex Street for microgrid electrical infrastructure

Project Uniqueness

The sites selected for the proposed microgrid include both private (Shaw's) and public (City Hall, Memorial Hall, Fire Station) microgrid participants. In addition, Shaw's and the municipal buildings are separated by Essex Street, which features a utility-owned duct bank. This project is unique due to the close proximity of all critical facilities as well as an elderly housing complex. Also unique to this project is the timing of the electrical distribution upgrades in National Grid's 5-year capital plan.

REPLICATION AND SCALABILITY

There is a large potential to replicate/scale this microgrid study due to the similar characteristics that can be found in most of the 351 towns and cities in Massachusetts. New England is routinely subjected to severe winter storms that cause electric power outages ranging in duration from a few hours to several days. Many towns have critical facilities that need to remain operational during these outages but lack the budget allocations needed to implement resiliency. This study identifies the barriers required to be broken down before making the proposed solution scalable.

One aspect which could be considered a benefit for scalability is having a national or regional company as a private partner. If a national or regional private partner were interested and bought into the concept, there wouldn't be a need to continually educate another private company for every new microgrid opportunity. The approach and familiarity by decision makers if one project could be successfully implemented means there is less work to get to the next site. Further, if the project is a success, the private partner may be mining their own data to identify candidates for rolling out a program at scale.

PROMOTION OF STATE POLICY OBJECTIVES

The Global Warming Solutions Act (GWSA) set the goal for Massachusetts to reduce greenhouse gas (GHG) emissions between 10%-25% below statewide 1990 GHG emission levels by 2020 and 80% below statewide 1990 GHG emission levels by 2050. In 2018, the Comprehensive Energy Plan (CEP) was published to provide strategies to meet the goals laid out in the GWSA. The report identifies that the greatest amount of emission reductions will be achieved through a combination of reduced energy consumption and the use of clean energy.

The proposed microgrid promotes the goal set forth by the GWSA using both methods. Through implementation of energy conservation measures, all four buildings would reduce energy consumption by approximately 460,000 kWh or 19% of their combined annual electric consumption. In addition, the microgrid DERs consist of 819 kW of PV systems, which have a design annual output of approximately 950,000 kWh, or 48% of the total microgrid electric load. The combined effects of reduced energy consumption and renewable energy production results in a total of approximately 1,410,000 kWh or 58% of the building's current electricity use producing zero on-site emissions.

In May of 2015, Massachusetts launched the Energy Storage Initiative (ESI) with a target of installing 1,000 MWh of energy storage by the end of 2025. The proposed microgrid concept includes 3.3 MWh of BESS capacity, or 0.33% of the state's ESI target.

MA STATE BENEFITS

The proposed microgrid offers both direct and indirect benefits to the Commonwealth. The microgrid would be operated and maintained in Massachusetts, giving the opportunity for local companies to participate in the design, construction, and maintenance of the microgrid. Massachusetts-based OPR consulting and design firms would likely be the most equipped to work with the local utilities, microgrid participants, and state officials in the design of the proposed microgrid. During the bid process, it is likely that the MaaS provider will request quotes from local subcontractors for the construction; electrical, mechanical, controls, and IT subcontractors would all be needed in the development of the microgrid. Continued maintenance would be required on all DERs, providing additional opportunity for local contractors. Lastly, there are several local providers of the DERs that could be procured, such as NEC Energy Solution battery storage systems, Aegis combined heat and power systems, and Russelectric microgrid controls, to name a few.

Indirect benefits to the state include the promotion of microgrid opportunities within the state. The proposed microgrid would be visible to state and local community members, resulting in increased recognition of the technology. The exposure of the microgrid has the potential to increase market sector business within the state.

PROJECT TEAM

PROJECT SUPPORT

SUPPORT FROM POTENTIAL MICROGRID PARTICIPANTS

Current support for a microgrid from the City of Melrose is primarily from the energy and facilities personnel, who identified the potential opportunity to improve energy resiliency. Shaw's and Albertsons are supporting this study by contributing information and time from their personnel to provide information and site walkthroughs. This study was also supported by leadership of the microgrid participants as the pursuits of energy resiliency, renewable energy, and energy conservation align with their climate stewardship goals. Ultimately, however, support for moving ahead to further develop and implement a microgrid is dependent upon the overall feasibility and the potential ROI. The ROI calculations presented in this study are based solely on energy-related benefits, grants, and incentives, as discussed in other sections of this report, and are structured to provide a payback to the City of Melrose and Shaw's. However, the ROI for the developer presently is not sufficient to generate interest from a project MaaS provider and/or financier in a formulation that also meets Shaw's and Melrose's financial requirements to pursue a project. The financial gaps identified in other sections of this report could be reduced if the value of being resilient and the cost of not being resilient was considered in the project economics from the microgrid participant's perspective. In particular, quantifying the value of resiliency and the cost of not being resilient to its customers and community stakeholders could make the case for Melrose and Shaw's to contribute financial resources to support a microgrid project. This ties back to community and stakeholder support for a microgrid during conception and development. Stakeholders need to embrace "outside the box" building technologies which could directly and/or indirectly support a microgrid. Another component of the importance of stakeholder interest is the willingness to share key data and input for the microgrid and resiliency plan conceptual development such as emergency plans and operating procedures or energy commodity rates which are often otherwise considered to be confidential. In some cases, the stakeholder may in fact be bound by a non-disclosure agreement and bound to such confidentiality, so new pathways may need to be developed to capture this and other critical, yet sensitive information.

SUPPORT FROM THE COMMUNITY

Community support is critical to moving this project or any community microgrid forward to implementation, as community opinion influences political decisions and support, or lack thereof, from the municipal government. In order to advance the microgrid concept in the City of Melrose, community stakeholders such as energy conservation commissions, Metropolitan Area Planning Council (MAPC), emergency management teams, first responder associations and local business associations would need to be engaged and actively involved in greater outreach to members of the community to strengthen support for resiliency initiatives with the goal of translating into political support and leverage that to support the microgrid project. This outreach should include soliciting input from supporters to help quantify the value of being resilient and cost of not being resilient in an effort to garner community support for a municipal investment in this microgrid.

Additional support from the community is present as shown in the capital improvement plan for the fiscal year of 2020. The first priority capital improvement project in the plan calls for the installation of a back-up generator at City Hall. The planned generator shows that the City is motivated and sees the value in the implementation of resiliency for their critical facilities. The generator at City Hall was voted as the top recommendation to improve resiliency in Melrose as part of the City's Natural Hazards Mitigation Plan (NHMP) (CDM Smith 2020). The planned generator installation could be used to supplement the proposed microgrid.

The City of Melrose signed a commitment in 2017 to achieve net zero emissions by 2050. This is a strong indication that the local community generally supports climate change mitigation and energy conservation efforts. The MAPC is currently working with Melrose to draft a net zero plan for the community, which according to the MAPC website will influence net zero plans for other communities across Massachusetts and set ambitious climate goals for the City. Discussion of the results of this microgrid study should feed into the net zero plan to broaden support for the project at a regional level as well as to establish how a microgrid concept similar to this one could be leveraged for both resiliency and furthering climate goals.

Support from the Utility

Support from the utility is a key success factor in the development and implementation of a microgrid. National Grid supported the study by providing information and was receptive to customer input as it relates to this feasibility study and their infrastructure planning. National Grid also provided thoughtful preliminary feedback on the microgrid concept. While National Grid is including investments in local infrastructure in their 5-year capital plan, this microgrid concept could be supported through further consideration of this area for NWA potential. The goal would be to understand whether investments from National Grid into such a project could support their infrastructure goals and have a cost-benefit when compared to traditional infrastructure upgrades through "wires-construction." If there is found to be a cost-benefit to the utility for investing in this project either through the NWA program or through another channel, it could improve the project economics. Support from National Grid is also needed to better understand the utility infrastructure costs associated with the microgrid project in order to improve confidence in the return on investment calculation. Further, an opportunity for further study is for National Grid to explore the possibility of owning, maintaining and operating the portion of the microgrid bus that crosses the Essex Street right of way. This would provide valuable insight to inform this and future projects.

Creating the Public Private Partnership

The nature of the proposed microgrid is based on a public-private partnership that would be needed to be created in order to develop the project further. This would necessitate creating legal agreements between the City and Shaw's, the exact nature of which would need to be determined in the future by the City's and Shaw's legal teams. Developing the partnership agreement would likely require a legal advisor or consultant experienced in public-private partnerships, energy and utility work to work on behalf of the City of Melrose, and the City may need to issue an Request for Proposal (RFP) to procure these services. Since Albertsons (and Shaw's) is a national company with broader resources, they may be able to develop their side of the partnership agreement using internal resources, however it may be beneficial to engage outside advice for this task. In addition, for setting the legal terms upon which the two entities would work together, a key project team-related aspect of the agreement would be to create a committee formed of a team of representatives from both organizations. The purpose of the committee would be to refine the project criteria, develop qualification and proposal request documents for, and eventually select, the Owners Project Representative, and generally provide project management and oversight from the participant's organization. Entering into this agreement is likely to require a city council vote by Melrose and support from Shaw's and Albertson's senior leadership.

SELECTING THE MAAS PROVIDER

The Owners Project Representative would work on behalf of the microgrid participants and would need to have consulting and engineering capabilities either internally or supported by a team of subconsultants, including an energy/microgrid specialist as a key team member. The OPR would draft the project criteria and create the RFP for the MaaS provider, working with the public-private partnership committee to gain their input. Due to the first cost and nature of the project, the MaaS provider may likely need to be selected through a bidding process that meets both municipal procurement law as well as Shaw's procurement requirements. The procurement and legal departments from each customer would be key project team members during the early stages of partnership development, including some involvement and interaction with the selection committee and the OPR to provide key input on selection processes, verbiage, and execution. It is worth noting that with an improved project return on investment, more potential project developers would respond to the RFP creating greater diversity and generating price competition between the pool of developers bidding on the project.

Development Phase General Responsibilities for Key Team Members

City of Melrose	• Engage community groups for support for energy resiliency project • Hires legal advisor/consultant to support/augment city solicitor • Provide input during OPR creation of project criteria and MG operation plan • Acquire funding and support to implement the identified ECMs to reduce the buildings' base loads • Conduct a study to identify need/demand for additional EV charging station(s) • Participate in OPR selection • Initiate dialogue with utility • Allow on-site access to MaaS provider, assist in walkthroughs and provide necessary information
Shaw's	• Provide input during creation of project criteria and MG operation plan • Participate in OPR selection • Initiate dialogue with utility • Implement the identified ECMs to reduce the building's base load • Allow safe, on-site access to MaaS provider, assist in walkthroughs and provide necessary information/documentation
OPR	• Hires subconsultants as needed – for site, civil, power, controls, energy, mechanical, financial RFP development and oversight of developer • Develop owners project requirements and MaaS provider bid documents • provide bid assistance and bid evaluation, including review of proposed subcontractors and equipment • work with microgrid participants to develop dialogue utility • negotiate value engineering and design alternatives • work with customer's legal teams and advisors, and MaaS provider to review and provide input on contract between MaaS provider and microgrid participants • Technical support such as support interconnection application documents review • Takes over administrative leadership during development phase once selected • re-confirm project economics throughout development as design evolves and funding sources are developed

MaaS Provider	• Conduct site visits to determine required infrastructure upgrades • Develop design drawings and specifications for all infrastructure (communication, electrical, thermal, DERs) • Submit interconnection agreements to National Grid • Develop and review RFPs. Contractors will be selected based on previous project experience and proposed cost. Massachusetts-based suppliers and contractors would be preferred • Acquire funding for capital improvements from private investors. Investors will be acquired through the MaaS provider's typical procurement methods • Hires subconsultants and subcontractors
National Grid	• Review opportunity for NWA evaluation • Assist MaaS provider in the technical design requirements for the proposed microgrid interconnections • Conduct a system impact study to determine the impact of DERs • Review interconnection agreements • Upgrade utility infrastructure as needed • Process energy efficiency incentives

Construction Phase General Responsibilities for Key Team Members

City of Melrose	• Allow on-site access to contractors, utilities, and MaaS provider • Attend construction meetings as appropriate • Participate in customer training
Shaw's	• Allow on-site access to contractors, utilities, and MaaS provider • Attend construction meetings as appropriate • Participate in customer training
OPR	• Approve key submittals • Review commissioning documentation • Construction and commissioning close out
MaaS Provider	• Provide project management and host meetings between all relevant stakeholders including utilities, contractors, Shaw's, and the City of Melrose • Manage contractors, ensuring specifications are being met
National Grid	• Respond to MaaS Provider and contractors' requests for information (RFIs) • Manage utility infrastructure upgrades • Oversee contractor interconnections • Participate in witness testing of microgrid protection schemes for grid infrastructure • Possibly construct, own, and maintain the MG bus connecting microgrid participants

OPERATION PHASE GENERAL RESPONSIBILITIES FOR KEY TEAM MEMBERS

CITY OF MELROSE	• Provide access to MaaS provider and DER maintenance personnel • Document experience and reflect on best practices and lessons learned to spread understanding of benefits and value chains
SHAW'S	• Document experience and reflect on best practices and lessons learned to spread understanding of benefits and value chains • Provide access to MaaS provider and DER maintenance personnel
MAAS PROVIDER	• Manage billing of microgrid users • Manage maintenance of DER assets and controls • Maintain communication between utility, microgrid users, and ConnectedSolutions/ESP • Document experience and reflect on best practices and lessons learned to spread understanding of benefits and value chains
NATIONAL GRID	• Maintain communication with MaaS provider • Document experience and reflect on best practices and lessons learned to spread understanding of benefits and value chains • Possibly construct, own, and maintain the MG bus connecting microgrid participants

Creating and Delivering Value

Value Delivered by Microgrid Technologies

The following sub-sections are an analysis of the benefits and challenges associated with the microgrid technologies that were selected for integration into the proposed microgrid. It should be noted that the technologies were selected to promote clean energy initiatives set forth by the Commonwealth of Massachusetts. From a purely economic analysis, fossil-fuel generators would be the most cost-effective method at meeting the immediate need for resiliency at sites included in this microgrid.

Photovoltaic

Benefits

Solar arrays are a time-proven technology that provide a 100% renewable source of thermal or electrical energy. The systems selected for the proposed microgrid would be used for electrical generation. This technology is widely deployed and would have high visibility in the community. Once installed, solar requires minimal maintenance and can serve as an emission-free energy source for an average lifetime of 20-25 years. For canopy solar arrays located in parking lots, such as the proposed Plaza Parking Lot array, the PV system could provide shade in the summer and snow cover in the winter, as well as improve rainwater management, for employees and visitors parking their car in the lot.

Challenges

One of the main disadvantages of photovoltaic systems for resiliency applications is the variability of their electric generation. PV output is highly dependent on weather, time of day, and time of year. A solar array of the size included in the concept of this microgrid has the potential to create a “duck curve” load on the local distribution system, which occurs when a significant portion of the local load is served by solar PV when the sun is shining, and as the sun sets and generation from the solar PV diminishes the load seen on the grid significantly increases, shifting the peak load period on the local grid towards dusk. Another challenge is that solar PV cannot be independently relied on during an off-grid scenario as it is a passive technology and PV inverters require an established electrical grid to follow for voltage and frequency regulation. In order to utilize PV arrays for off-grid resiliency applications, battery energy storage of the appropriate capacity is necessary to form the grid and black start the solar PV generation for microgrid use. The challenges identified above are technical in nature and can be addressed through a BESS, and would be able to be addressed in the proposed microgrid concept.

Due to space constraints, the proposed microgrid utilizes canopy PV in the Plaza Parking Lot. Canopy solar is typically more costly to install than traditional rooftop solar. In addition, the canopy solar array would likely eliminate a number of parking spaces in order to accommodate the proposed solar system, depending on the location of the electrical gear and placement of the solar PV canopy footings and supports. This challenge would need to be addressed by the project team through strengthening community support to outweigh the negative aspects of reduced parking spaces.

An additional challenge that would need to be vetted during the design phase is the structural capacity of the Shaw's, City Hall, and Memorial Hall rooftops. The structure of the buildings and their rooftops would need to studied in order to determine what, if any, upgrades are required to support the added weight of the rooftop arrays. Similarly, borings would need to be performed to collect soil samples from the Plaza Parking Lot. The soil samples would determine what foundation types are needed for the canopy array, which can significantly impact costs.

Battery Storage

Benefits

The proposed microgrid would contain (1) 3,300kWh/500kW lithium ion BESS. The battery storage would be utilized to meet the microgrid's electric demand during an islanding event. In the absence of a utility connection, the BESS would be able to form the grid, maintaining the bus voltage and frequency for all other passive DERs to follow. With this capacity, the BESS could support operation of the supermarket refrigeration systems overnight. In addition, the BESS can precisely load follow the entire microgrid's electrical demand, charging during instances when the DER electric output exceeds the electric demand and discharging when the electric demand exceeds the DER electric output. The BESS would allow passive, renewable DERs to operate at maximum capacity without the need to curtail. During normal operation, the BESS can be used to participate in utility and state programs, such as demand response, to provide a source of revenue and to reduce congestion on the electric grid.

Challenges

The substantial battery capacity would be required for resiliency due to the large nighttime electric load from Shaw's refrigeration and the lack of DERs with nighttime generation capabilities to meet the microgrid baseload. Due to the energy storage capacity required, the BESS would have a high capital cost. Additionally, it would require a significant amount of physical space and produce a challenge to locate the system in the busy Downtown Melrose area. The space required for a BESS of this size would require the elimination of several parking spots. The BESS was proposed to be located in the Plaza Parking Lot due to space constraints in other locations as well as to match the BESS capacity with the largest DER - the Plaza Parking Lot canopy array. New NFPA standards require BESS to have 10 feet of distance from nearby buildings and infrastructure. To accommodate the BESS, civil engineering may be required to modify the parking lot lawn, garden, and walking areas.

Combined Heat and Power

Benefits

The proposed microgrid would contain a CHP system located on the exterior of City Hall. The system would provide a source of electricity and heat for City Hall, only requiring a utility gas connection. CHP systems can typically operate for 97% of the hours of the year, assuming minimal downtime for service and maintenance. Unlike other DERs included in the proposed microgrid, the CHP system can continue to provide electric and thermal output regardless of the time of day. The system would be sized to be capable of meeting the electric demand of City Hall's data center and emergency dispatch infrastructure.

Challenges

For resiliency applications, the main disadvantage of combined heat and power systems is that it requires an external fuel source to operate. Given an interruption in the utility gas connection, the system would be unable to operate. CHP systems are most cost-effective when they can operate at maximum electrical output and have minimal thermal dumping; however, the thermal load at City Hall is near zero in warmer weather, which would result in decreased performance and efficiency of the operating CHP. The reduced overall efficiency of the CHP at City Hall could potentially disqualify the unit from meeting benchmark metrics required for higher utility incentive levels. More importantly, the thermal load limitation reduced the capacity of CHP that could be realistically installed resulting in a negative impact on the required energy storage capacity to meet the microgrid nighttime baseload. As mentioned previously, City Hall would be better suited for a back-up emergency generator.

Electric Vehicle Charging Stations

Benefits

EV charging stations, while not a DER in the proposed application, have the ability to become an important component of the microgrid. Paid charging stations could be installed by the MaaS provider to create a new system load with an additional source of revenue utilizing the excess energy generated by the solar PV canopy. Future demand response and energy storage benefits could be realized if V2G charging stations became commercially available.

The implementation of the proposed EV charging stations could result in deeper market penetration of charging stations in downtown Melrose, building upon the existing (2) charging stations that are known to be available at the time of this study. The installation of additional EV charging stations at the Plaza Parking Lot could directly support municipal fleet electrification as well as the broader community and state climate goals as they relate to vehicle emissions. The charging stations could also indirectly support market adoption of EVs in general by providing increased local operations for charging. Lastly, the project presents the opportunity to evaluate incorporating infrastructure upgrades that could support DC fast chargers.

Challenges

One of the greatest challenges in the implementation of the proposed EV charging stations is the lack of data needed to match installed capacity with local demand. In order to more accurately quantify the potential revenue from paid EV charging stations, the present and future localized market penetration of electric vehicles as well as the market saturation of charging stations in the area would need to be better understood. It is recommended for further study to more concretely quantify the potential revenue from paid EV charging stations and the potential future increase in paid charging station customers. Another challenge for the EV charging stations is the implementation of the required infrastructure needed to support the electric loads. Requirements for infrastructure improvements may be resolved through the proposed BESS and PV installation that would be on the same parcel, however further investigation is required.

Leveraged Existing Assets

The existing diesel generator at the Fire Station, although it would not be tied in to the proposed microgrid bus, would be able to meet the Fire Station’s load during an electrical outage. The existing generator would enable the microgrid to remove the Fire Station's load from the microgrid if the BESS and DERs would be unable to maintain the entire microgrid electric load.

The existing data center at City Hall is equipped with existing data and tele/com infrastructure that could be utilized in the proposed microgrid's controls.

CHARACTERIZATION OF DISTRIBUTED ENERGY RESOURCES

Existing and proposed DERs are shown in Table 35. It can be seen that the mix of DERs is weighted heavily towards solar and storage assets. The only DER with thermal output is the proposed City Hall micro combined heat and power (micro-CHP) system. The 10kW micro-CHP would only serve the thermal loads at City Hall. It should be noted that the existing natural gas generator at Shaw's and the existing diesel generator at the Fire Station would not be utilized in the proposed microgrid, but have been included in the table below for reference.

Table 35: DER summary.

Location	Asset Type	New/Existing	Fuel Source	Electric Capacity	Thermal Capacity
Shaw's Rooftop	NG Generator	Existing	NG	20 kW	N/A
Fire Station Basement	Diesel Generator	Existing	Diesel	33 kW	N/A
City Hall Exterior	NG Micro-CHP	New	NG	10 kW	57.3 kBtu/h
Shaw's Rooftop	PV	New	N/A	186 kW	N/A
Memorial Hall Rooftop	PV	New	N/A	73 kW	N/A
Plaza Parking Lot	PV	New	N/A	560 kW	N/A
Plaza Parking Lot	BESS	New	N/A	500kW/3300kWh	N/A

The average operating outputs for normal and islanded operation are shown in Table 36. Note that the existing generator at Shaw's will not be included in the proposed microgrid's operation. As shown below, the units will not operate during normal and islanded operation. The annual electric output of City Hall's CHP assumes an average availability of 97% during normal operation; during islanded operation, it is assumed that CHP would operate without interruption. Daily production of photovoltaic DERs is largely dependent on the time of year and weather conditions during the power outage. The daily production values shown for the PV systems are based on the daily average for the entire year.

Table 36: DER production summary. Note that on-site fuel storage is shown in equivalent full load hours (EFLH).

Location	Asset Type	Average Annual Production - Normal Operation	Average Daily Production - Islanded Operation	Fuel Input Per Electric Output	On-Site Fuel Storage
-	-	MWh/year	MWh/day	MMBtu/MWh	EFLH
Shaw's Rooftop	NG Generator	0	0.00	9.7	N/A
Fire Station Basement	Diesel Generator	0	0.00	8.5	6
City Hall Exterior	NG Micro-CHP	85	0.24	10.8	N/A
Shaw's Rooftop	PV	237	0.65	N/A	N/A
Memorial Hall Rooftop	PV	90	0.25	N/A	N/A
Plaza Parking Lot	PV	618	1.69	N/A	N/A
Plaza Parking Lot	BESS	0	0.00	N/A	N/A

ENERGY BALANCE

The available space for PV installations at each parcel did not match that parcel's electric demand in many cases. For example, the Plaza Parking Lot parcel consumes approximately 32,000 kWh annually; however, the parking lot has the capability of housing a 560 kW PV array which can produce approximately 618,000 kWh annually. In order to maximize the energy production of the microgrid to increase resiliency during an extended outage, all feasible PV would be installed. The proposed DERs as a result were not expected to equally balance energy production and microgrid electric demand.

Table 37: Summary of DER generation versus load by site.

Location	Annual DER Generation	Annual Electric Load
-	kWh	kWh
Shaw's	236,889	1,607,243
City Hall	84,972	182,805
Memorial Hall	89,597	84,266
Fire Station	0	81,312
Parking Lot Plaza	617,989	32,142
Totals	**1,029,447**	**1,987,768**

During an islanding event, excess PV generation from the daytime would be stored in the proposed 3.3MWh BESS located in the Plaza Parking Lot. The daytime BESS charge would enable the microgrid to continue operating throughout the night when the microgrid DERs are no longer generating energy. The BESS capacity was selected with the intent of maintaining continuous islanded operation of 24 hours, balancing microgrid energy production with microgrid energy demand.

During normal operation, the BESS would allow the parking lot canopy array to reduce the amount of energy sold to the grid at wholesale rate during peak solar hours by storing the energy when the solar production is high and discharging when the solar production diminishes. This would prevent the array from contributing the duck curve effect. The selected BESS location allows the canopy array and BESS to maximize financial support through current utility and state programs such as SMART and ConnectedSolutions. During the daytime, the BESS would be charged with excess PV production from the parking lot's canopy array. In the summer or winter, the BESS would discharge available charge to the grid to participate in National Grid's ConnectedSolutions Demand Response program.

Changes in state/utility programs and legislature could be made to improve the energy balance and economic feasibility of the proposed microgrid. For instance, by expanding the net metering cap to allow for solar arrays participating in microgrids, the parking lot array's energy production could be used to offset the electric import billed to the microgrid sites. If the microgrid could take advantage of net metering, it would improve project economics by eliminating the wholesale of the Parking Lot Plaza's PV energy.

DEVELOPMENT, CONSTRUCTION, OPERATION, AND PERMITTING

The recommended method for project development, construction, and operation would be through a MaaS provider. The MaaS provider would utilize existing staff experts or consultants to assist in the design, permitting, construction and commissioning process. The MaaS provider would also utilize in-house maintenance providers or subcontract maintenance services for the continued operation of the microgrid assets. Refer to the Project Team section above for a complete description of each group's role in the fulfillment of this project.

Common permits required for this project include the installation and interconnection of solar and small-scale CHP assets. Unique permitting would also be required due to the large BESS and the street crossing connecting the MG bus between the municipal buildings and Shaw's.

The 3,300kWh BESS would be used to participate in the ConnectedSolutions Daily Dispatch and Winter Dispatch programs, discharging stored energy during peak demand periods in the summer and winter. To maximize revenue and utility benefit, the battery would be discharged at a rate up to 500kW. Although this program does not require a special permit, the magnitude of generation would need to be reviewed at a circuit and substation level to determine the feasibility of the control strategy.

National Grid has also stated that they will not provide a utility easement that would allow the MG bus connection through the existing duct bank that crosses Essex Street unless they construct, own, and maintain the MG bus.

Noise and air quality requirements would need to be considered during the design phase of City Hall's CHP. The exact make, model, and location of the CHP would be contingent upon maintaining code compliance and meeting local ordinances.

DELIVERING COMMUNITY BENEFITS

The goal of the proposed microgrid is to provide a sustainable and resilient form of energy to the City of Melrose and Shaw's. In the event of a power outage, all components of the microgrid must be ready to operate as expected or none of the proposed benefits will be realized by any party. To ensure proper operation, it is important that all components are tested during start-up and commissioning. Monitoring based commissioning can also be done throughout the life of the microgrid via fault diagnostics and analytics on the system data flowing through the SSC. Periodic maintenance and service will also need to be provided adequately by the MaaS provider or their subcontractor/factory technician to ensure equipment is operating at its peak performance.

UTILITY UPGRADES

National Grid has recently discussed the planned demolition of the substation currently serving all facilities included in this microgrid. Future considerations to utility upgrades as they relate to this microgrid concept will be dependent on the proposed configuration of the new utility infrastructure, unless the microgrid concept development can be incorporated into National Grids capital plan either through NWA evaluation or some other channel. It should also be noted that the microgrid's capital costs could be reduced if the substation demolition and infrastructure upgrades are refined to be implemented in a manner that could augment and support the proposed microgrid's design intent. As discussed previously, the capital infrastructure improvements conducted with national grid, when considered in tandem with the proposed microgrid, may offer a NWA cost-benefit. Input from the utility on the optimal tie-in points for the microgrid in the distribution system would help streamline the conceptual development effort as well as potentially benefit the utility's plans.

To support the current microgrid design, several upgrades to utility infrastructure would be required. Though actual infrastructure upgrades would be determined during the system impact study during the interconnection agreement process, a preliminary list of anticipated upgrades that are major cost-factors would likely include the following:

- Converting the single-phase overhead circuit serving the Plaza Parking Lot to three phase
- Upsize the transformer serving the Plaza Parking Lot
- Upgrade transformer's grounding system with redundant protection
- Install electrical equipment to protect the utility grid from anomalies and unintentional islanding, such as direct transfer trips (DTTs) and reclosers.
- Protective controls such as lockout relays with network communication that allows the utility to disconnect the microgrid facilities from the grid if there are anomalies or problems.

MICROGRID OPERATION

The proposed operational scheme for the microgrid would be developed through contractual agreements between:

- MaaS provider and the utilities (interconnection agreements, ConnectedSolutions, electricity wholesale)
- MaaS provider and purchasers of electricity (Melrose and Shaw's)
- MaaS provider and the service/maintenance subcontractors

The MaaS provider would be solely responsible for the development, construction, and operation and maintenance of the DERs and all associated infrastructure. The MaaS provider would manager or subcontract the management of energy metering and billing to the City of Melrose and Shaw's according to a fixed rate PPA for the electricity generated from the microgrid. Microgrid energy consumption would be sub-metered via the SSC and billed to the appropriate party through a PPA.

Task 5: Financial Feasibility

The purpose of the following section is to:

- Develop the inputs and supporting information for a wholistic cost-benefit analysis of the microgrid.
- Estimate and quantify the resiliency benefits to the extent possible.
- Investigate the costs associated with the planning, design, implementation and operation of the resiliency driven microgrid.
- Investigate the revenue streams associated with the services provided by the microgrid.
- Determine the financial feasibility for all stakeholders of the proposed microgrid.

As noted within this section, the microgrid is not financially viable in its current configuration and will not be for the foreseeable future, without financial support of grants and incentives and/or a radical change in municipal funding, commercial support of the local utility, and support through state legislation. To that extent the financial structure used in the economic analysis of the proposed microgrid is arranged such that all economic loss falls on the MaaS provider, demonstrating the magnitude of financial shortcomings. A summary of the key financial metrics can be found in Table 38. Please refer to Appendix D, Appendix E, and Appendix F for 20-year life LCCA for the MaaS provider, City of Melrose, and Shaw's, respectively.

Table 38: Summary of key financial metrics.

Party	Capital Costs	Internal Rate of Return
Project Developer		
MaaS Provider	$9,409,600	-0.5%
Customer		
Shaw's	$448,025	13.3%
City of Melrose	$126,546	0.8%

Supporting Customer Information

Financial Criteria

Shaw's Supermarket belongs to the retail trade economic sector. Although exact financial criteria have not been specified by Shaw's, the anecdotal indication is that an energy improvement project would require a simple payback of two years or less to be considered attractive.

City Hall, Memorial Hall, and the Fire Station are municipal buildings that belong to the public sector. Historically, the City has tended to prefer projects with attractive paybacks, but they do not have any required financial criteria. The City understands that the need for resiliency is crucial, especially for City Hall's IT servers. The City has currently budgeted $480,000 for a generator at City Hall in FY2020 and has placed the project at the top of their priority list (City of Melrose 2019). The generator would only be utilized for emergency power and would produce no monetary benefits other than that created by resiliency. This indicates that the City of Melrose has placed a substantial value to resiliency, without any financial criteria.

Existing Utility Service

Natural gas and electricity are supplied by National Grid to the four buildings within the proposed microgrid. The Plaza Parking Lot's lighting is also served by National Grid but the parking lot is not equipped with a utility gas connection. The rate class to which each facility belongs, Small Commercial (SC) or Large Commercial (LC), is shown in Table 39. Annual electric use and peak electric demand for each site is also shown in Table 39. Each facility's utility services are paid by a single ratepayer; however, if the microgrid was expanded in a future revision of the concept, multi-tenant commercial buildings could be integrated.

Table 39: National Grid rate class and annual electric use,

Location	Economic Sector	Electric Rate Class	Natural Gas Rate Class	Annual Electric Use (MWh)	Peak Electric Demand (MW)
Shaw's	Retail Trade	LC	SC	2,004	0.332
City Hall	Public	SC	SC	213	0.084
Memorial Hall	Public	SC	SC	104	0.051
Fire Station	Public	SC	SC	96	0.024
Plaza Parking Lot	Public	SC	N/A	42	0.011

Each building included in the microgrid has minimal non-essential electric use; although emergency lighting could be utilized to dim the proposed LED lights in addition to other identified in the Load Shedding Strategies section. On average, given a typical meteorological year, the microgrid could provide power 30 consecutive hours. After which, it is expected that Shaw's Supermarket utilize a dispatchable generator to remove its entire load from the microgrid, allowing the microgrid to provide continuous power via the remaining DERs.

CURRENT COSTS DURING A POWER OUTAGE

The existing backup generators at the sites within the proposed microgrid are shown in Table 40. The Shaw's natural gas backup generator is served by the building's natural gas utility service. The generator is sized and connected to provide power for emergency lighting during an electrical outage. During an extended outage, it is expected that the backup generator would operate at 100% of its 20kW nameplate capacity to power emergency lighting as Shaw's staff relocate frozen and refrigerated produce. The fire station's diesel backup generator is tied in to a subset of the building's electrical circuits and can meet all critical loads during a power outage. During an extended power outage, it is expected that the unit operates at approximately 50% of its 33kW nameplate capacity. City Hall and Memorial Hall currently do not have any backup power. As discussed previously, City Hall has included $480,000 in its FY2020 budget for a new generator to provide emergency power. At the time of this report, the project specifications are not available, therefore detailed discussion has been excluded from this analysis.

Table 40: DER design summary and current islanded operation performance.

Location	Asset Type	Fuel Source	Electric Capacity	Average Daily Production - Islanded Operation	Average Daily Consumption - Islanded Operation
-	-	-	kW	MWh/day	MMBtu/day
Shaw's Rooftop	NG Generator	NG	20	0.48	4.68
Fire Station Basement	Diesel Generator	Diesel	33	0.40	3.38

Both backup generators are already connected to the existing electrical distribution of the panels. Continuous costs associated with maintaining operation of the backup generators are primarily fuel and maintenance costs and are estimated to be between $500 to $1,500 per year for each generator. Additional costs are identified in the Quantifying the Value of Resiliency in a Short-Term Outage section.

REVENUE STREAMS AND SAVINGS

MAAS PROVIDER

Table 41: Summary of average annual revenue streams for the MaaS provider.

Revenue Source	Revenue Type	Annual Revenue
PPA	Sales	$64,231
Electric Wholesale	Sales	$16,827
EV Charging	Sales	$40,600
ConnectedSolutions	Incentive	$112,500
SMART Program	Incentive	$160,561
SMART Battery Adder	Incentive	$24,720
SMART Canopy Adder	Incentive	$37,079
Total Annual Revenue		**$456,518**

All revenue streams for the MaaS provider are variable and will depend on DER performance. For the 20-year life of the microgrid, the average annual revenue streams are shown in Table 41. Of the seven revenue streams, three sources of revenue are generated via the sale of electricity. Energy sold directly to the buildings included in the proposed microgrid would be sold under sub-metered connections and billed at the fixed PPA rate. Energy produced by the Plaza Parking Lot PV system and stored in the BESS would be sold through EV charging stations located within the parking. Excess energy produced by the PV arrays would be sold through interconnection agreements at the wholesale rate. Four additional revenue streams would be achieved through state and utility funded programs, described in greater detail below in the Incentives section. Additional, one-time incentives are also discussed below. Tax incentives, discussed in greater detail below, provide significant cash inflows in the first year of operation.

SHAW'S

The energy cost-savings for Shaw's are achieved in the form of avoided costs. In the base case, all electricity is purchased through National Grid. In the proposed case, ECMs are implemented to reduce the total building load. In addition, utility electric load is offset by electricity purchased from the MaaS provider generated via the PV array on the rooftop of Shaw's. Lastly, the savings shown in Table 42 assume a carbon tax scheduled per Massachusetts Bill S.1821. The carbon tax would be equal to \$10/ton CO_2e in the first year of implementation and increase by \$5/ton CO_2e until a maximum tax of \$40/ton CO_2e is reached. Note that there is no current or near-term plan for the implementation of a tax on carbon emissions; however, if this changes the impact would be favorable for the project's economics. The data is included in the analysis for informational purposes to give an indication of the magnitude of potential value that could be achieved if a carbon tax were put into effect. It is assumed that the full cost of the tax will be burdened by the purchaser of the energy, although if a carbon tax were implemented it is possible that the value may be realized for the end-user indirectly through reduced energy costs.

Table 42: Summary of lifetime average base and proposed case energy costs for Shaw's.

Cost Source	Base Case	Proposed Case	Savings
Utility Electricty Use Costs	$267,475	$220,767	$46,708
Utility Electric Demand Costs	$20,601	$16,409	$4,192
Utility Natural Gas Costs	$37,349	$37,349	$0
Totals	**$325,424**	**$274,525**	**$50,900**
Carbon Tax	$35,014	$26,112	$8,901
Totals w/ Carbon Tax	**$360,438**	**$300,637**	**$59,801**

CITY OF MELROSE

The savings for the City of Melrose are achieved in the form of avoided energy costs, as shown in Table 43. In the base case, all electricity is purchased through National Grid. In the proposed case, ECMs are implemented to reduce the total building load. In addition, utility electric load is offset by electricity purchased from the MaaS provider generated via the CHP at City Hall as well as the PV arrays on the rooftops of City Hall and Memorial Hall. Lastly, the savings shown in Table 43 assume a carbon tax scheduled per Massachusetts Bill S.1821. The carbon tax would be equal to $10/ton CO_2e in the first year of implementation and increase by $5/ton CO_2e until a maximum tax of $40/ton CO_2e is reached. Note that there is no current or near-term plan for the implementation of a tax on carbon emissions; however, if this changes the impact would be favorable for the project's economics. The data is included in the analysis for informational purposes to give an indication of the magnitude of potential value that could be achieved if a carbon tax were put into effect. It is assumed that the full cost of the tax will be burdened by the purchaser of the energy, although if a carbon tax were implemented it is possible that the value may be realized for the end-user indirectly through reduced energy costs.

Table 43: Summary of lifetime average base and proposed case utility costs for Melrose.

Cost Source	Base Case	Proposed Case	Savings
Utility Electricty Use Costs	$74,730	$62,788	$11,942
Utility Electric Demand Costs	$4,415	$3,073	$1,343
Utility Natural Gas Costs	$22,510	$28,960	($6,450)
Totals	**$101,656**	**$94,821**	**$6,835**
Carbon Tax	$10,405	$6,550	$3,855
Totals w/ Carbon Tax	**$112,061**	**$101,371**	**$10,690**

INCENTIVES

The following section explores potential incentives that may be pursued by the MaaS provider, City of Melrose, or Shaw's in the development of the microgrid or in the implementation of energy conservation measures. Prior to implementation or construction, it would be in all parties' best interest to acquire pre-approval and all necessary commitments from the utilities and state programs in order to ensure that the applicable party receives the full incentive amount.

MaaS Provider

SMART Program and Adders

At the time of this report, the DOER's SMART program for National Grid territories has been expanded to include 8 more blocks. The incentivized rate for solar kWh produced will be based on the capacity of the PV system and the Capacity Block the system was placed into.

The battery adder is designed to incentivize the use of battery storage with PV assets. To participate in the program, the battery must achieve 52 full cycle discharges per year. In the proposed microgrid, this would be achieved through the existing Daily Dispatch and Winter Dispatch programs. The incentive is offered every year of operation and the rate ranges from $0.04/kWh-PV/year to $0.07/kWh-PV/year.

Location-based adders are designed to incentivize the use of solar in less-desirable areas, such as the floating solar and landfill adders, or in more expensive installations, such as the solar canopy adder. The solar canopy adder, which applies to the proposed Plaza Parking Lot array, offers a fixed incentive of $0.06/kWh-PV/year.

Federal Investment Tax Credit

The federal Investment Tax Credit (ITC) allows a percentage of the total installed cost of the solar and battery system to be deducted from the company's federal tax liability. For commercial installations, the percentage of the installed cost that is eligible for a deduction will continue to decline down to 10% in 2022. Assuming the proposed microgrid is installed in 2023 and operational in 2024, the ITC would be 10% of the installed cost. Assuming the total installed cost of the solar and battery system, including engineering design and construction, is approximately $6,800,000, the project would result in a federal tax credit of approximately $680,000.

Accelerated Depreciation Tax Deduction

Until 2022, solar projects are eligible for 100% bonus depreciation in the first year, meaning the total installed cost of the solar and battery system is eligible as a federal tax deduction. Beginning in 2023, the bonus depreciation tax reduction will be phased down; however, the remainder of the depreciation tax reductions may still be claimed using 5-Year MACRS. Assuming the gross revenue of the MaaS provider exceeds the total installed cost of the solar and BESS of approximately $6,800,000 and a corporate tax rate of 21%, the project would result in an equivalent tax credit of approximately $1,450,000.

CHP Incentive

National Grid offers an incentive between $900 to $1,250 per kWe of CHP capacity installed. To reach the maximum incentive of $1,250/kW, the installation of the CHP must be combined with energy efficiency (EE) projects that reduce the total facility energy use by 5% or more. In addition, the CHP's average annual system efficiency must exceed 60%. Given the requirements shown in Table 44, the 10kW CHP that would be installed at City Hall would range from $9,000 to $12,500. Current electric and thermal loads indicate that the microgrid would qualify for $1,125/kW in incentives, assuming the CHP is installed in tandem with the proposed lighting LED retrofit ECM.

Table 44: National Grid's tiered CHP incentive rates.

5% EE Reduction	System Efficiency	Incentive ($/kW)
No	< 60%	$900
No	>= 60%	$1,000
Yes	< 60%	$1,125
Yes	>= 60%	$1,250

SHAW'S AND THE CITY OF MELROSE

PRESCRIPTIVE INCENTIVES

To help improve project economics, National Grid offers prescriptive incentives for interior LED lighting retrofits in the range of $2 - $4 per watt saved. The incentive rate is determined according to the controls utilized and the retrofit lighting power density (LPD) in relation to the applicable energy code for that space type.

CUSTOM INCENTIVES

For non-prescriptive ECMs, such as the refrigerated case door retrofit and RTU-4 replacement, Shaw's would pursue a custom incentive application. Custom incentives are offered entirely at the discretion of the utility and there is no published formula to calculate the incentive amount. A conservative incentive offer can be estimated at $0.18/kWh and $1.25/therm saved.

QUANTIFYING THE VALUE OF RESILIENCY IN A SHORT-TERM OUTAGE

The value of resiliency for each site can be quantified through an analysis of avoided costs for short-term outages using available data sources. The avoided costs are categorized as direct, indirect, and induced costs (U.S. Department of Energy 2016). The US DOE report defines direct costs of an extreme weather event or the impacts of climate change as the economic losses to the affected entities. Indirect costs of an outage are defined as a result of the loss of electrical service and associated damage to equipment. Induced costs are considered societal costs that emerge from services being interrupted but do not necessarily affect the facilities involved in the microgrid directly or indirectly, such as poorer outcomes from emergency response services, insurance claims, or lost jobs from economic fallout.

This study utilizes three approaches for estimating avoided costs in an effort to quantify the value of resiliency. The IRC approach is a "bottoms up" method which calculates the additional costs incurred to maintain operation through a power outage and additional costs required to resume normal operation. The ICE calculation estimates the value of the unserved kWh energy consumption sustained during a power outage, based on market survey data. Both the IRC and ICE account for direct and indirect costs in estimating the total cost of potential measurable damages or lost revenue to the affected entities caused by a power outage. The IRC and ICE methods are considered mutually exclusive. These two methods, however, do not account for induced societal costs that could be stacked on the direct and indirect costs to more completely quantify the value of resiliency for a community microgrid. Therefore, the induced approach is included to estimate the societal costs that could be avoided in a short-term outage scenario if a microgrid were implemented. The table below presents a top-level summary of the value estimated by each method.

Table 45: Summary table of estimated value of resiliency.

Cost	IRC	ICE
Direct/Indirect	$96,420	$116,526
Induced	$168,904	$168,904
Total	**$265,324**	**$285,430**

INTERRUPTION RELATED COST

Within the context of sites included within this microgrid, interruption-related costs may include potential damage or loss of equipment, damage or loss of product, additional labor to maintain operation, additional labor to restart normal operation, and costs to operate backup generation equipment (Lawrence Berkeley National Laboratory 2018).

All costs assume a consecutive eight-hour loss of electric power due a severe winter storm. An outage duration of 8 hours was selected based on historical data and anecdotal information from municipal and Shaw's staff. The total IRC for each site has been summarized in Table 46 and is explained in greater detail below.

Table 46: IRC summary table.

Site	IRC
-	$
City Hall	$8,400
Memorial Hall	$4,500
Fire Station	$1,920
Shaw's	$82,320
Total	**$97,140**

CITY HALL

Table 47: IRC for City Hall due to an 8-hour loss of power in the winter.

Temporary Office Space	$3,000
IT Support	$2,400
Service Requests for Equipment Start-Up	$500
Plumbing and Equipment Repairs	$2,500
Total IRC	**$8,400**

During a winter outage, IRCs for City Hall are primarily associated with starting the building back up once the interruption has ended. It is estimated that the costs incurred during a consecutive eight-hour loss of power is $11,200, as shown in Table 47. During a power outage, the City resorts to cell phones and walkie-talkies for emergency dispatch operations. The estimate has included costs associated with temporary office space and IT support for rerouting dispatch services to allow the City to maintain emergency dispatch capabilities.

Without power, the building's heating hot water pumps would be unable to operate. Equipment and controls could be damaged during an outage of this type. In the event significant plumbing damage is sustained due to frozen piping, it is likely that the city would file an insurance claim. For minor damage sustained, such as a failed equipment controller it is assumed that the city may pay for the repairs. For the purposes of IRC, it is estimated that $3,000 in repairs and service to bring all equipment and plumbing back to operation once power is restored.

MEMORIAL HALL

Table 48: IRC for Memorial Hall due to an 8-hour loss of power in the winter.

Lost Revenue	$1,500
Service Requests for Equipment Start-Up	$500
Plumbing and Equipment Repairs	$2,500
Total IRC	**$4,500**

During a winter outage, IRCs for Memorial Hall include the value of lost revenue associated with the inability to serve as a venue to the community in addition to the costs associated with starting the building back up once the interruption has ended. The base rate rental fee for the Main Hall and GAR Room within Memorial Hall is $1,000 for an eight hour event, although ancillary services for set-up and stage use can result in additional costs (City of Melrose 2020). For the purposes of the IRC, it is estimated that the cancelation of an event due to lack of building operation could result in approximately $1,500 of lost revenue generated from the rental of the facility and associated services. Similar to the City Hall, for the purpose of IRC, plumbing and equipment service calls are estimated at $500 and resulting repairs which may be required are estimated at $2,500.

FIRE STATION

Table 49: IRC for the Fire Station due to an 8-hour loss of power in the winter.

Backup Generator, Monitoring and Re-Supply	$1,200
Backup Generator, Fuel and Maintenance	$720
Total IRC	**$1,920**

During a winter outage, IRCs for the Fire Station include costs associated with maintaining operation of the existing backup generator. With the generator, the Fire Station is capable of maintaining normal operations. The project team estimates that fuel, maintenance, and monitoring costs incurred during an eight-hour winter outage would result in an estimated $1,920 of cost.

SHAW'S

Table 50: IRC for Shaw's due to an 8-hour loss of power in the winter.

Lost Revenue	$62,000
Backup Generator, Fuel and Maintenance	$720
Staff for Relocation	$9,600
Refrigerated Truck Rental/Relocation of Fleet	$10,000
Total IRC	**$82,320**

During an outage, Shaw's Supermarket is unable to operate cash registers and maintain mechanical cooling of its refrigerated and frozen product. To mitigate product loss, it has been assumed that refrigerated and frozen goods would be temporarily stored in refrigerated trucks or relocated to nearby grocery stores. The IRCs associated with preventing loss of frozen goods has been estimated at $10,000 for the rental and relocation of refrigerated trucks and $9,600 in labor to relocate the product. Using industry averages, the IRC also includes an estimated $62,000 in lost revenue due to the inability to operate the store (Food Industry Association 2020).

Interruption Cost Estimate

The ICE calculator utilizes a database of over 105,000 customer surveys completed between 1989 and 2012 to provide an estimated cost associated with an interruption in customer power supply (Lawrence Berkeley National Laboratory 2018). The calculator uses inputs based on the duration of the outage and customer characteristics to determine the value of the service interruption. Customer sectors are broken out into small C&I, medium/large C&I, and residential. For C&I, market sector breakdown can also be input as percentage of construction, manufacturing, and other. All sites included in the proposed microgrid were modeled as medium/large C&I and were classified as belonging to the “other” market sector. Similar to the IRC estimate, all costs shown in Table 51 assume a consecutive eight-hour loss, or a Customer Average Interruption Duration Index (CAIDI) of 480, per customer of electric power during the winter (Lawrence Berkeley National Laboratory 2020).

Table 51: ICE summary table and associated inputs.

Site	Annual Usage	CAIDI	Backup Generation	ICE
-	MWh	-	% on Backup	$
City Hall	213	480	0%	$22,491
Memorial Hall	104	480	0%	$16,253
Fire Station	96	480	80%	$15,674
Shaw's	2,004	480	9%	$62,108
Total	**2,418**			**$116,526**

The ICE calculator can be used to estimate the total interruption cost depending on the duration of event. The profile shown in Figure 34 illustrates the ICE for an outage duration of 1 to 15 hours at City Hall. Estimated interruption costs tend to proportionally increase as the duration of the event increases until approximately the 12th hour of the event, after which the added interruption cost for each additional hour of interrupted power is not as significant.

Figure 34: ICE vs interruption time for City Hall during a mid-day winter outage event.

Societal Cost – Induced Cost Approach

The value of resiliency also has an induced societal impact because of the nature of the facilities that comprise the microgrid and have resilient energy sources. The induced costs as a societal burden are more difficult to quantify than direct and indirect costs. Induced costs are also subject to compounding probabilities of the severity and scope of the impact to local infrastructure which could result from a short-term outage as well as the likelihood that emergency response is necessary for health and safety emergencies during an outage. Rigorous effort to investigate and quantify each of the applicable societal induced costs cannot be performed within the scope of this study. Therefore, high-level estimates of the potential societal benefits which may apply are provided in the table below as a starting point for further investigation.

Table 52: Summary table of estimated societal induced costs.

Societal Induced Cost	Cost Type	Cost		
-	-	Low	High	Median
Critical Medical Response, extend quality of life by one year, 1-minute delay avoided	Medical/Healthcare Cost	$100,717	$129,090	$114,903
Additional Medical Services, Cardiac and Severe Trauma, 1-minute delay avoided	Medical/Healthcare Cost	$992	$1,542	$1,267
Fire Response to residential fire, 1-minute delay avoided	Damage Cost	$2,700	$6,000	$4,350
Supermarket customers, added trip time to another supermarket	Economic Cost	$5,256	$10,512	$7,884
Burst Pipes in City Hall and/or Memorial Hall	Damage Cost	$27,000	$54,000	$40,500

Medical/Healthcare Benefits

A key benefit for this microgrid is to enable the emergency response services to perform at "normal" levels and avoid response time delays during a short-term outage. Based on an analysis of EMS call statistics in New York, Wyoming, Wisconsin, and Utah, RapidSOS estimates that critical medical incidents such as cardiac and neurological emergencies comprise approximately 5% of emergency calls overall and 25% of medical emergency calls. The paper uses the conclusions from a number of studies and journal articles published by the American Heart Association, Pre-Hospital Care Journal, and Academic Emergency Care Journal to estimate that a one-minute delay in response time increases mortality rate by 1 to 2% (RapidSOS 2015). However, morbidity is an extreme outcome for emergency response services and therefore the costs associated with prolonged hospitalizations and higher healthcare resource utilization resulting from delays in response time would be more appropriate to be considered as a representation of the societal value. The RapidSOS paper presents that each minute of delay in response time increases hospital treatment costs by 7%. This could translate to $992 in added hospital costs per patient for severe trauma or $1,542 for a typical cardiac emergency, per minute of delay. The paper also notes that the faster response time results in a better quality of life for patients (RapidSOS 2015). The Dialysis Standard, used in health insurance calculations, values one year of "quality life" at an upper limit of $129,000 (Lee, Chertow and Zenios 2008).

Emergency Fire Services Benefits

Fire response is similarly impacted by the ability to perform at normal levels and avoid delays in response times. The NFPA Standard for Smoke and Heat Venting shows that fire growth of burning construction materials and other and household materials can grow at a rate that doubles the heat release rate of the fire every minute (National Fire Protection Association 2018). One study places a $2,700 cost of damage increase per every minute of delayed response (Challands 2010). Other estimates made by RapidSOS present a range of $4,000 to $6,000 in additional damages per minute to residences (RapidSOS 2015).

Value of Community Time

Another societal induced cost source is simply a function of the customers of Shaw's who would need to travel further to purchase goods and supplies if Shaw's were unable to operate due to a grid outage. If the assumption is made that traveling to another grocery store increased average travel time, and of the 15,000 residents served by the grocery store, 900 of them would be shopping on any given day when the outage could occur, an estimate of the time value to the community can be made. The median household income in Melrose is $93,434, and assuming 4,000 annual working hours per household, this equates to $23.36/hour. Using the median hourly rate, for Shaw's customers to shop elsewhere when their local grocery store is not able to be open due to an outage, this equates to a societal time-cost of $5,256 if the average trip is increased by 15 minutes, or $10,512 if the average trip is increased by 30 minutes.

Catastrophic Failure of Building Systems

Extreme weather events in a short-term outage can also result in catastrophic events within each building in the event of an outage. Since the City Hall and Memorial Hall both do not have backup power, their boilers and pumps are unable to operate and provide heat to the building in the event of an outage during the heating season. This has the potential to cause a burst pipe, creating a significant cost that would also likely become an insurance claim. According to Philadelphia Insurance Companies, the average loss related to frozen and burst pipes is $27,000 (Philadelphia Insurance Companies 2018).

The Value of Energy Resiliency in a Disaster

The methods outlined above are intended to quantify the value of resiliency for a microgrid enabling the sites to avoid a short-term outage that can be expected based on historical outage data. However, these methods do not account for the value of resiliency that these critical sites would have to the community in the event of a disaster. The value of a microgrid in the event of an extended outage and/or climate disaster has been modeled in other studies using methods such as the FEMA Benefit-Cost Analysis (BCA) tool and IMPLAN input-output economic models.

FEMA Benefit-Cost Analysis Tool

The FEMA BCA tool was developed to calculate the cost-effectiveness of a hazard mitigation project in relation to the economic benefits achieved through project implementation (Department of Homeland Security 2020). The application of the tool is limited to certain event-cases based on each facility type; however, not all event-cases can be modeled in the tool for each type of facility. For example, the impact of extreme temperatures, high wind, or a winter storm cannot be modeled for a non-residential building using this tool. In addition, the hazard mitigation projects available within the FEMA BCA tool do not specifically address microgrid and energy resiliency efforts. Although the tool cannot be directly applied, it incorporates a metric that places a unit value on the broader economic cost of interruptions. This metric values the availability of electric utility service, or lack thereof, at $148/person/day of outage. This value was determined by the impact of availability a utility is to the regional economy and is developed from national gross domestic product normalized per-capita. Because the frequency, duration, and overall impacted population of a discrete climate-related disaster(s) is not possible to forecast with certainty, the inputs required to utilize this metric for an extended outage scenario would be gross assumptions. Despite these shortcomings in applying this metric of the value of electric utility service, a review of the calculation by parametrically varying the inputs can give some insight as to the magnitude and range of the cost benefit under various event scenarios. The table below presents the parametric results using varied inputs.

Table 53: Parametric results of the value of power as a function of outage duration and population affected.

Outage Duration	Population Affected				
	1	10	100	1,000	10,000
1 Day	$148	$1,480	$14,800	$148,000	$1,480,000
3 Days	$444	$4,440	$44,400	$444,000	$4,440,000
1 Week	$1,036	$10,360	$103,600	$1,036,000	$10,360,000
3 Weeks	$3,108	$31,080	$310,800	$3,108,000	$31,080,000

Economic Models

Economic input-output models such as IMPLAN can be used to develop economy-wide analyses of the impacts of energy resilience. While the IMPLAN marketing literature indicates that this model could be used at a local level, only one of the sites included in the current microgrid configuration is in the commercial market sector (IMPLAN 2020). The authors of the NARUC study on the value of resilience note that this type of model may not have enough granularity to calculate a significant economic impact from a microgrid of this scale (National Association of Regulatory Utility Commissioners 2019). Because of this indication, and because the effort associated with creating such a model is considerable, the analysis in this report does not include economic modeling of this nature. It is important to note that there may be value in performing such an analysis in the future if the microgrid was increased in scale and the concept was expanded to include more participants, especially those with downtown commercial storefronts.

The Value of This Microgrid in a Disaster

The value of the facilities in this microgrid to the community is realized through the services they provide, namely emergency services and operations, supplies and shelter. The longer-term resiliency value of the city hall, fire station, and Shaw's to the community could be valued by multiplying the direct, indirect, and induced costs by the duration of the outage adjusting them for the scale of the impact, using a similar parametric analysis as shown above with the FEMA BCA tool data. However, a key difference in the value can be seen at Memorial Hall, where the narrative is significantly more compelling in light of the potential disaster scenario. Memorial Hall does not provide critical services that are impacted by a short-term outage, rather, the purpose of Memorial Hall being included in the microgrid is because it is a designated emergency disaster shelter for the city. The NHMP prepared by the city and submitted to FEMA identifies both that Memorial Hall is one of two designated shelters in the city and acknowledges that the facility is not well-suited to provider sheltering services in the event of extreme weather (CDM Smith 2019). This is because the building currently has no backup power and therefore, cannot operate heating and air-conditioning systems in the event of any outage, let alone an extended outage. The NHMP identifies that the shelter would be used to house the local vulnerable population of seniors and disabled individuals who may need to be relocated to the shelter in the event of a winter storm causing outages or an extreme heat wave.

In the event of extreme weather or a climate disaster, such as one that would require relocating the city's vulnerable population to Memorial Hall, the microgrid could not mitigate the physical damages caused by the event. However, it could be argued that there is a value to protecting and supporting a highly vulnerable population, and having a microgrid would enable the capabilities for heating and air-conditioning when utility grid power is not available. This protection could be quantified in terms of loss of life that could be prevented. The argument is similar for the city hall and fire station emergency services being enabled and available in the event of a disaster through a microgrid. It is important to acknowledge that there is no "value" that can be directly placed on a life or avoiding a morbid health outcome, and that there is considerable sensitivity to the methods and inputs used in any attempt to estimate this value. Notwithstanding, there is high-level data that is used by authorities to estimate the value of a human life for insurance calculations. Various federal agencies place the estimate the value of a human life between \$7.9 million (FDA) (Appelbaum 2011) and \$9.6 million (USDOT) (Moran 2016). While these values do not directly translate to a quantifiable value of resiliency for this specific project, they give an indication of the order of magnitude of the potential value of resiliency for facilities which the community depends on to provide critical services in the event of a disaster.

CAPACITY IMPACTS AND ANCILLARY SERVICES

PEAK LOAD SUPPORT AND DEMAND RESPONSE

The proposed microgrid DERs include 819 kW of solar capacity, 10 kW of micro-CHP capacity, and a 3,300kWh/500kW BESS. Modeling results show that the solar PV systems could provide up to 0.68 MW of passive peak load support. The solar is passive and output is expected to be less than nameplate capacity as it is dependent upon weather conditions. In addition, the BESS could be utilized to provide up to 0.5 MW of demand response for up to 6 hours depending on the battery's state of change. The EV charging stations would be configured to limit demand during peak periods to reduce their negative impact on grid stress. Additionally, the ECMs implemented as a part of this project will provide approximately 0.05 MW of passive peak load support.

TRANSMISSION AND DISTRIBUTION

National Grid's 2019 Local System Plan (LSP) does not indicate any planned upgrades to the local distribution through 2023; however, National Grid staff have indicated there are plans to transition Shaw's to a 13.8kV feeder (National Grid 2019). The capability to offset 0.5MW/year via the BESS in an as-needed basis through demand response may offer the utility an opportunity to defer local transmission and distribution capacity requirements. The life of the BESS is 10 years, and by replacing the Li-ion cells in year 10, it can be extended to twenty years. If there were no new loads added, capacity upgrades could potentially be deferred or possibly even avoided. However, as noted elsewhere in this report, the actual value this project could have on transmission and distribution deferral/avoidance as well as in providing any ancillary services to the utility are presently unknown.

The hurdle of utilizing National Grid infrastructure for the microgrid bus street crossing underneath Essex street was identified in Task 3: Technical Feasibility. As discussed, the only way that National Grid would allow this is if the microgrid bus was utility-owned. The microgrid presents the utility with a potential opportunity to defer transmission and distribution investment, because if they owned the microgrid bus, they could activate the microgrid and remove the Shaw's load and municipal building loads from the grid when the grid was stressed. It is estimated that this could potentially be a near- to medium-term investment deferral strategy. According to a study by Sandia National Labs, typical transmission and distribution upgrade costs range between $25/kW and $250/kW (Eyer 2009). Assuming National Grid owned the microgrid bus and could initiate islanding to reduce load on the grid as needed, and using the median upgrade value of $137.5/kW, the capability of the BESS to offset 500kW of load could be worth $68,750 in annual deferred cost of upgrades. If the 0.68MW of passive benefits of the solar PV are included in the deferral calculation, it could potentially add another $93,500 in annual upgrade cost deferral. Another benefit to the utility is that in deferring upgrades, valuable resources could be prioritized for other utility construction projects.

The proposed micro-CHP at City Hall is the only DER that would produce on-site emissions. Assuming 97% availability, the micro-CHP would offset approximately 85 MWh of electric utility import from City Hall in addition to reducing boiler gas consumption by approximately 3,200 therms. Because the micro-CHP is not being used as a generation site and because of its small size, environmental regulations mandating the purchase of emissions allowances included in 225 CMR and 310 CMR do not apply. The micro-CHP has an electric efficiency of 31%, resulting in the equivalent emission rates shown in Table 54. Note that the particulate matter (PM) emission rate shown below includes condensable and filterable PM and is based on average rates from natural gas combustion (United States Environmental Protection Agency 2020).

Table 54: Emissions summary from micro-CHP.

Pollutant	lbs/MWh
CO_2	1,271
SO_2	0.0064
NOx	0.0068
PM_1	0.0805

The use of PV DERs in the proposed microgrid reduces the amount of electricity imported from the utility. According to the United States Energy Information Administration (EIA), the average emission rates in 2018 for electricity purchased from the utility are shown in Table 55 (United States Energy Information Administration 2020). Excluding life cycle emissions associated with PV systems, all avoided utility electricity import either through implemented ECMs or offset by PV would result in no associated emissions. The average annual emissions in the base and proposed case are shown in Table 56.

Table 55: Average emission rates for Massachusetts grid electricity in 2018.

Pollutant	lb/kWh
CO_2	0.808
SO_x	0.0002
NO_x	0.0007

Table 56: Microgrid emissions summary.

	Annual Utility Electric Import	Annual Utility Gas Use	Annual Emissions		
	kWh	therms	tons CO_2	tons SO_x	tons NO_x
Base	2,450,432	57,522	1,307	0.25	1.29
Proposed	1,586,323	63,720	992	0.16	1.03
Savings	**864,109**	**-6,198**	**315**	**0.09**	**0.26**
Savings, %	*35%*	*-11%*	*24%*	*35%*	*20%*

PROJECT COSTS

The anticipated cost of design, furnishing, and installation was developed for use with financial modeling. It is important to note that B2Q's opinion of probable construction costs are opinions of probable cost and are based upon traditional sources such as the Means Cost Estimating guide, previous experience, high level utility infrastructure costs provided by National Grid from other similar projects, budget quotes from vendors (pre-design), and/or engineering rules of thumb. Due to the volatile nature of labor, material and equipment pricing and unforeseeable factors affecting the construction industry, B2Q does not expressly or implicitly warrant or represent that B2Q project cost estimates presented in this report will be the actual cost of equipment and/or installation.

FINANCING STRUCTURE

The MaaS provider would provide all capital required for the development, construction, and operation of the microgrid. While the financing instrument would be selected at the sole discretion of the MaaS provider, several options exist, as outlined in the Climate Resilience Handbook (Marsh & McLennan Companies 2020). One of the most popular financing instruments are Green bonds, which are tax exempt bonds issued to support sustainable and environmentally friendly projects. Alternative financing that may be used to supplement or replace the use of Green bonds are government and state grants, multilateral development banks, and private-sector funding providers (Marsh & McLennan Companies 2020).

The City of Melrose and Shaw's would only be responsible for paying for ECM implementation costs shown above. The City of Melrose may pursue funding through state funded programs such as the Green Communities Act or MVP. If Shaw's chooses to finance their capital improvements, funding may be possible through a future Property-Assessed Clean Energy (PACE) program, which could become available in Massachusetts by the end of 2020. Eligibility for PACE funding will be dependent upon the yet to be released program rules as well as adoption by the City of Melrose.

SHAW'S

Shaw's would implement energy conservation measures to reduce their baseload prior to the implementation of the microgrid. The estimated costs to make these upgrades are shown below in Table 57. These would be fixed, one-time costs and would likely be eligible for utility incentives, as discussed in greater detail below. An additional one-time cost would be the estimated $200,000 cost for the OPR. The OPR costs have been excluded from the financial analysis at this time because it is more appropriate for this cost to be paid outside of the MaaS economics and should be pursued by each party based on their interest in initiating the resiliency project. If it were to be included, for Shaw's to maintain a 20-year payback, the PPA rate would have to be $0.14/kWh or less.

Table 57: Estimated capital investment costs for Shaw's.

Investment	Project First Cost	Potential Utility Incentive	Net Cost
Case Door Retrofit	$247,232	$27,207	$220,025
RTU-4 Replacement	$135,321	$24,368	$110,953
LED Lighting Retrofit	$146,147	$29,100	$117,047
Total	**$528,700**	**$80,675**	**$448,025**

CITY OF MELROSE

The City of Melrose would implement LED lighting retrofits at all three municipal buildings to reduce the electric baseload prior to the implementation of the microgrid. The estimated costs to make these upgrades are shown below in Table 58. These would be fixed, one-time costs and would likely be eligible for utility incentives, as discussed in greater detail below. An additional one-time cost would be the estimated $200,000 cost for the OPR. The OPR costs have been excluded from the financial analysis at this time because it is more appropriate for this cost to be paid outside of the MaaS economics and should be pursued by each party based on their interest in initiating the resiliency project. If it were to be included, for the City of Melrose to maintain a 20-year payback, the PPA rate would have to be $0.10/kWh or less..

Table 58: Estimated capital investment costs for the City of Melrose.

Investment	Project First Cost	Potential Utility Incentive	Net Cost
City Hall LED Lighting Retrofit	$68,676	$18,000	$50,676
Memorial Hall LED Lighting Retrofit	$64,570	$11,400	$53,170
Fire Station LED Lighting Retrofit	$26,150	$3,450	$22,700
Total	**$159,396**	**$32,850**	**$126,546**

MAAS PROVIDER

The proposed microgrid consists of (3) PV systems, (1) micro-CHP system, (1) BESS, and (1) SSC distributed across (5) parcels of land. Each parcel of land is served by a separate utility transformer and has its own electric distribution system. All DERs and electrical distribution systems would be tied together via a single microgrid electric bus. The microgrid bus would only be closed when the utility bus for the parcel has been opened. A summary of the costs associated with the proposed microgrid is shown in Table 59. Costs associated with the planning, design, furnishing, installation, maintenance, and operation of the proposed microgrid are discussed in greater detail below. This estimate includes a 15% contingency on top of the cost opinions for infrastructure upgrades and installation. Note that internal costs from Melrose and Shaw's are not included in the analysis below.

Table 59: Microgrid capital investments.

Phase	Cost
Planning	$290,000
Design	$596,000
Infrastructure Upgrades	$1,370,000
Equipment and Installation	$5,328,000
Contingency	$1,004,700
OPM, CA, Cx, and Admin	$820,900
Total	**$9,409,600**

PLANNING

At the time of this report, further investigation is required to determine the feasibility and technical specifications of the proposed microgrid. Prior to installation, an investment grade audit of the existing electrical, mechanical, and communication infrastructure must be performed in order to determine the upgrades and investments required to achieve the microgrid's design intent. During the planning phase, short circuit, ground fault, and arc flash electrical studies would be performed. Upgrades to existing electrical panels and utility distribution equipment which are presently unknown could be identified to be required during the planning phase.

For the rooftop PV systems, a structural analysis would be required at Shaw's and Memorial Hall to identify what, if any, architectural improvements are needed in order to support the proposed PV DERs. For the canopy array, boring samples would need to be collected in the Plaza Parking Lot in order to determine the appropriate supports that are needed to house the canopy PV system, significantly impacting the installed cost. The planning process would also require an owner's project manager.

The results of all of the above audits could significantly impact the overall cost of the microgrid and/or the feasibility of the microgrid's design intent. The anticipated costs associated with the planning of the microgrid can be found in Table 60.

Table 60: Opinion of probable cost for the proposed microgrid planning.

Item	Cost
Electric Infrastructure Audit	$48,000
Electric Hazard Study	$24,000
Mechanical Infrastructure Audit	$16,000
Communication Infrastructure Audit	$8,000
Civil and Environmental Audit	$24,000
Structural Analysis (Solar)	$32,000
Legal	$90,000
Owner's Project Requirements	$48,000
Total	**$290,000**

DESIGN

Opinion of probable costs for the development of bid specifications and construction drawings are shown in Table 61. The design costs are highly dependent on the results of the investment grade audits of the existing electrical and mechanical infrastructure.

Table 61: Opinion of probable cost for the proposed microgrid design.

Item	Cost
Electric Infrastructure Design	$256,000
Mechanical Infrastructure Design	$40,000
Communication Infrastructure Design	$48,000
Civil and Environmental Design	$60,000
Solar Design	$96,000
Utility System Impact Study	$48,000
Energy Engineering	$48,000
Total	**$596,000**

INFRASTRUCTURE UPGRADES

During the study, the project team identified several infrastructure upgrades that would need to be implemented in order to support the proposed microgrid. As discussed previously, additional infrastructure improvements may be identified as part of the detailed planning and design phases of the microgrid; however, only the currently identified upgrades and their opinions of probable cost are summarized in Table 62.

Table 62: Opinion of probable cost for the proposed microgrid infrastructure upgrades.

Item	Cost
IT Infrastructure	$50,000
Utility Protection - Budget for DTT, Reclosures, Lock-out relays	$330,000
Buried Electrical Infrastructure - Munipal	$420,000
Buried Electrical Infrastructure - Shaw's	$120,000
Street Crossing	$100,000
Convert Parking Lot Service to 3 Phase	$200,000
Shaw's Electric Room Upgrades	$150,000
Total	**$1,370,000**

To support the communication of DERs and the SSC with each other, the utility, and the curtailment service provider, the installation of IT infrastructure is required. The proposed microgrid is currently designed to communicate over a dedicated local area network, hosted in the existing City Hall IT server room. Communication cables would be wired to each asset in buried, shielded conduit. The opinion of probable cost for IT infrastructure assumes that the IT conduit and electrical conduit would utilize the same trench for installation.

To support islanded operation of the microgrid, the current design requires a new electrical line to be run that would connect all of the municipal buildings, the plaza parking lot, and Shaw's. The electrical line, referred to as the microgrid bus, would connect to each building load behind the meter and the general routing of the cabling would be underground along the border between the plaza parking lot and the municipal buildings, and buried under Essex Street to interconnect with Shaw's. It has been assumed for the purpose of cost estimating that new buried duct banks would be required for the microgrid bus and that existing utility owned duct banks would not be utilized.

Additional infrastructure upgrades are required at the utility distribution level to support the microgrid. Utility protection mechanisms, including reclosures, lock-out relays, and DTTs are required to safely isolate the microgrid bus from the utility service. This cost opinion assumes one DTT for the plaza solar plus storage system and two reclosers, one each for both the plaza and for Shaw's. Lastly, the current utility parking lot service currently provides single phase power for the parking lot lighting system. As part of the proposed microgrid upgrades, this service would need to upgraded to 3 phase service.

EQUIPMENT AND INSTALLATION

As discussed above, the installation costs of equipment, including the support, tie-ins and infrastructure are highly dependent on the results of an investment grade audit. The opinions of probable cost for furnishing and installing the proposed DERs are shown in Table 63. Installed cost for solar is estimated at $2,500/kW for rooftop solar and $4,000/kW for canopy solar. The installed cost for the battery storage system is estimated at $600/kWh, which is slightly higher than the upper end of the normal cost range due to its use in a microgrid application (Pacific Northwest National Laboratory 2019). The installed cost of the CHP is estimated at $5,000/kW according to the manufacturer's literature (Aegis Energy 2020). The cost of the SSC is estimated based on past experience and anecdotal information from controls vendors. The costs of DC fast chargers and Level 2 chargers were estimated based on the ranges presented the US DOE report on non-residential EV equipment costs (New West Technologies, LLC 2015).

Table 63: Opinion of probable cost for the propose microgrid equipment and installation.

Item	Cost
Rooftop Solar	$680,000
Canopy Solar	$2,240,000
BESS	$1,980,000
City Hall CHP	$50,000
DC Fast EV Chargers	$80,000
Level 2 EV Chargers	$48,000
SSC	$250,000
Total	**$5,328,000**

OPERATIONS AND MAINTENANCE (O&M)

FIXED O&M

To meet the expected 20-year life of the proposed microgrid, it is expected that the DERs receive regular operation and maintenance improvements. The opinions of probable cost for operating and maintaining the proposed DERs are shown in Table 64. Expected O&M costs for solar panels are estimated at $19/kW/year and include annual cleaning and inverter replacements, as needed

(NREL 2020). Expected O&M costs for the BESS are estimated at $10/kW/year and include all necessary costs required to keep the system operational regardless of energy cycles (Pacific Northwest National Laboratory 2019). O&M costs for the EV charging stations are estimated at $500/year and include required electrical repairs based on wear and tear on the electrical hardware (New West Technologies, LLC 2015). The micro-CHP O&M costs are estimated at monthly fixed fee of $500. Lastly, an annual cost for the monitoring and maintenance of the proposed SCC and electrical infrastructure is estimated at $10,000/year. One-time costs for the replacement and/or upgrades of proposed DERs are included in year 10 of the project (Pacific Northwest National Laboratory 2019).

Table 64: Fixed operations and maintenance costs.

Item	Period	Cost
Solar O&M	Annual	$15,808
Battery O&M	Annual	$5,000
EV Charging O&M	Annual	$500
Controls and Electrical O&M	Annual	$10,000
CHP O&M	Annual	$6,000
Battery Cell Replacement	Year 10	$894,300
CHP Overhaul	Year 10	$15,000
EV Charging Replacement/Tech Upgrade	Year 10	$100,000
Annual Total		**$37,308**
20-Year Lifetime Total		**$1,755,460**

VARIABLE O&M

In addition to the fixed O&M costs for the BESS, additional variable O&M costs can be expected that are proportional to the BESS annual output. The variable O&M costs for the BESS is estimated at $0.03/kWh and is associated with the wear and tear expected from the charging and discharging of the system (Pacific Northwest National Laboratory 2019). Based on current models, it is estimated that the annual variable O&M cost is $7,312.

PROFITABILITY

The proposed microgrid concept does not presently have viable economics. The implementation of this project via a MaaS provider, assuming a project life of 20 years, would result in an internal rate of return (IRR) of approximately -0.5%. However, given the level of risk involved in the capital investment, it is likely that the MaaS provider would be seeking an IRR of approximately 10%.

Table 65: Summary of key financial metrics.

Party	Capital Costs	Internal Rate of Return
Project Developer		
MaaS Provider	$9,409,600	-0.5%
Customer		
Shaw's	$448,025	13.3%
City of Melrose	$126,546	0.8%

Appendix D, Appendix E, and Appendix F show 20-year LCCA's for each party of the proposed microgrid. DER generation and microgrid loads were calculated assuming the electric consumption remains constant each year. Additional assumptions are listed within the appendices.

A summary of the key financial inputs can be found in Table 66. Monthly commercial electric and gas rate trends in the Boston area from 2018 through 2019 were analyzed to develop average escalation rates of 0.3% and 0.4%, respectively (U.S. Bureau of Labor Statistics 2020). As discussed previously, the fixed PPA rate for electricity was determined to maintain a simple payback period of 20 years or less for both microgrid participants included in the proposed microgrid. It should also be noted that the PPA rate, while equal or greater to the customer's existing utility rate, would reduce peak demand charges by offsetting the power imported from the utility via PV production. This effect results in proposed blended cost of electricity that is equal to or less than the original blended rate.

Table 66: Summary of key financial inputs.

Input	Units	Shaw's	City Hall	Memorial Hall, Fire Station, and Parking Lot
Utility Electric Rate	$/kWh	$0.13	$0.15	$0.18
Utility Electric Demand Rate	$/kW	$5.76	$5.76	$0.00
Utility Gas Rate	$/therm	$1.00	$1.00	$1.00
PPA Electric Rate	$/kWh	$0.160	$0.160	$0.160
Discount Rate	%	10%	0%	0%
Electric Rate Escalation	%	0.3%	0.3%	0.3%
Electric Demand Rate Escalation	%	0.3%	0.3%	0.3%
Gas Rate Escalation	%	0.4%	0.4%	0.4%

Note that the PPA rate was selected to provide Shaw's and the City of Melrose a simple payback of 20 years or less. The data is presented in this manner to illustrate the financial shortcomings of the proposed project with respect to the MaaS provider. The MaaS provider will incur all costs associated with the development, construction, and maintenance of the microgrid. Similarly, the MaaS provider would obtain all revenue's and incentives associated with the operation of the microgrid. The financial hurdles associated with the large capital cost could be reduced if the participants lowered the first cost by contributing and/or, if the MaaS provider increased chargebacks to the participants over time.

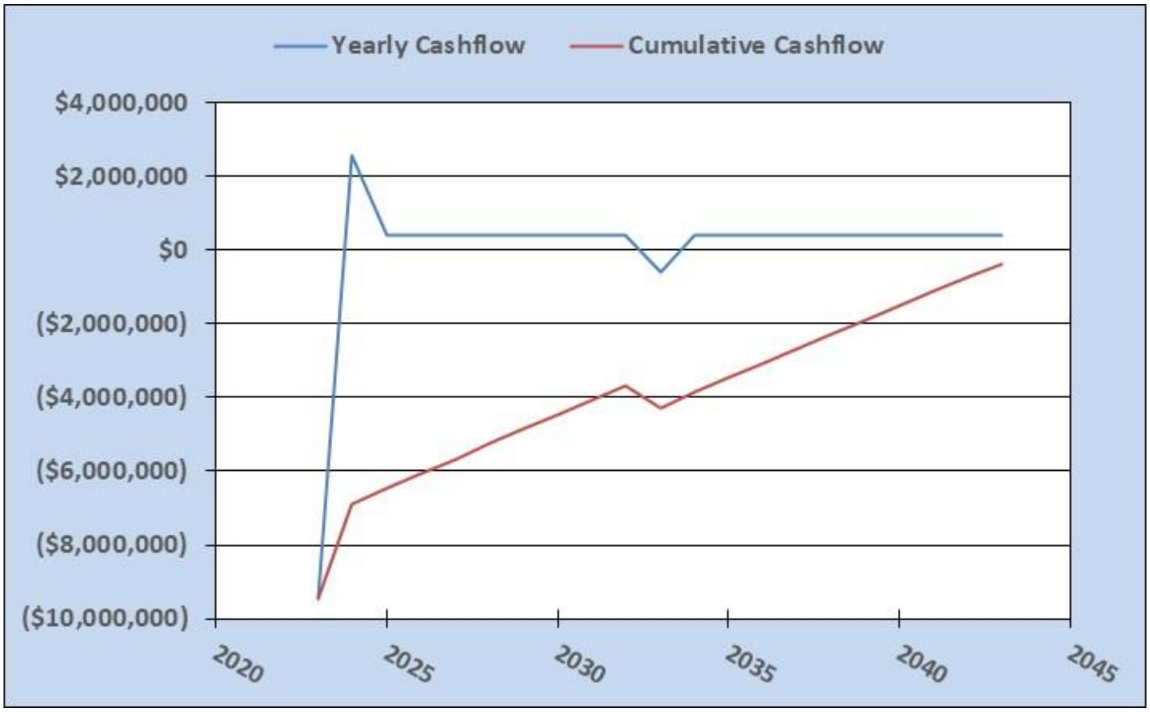


Figure 35: Yearly and cumulative cashflows for the MaaS provider.

APPENDICES

APPENDIX A: MAP SHOWING LOT NUMBER AS IDENTIFIED BY THE TAX ASSESSOR'S OFFICE

APPENDIX B: ELECTRICAL ONE-LINE DIAGRAM

APPENDIX C: EQUIPMENT LAYOUT DIAGRAM

APPENDIX D: MAAS PROVIDER 20 YEAR LCCA

Result Metric	Abbr	Value	Units
Net Present Value	NPV	-$4,461,925	
Internal Rate of Return	IRR	-0.5%	
Savings to Investment Ratio	SIR	0.47	

Assumption	Value	Units
Discount Rate	10.0%	
Maintenance Cost Inflation	2.0%	
Power Purchase Agreement Rate	$0.160	/ kWh
Wholesale Rate	$0.040	/ kWh
Tax Rate	21.0%	

Assumption	Value	Units
SMART Incentive Base Rate	$0.170	/ kWh
SMART Battery Adder Rate	$0.040	/ kWh
SMART Canopy Adder Rate	$0.060	/ kWh

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Year	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043
CASH FLOWS																					
Project Costs																					
DERs, Controls, and Infrastructure	$9,409,600																				
Internal Project Management	$25,000	$15,000	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000
Operations and Maintenance		$45,146	$46,049	$46,969	$47,909	$48,867	$49,844	$50,841	$51,858	$52,895	$53,953	$55,032	$56,133	$57,256	$58,401	$59,569	$60,760	$61,975	$63,215	$64,479	$65,769
10 Year Overhauls											$1,009,300										
Federal Investment Tax Credit		($688,370)																			
Depreciation Equivalent Tax Credit		($1,445,578)																			
EV Charging Station Incentives		($18,000)																			
CHP Incentives		($11,250)																			
Net Outflows	$9,434,600	($2,103,052)	$51,049	$51,969	$52,909	$53,867	$54,844	$55,841	$56,858	$57,895	$1,068,253	$60,032	$61,133	$62,256	$63,401	$64,569	$65,760	$66,975	$68,215	$69,479	$70,769
Inflows																					
PPA Revenue		$64,231	$64,231	$64,231	$64,231	$64,231	$64,231	$64,231	$64,231	$64,231	$64,231	$64,231	$64,231	$64,231	$64,231	$64,231	$64,231	$64,231	$64,231	$64,231	$64,231
Wholesale Revenue		$16,827	$16,827	$16,827	$16,827	$16,827	$16,827	$16,827	$16,827	$16,827	$16,827	$16,827	$16,827	$16,827	$16,827	$16,827	$16,827	$16,827	$16,827	$16,827	$16,827
EV Charging Station Revenue		$40,600	$40,600	$40,600	$40,600	$40,600	$40,600	$40,600	$40,600	$40,600	$40,600	$40,600	$40,600	$40,600	$40,600	$40,600	$40,600	$40,600	$40,600	$40,600	$40,600
ConnectedSolutions Revenue		$112,500	$112,500	$112,500	$112,500	$112,500	$112,500	$112,500	$112,500	$112,500	$112,500	$112,500	$112,500	$112,500	$112,500	$112,500	$112,500	$112,500	$112,500	$112,500	$112,500
SMART Program Revenue		$160,561	$160,561	$160,561	$160,561	$160,561	$160,561	$160,561	$160,561	$160,561	$160,561	$160,561	$160,561	$160,561	$160,561	$160,561	$160,561	$160,561	$160,561	$160,561	$160,561
SMART Battery Adder Revenue		$24,720	$24,720	$24,720	$24,720	$24,720	$24,720	$24,720	$24,720	$24,720	$24,720	$24,720	$24,720	$24,720	$24,720	$24,720	$24,720	$24,720	$24,720	$24,720	$24,720
SMART Canopy Adder Revenue		$37,079	$37,079	$37,079	$37,079	$37,079	$37,079	$37,079	$37,079	$37,079	$37,079	$37,079	$37,079	$37,079	$37,079	$37,079	$37,079	$37,079	$37,079	$37,079	$37,079
Total Inflows	$0	$456,518	$456,518	$456,518	$456,518	$456,518	$456,518	$456,518	$456,518	$456,518	$456,518	$456,518	$456,518	$456,518	$456,518	$456,518	$456,518	$456,518	$456,518	$456,518	$456,518
Net Cash Flow	($9,434,600)	$2,559,570	$405,469	$404,548	$403,609	$402,651	$401,673	$400,677	$399,660	$398,623	($611,735)	$396,486	$395,385	$394,262	$393,117	$391,949	$390,758	$389,543	$388,303	$387,039	$385,749
Cumlative Cash Flows	($9,434,600)	($6,875,030)	($6,469,561)	($6,065,012)	($5,661,403)	($5,258,752)	($4,857,079)	($4,456,402)	($4,056,743)	($3,658,120)	($4,269,855)	($3,873,370)	($3,477,985)	($3,083,722)	($2,690,605)	($2,298,656)	($1,907,898)	($1,518,355)	($1,130,052)	($743,013)	($357,264)
PRESENT VALUES																					
Outflows	$9,434,600	($1,911,866)	$42,189	$39,045	$36,137	$33,447	$30,958	$28,655	$26,525	$24,553	$411,858	$21,041	$19,479	$18,033	$16,695	$15,457	$14,311	$13,251	$12,269	$11,360	$10,519
Inflows	$0	$415,016	$377,287	$342,989	$311,808	$283,462	$257,692	$234,266	$212,969	$193,608	$176,007	$160,007	$145,461	$132,237	$120,215	$109,287	$99,352	$90,320	$82,109	$74,644	$67,858
Total	($9,434,600)	$2,326,882	$335,099	$303,943	$275,670	$250,014	$226,734	$205,610	$186,444	$169,055	($235,850)	$138,966	$125,982	$114,204	$103,520	$93,830	$85,040	$77,069	$69,840	$63,284	$57,339
Cumulative Total	($9,434,600)	($7,107,718)	($6,772,619)	($6,468,676)	($6,193,006)	($5,942,991)	($5,716,257)	($5,510,647)	($5,324,203)	($5,155,148)	($5,390,998)	($5,252,032)	($5,126,050)	($5,011,847)	($4,908,327)	($4,814,497)	($4,729,457)	($4,652,388)	($4,582,548)	($4,519,264)	($4,461,925)

APPENDIX E: CITY OF MELROSE 20 YEAR LCCA

Result Metric	Abbr	Value	Units
Net Present Value	NPV	$10,159	
Discounted Payback Period	DPP	18.9	yr
Internal Rate of Return	IRR	0.8%	

Assumption	Value	Units
Discount Rate	0.0%	
Electric Rate Escalation	0.3%	/ Year
Electric Demand Rate Escalation	0.3%	/ Year
Gas Rate Escalation	0.4%	/ Year
Power Purchase Agreement Rate	$0.160	/ kWh

Assumption	Value	Units
Lighting Incentive Rate	$2.00	/ kWh

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Year	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043
CASH FLOWS																				
Base Case																				
Utility Electricty Use Costs	$72,802	$73,001	$73,202	$73,402	$73,604	$73,806	$74,008	$74,211	$74,414	$74,619	$74,823	$75,028	$75,234	$75,441	$75,647	$75,855	$76,063	$76,272	$76,481	$76,691
Utility Electric Demand Costs	$4,302	$4,313	$4,325	$4,337	$4,349	$4,361	$4,373	$4,385	$4,397	$4,409	$4,421	$4,433	$4,445	$4,457	$4,470	$4,482	$4,494	$4,507	$4,519	$4,531
Effective Electricity Rate $/kWh	*$0.173*	*$0.173*	*$0.174*	*$0.174*	*$0.175*	*$0.175*	*$0.176*	*$0.176*	*$0.177*	*$0.177*	*$0.178*	*$0.178*	*$0.179*	*$0.179*	*$0.180*	*$0.180*	*$0.181*	*$0.181*	*$0.182*	*$0.182*
Utility Natural Gas Costs	$21,631	$21,722	$21,812	$21,903	$21,994	$22,086	$22,178	$22,271	$22,364	$22,457	$22,551	$22,645	$22,739	$22,834	$22,929	$23,025	$23,121	$23,217	$23,314	$23,411
Effective Natural Gas Rate $/therm	*$1.00*	*$1.00*	*$1.01*	*$1.01*	*$1.02*	*$1.02*	*$1.03*	*$1.03*	*$1.03*	*$1.04*	*$1.04*	*$1.05*	*$1.05*	*$1.06*	*$1.06*	*$1.06*	*$1.07*	*$1.07*	*$1.08*	*$1.08*
Carbon Tax	$2,994	$4,491	$5,988	$7,485	$8,983	$10,480	$11,977	$11,977	$11,977	$11,977	$11,977	$11,977	$11,977	$11,977	$11,977	$11,977	$11,977	$11,977	$11,977	$11,977
Total Base Case	$98,735	$99,036	$99,339	$99,642	$99,947	$100,253	$100,559	$100,867	$101,175	$101,484	$101,795	$102,106	$102,419	$102,732	$103,046	$103,362	$103,678	$103,995	$104,314	$104,633
Proposed Case																				
ECM Implementation Costs	$159,396																			
ECM Utility Incentives	($32,850)																			
PPA Electricity Costs	$26,329	$26,329	$26,329	$26,329	$26,329	$26,329	$26,329	$26,329	$26,329	$26,329	$26,329	$26,329	$26,329	$26,329	$26,329	$26,329	$26,329	$26,329	$26,329	$26,329
Utility Electricty Use Costs	$35,518	$35,615	$35,713	$35,811	$35,909	$36,008	$36,107	$36,206	$36,305	$36,404	$36,504	$36,604	$36,705	$36,805	$36,906	$37,008	$37,109	$37,211	$37,313	$37,415
Utility Electric Demand Costs	$2,993	$3,002	$3,010	$3,018	$3,026	$3,035	$3,043	$3,051	$3,060	$3,068	$3,077	$3,085	$3,094	$3,102	$3,110	$3,119	$3,128	$3,136	$3,145	$3,153
Effective Electricity Rate $/kWh	*$0.170*	*$0.171*	*$0.171*	*$0.171*	*$0.172*	*$0.172*	*$0.172*	*$0.172*	*$0.173*	*$0.173*	*$0.173*	*$0.173*	*$0.174*	*$0.174*	*$0.174*	*$0.175*	*$0.175*	*$0.175*	*$0.176*	*$0.176*
Utility Natural Gas Costs	$27,829	$27,945	$28,062	$28,179	$28,296	$28,414	$28,533	$28,652	$28,771	$28,891	$29,012	$29,133	$29,254	$29,376	$29,499	$29,622	$29,746	$29,870	$29,994	$30,119
Effective Natural Gas Rate $/therm	*$1.00*	*$1.00*	*$1.01*	*$1.01*	*$1.02*	*$1.02*	*$1.03*	*$1.03*	*$1.03*	*$1.04*	*$1.04*	*$1.05*	*$1.05*	*$1.06*	*$1.06*	*$1.06*	*$1.07*	*$1.07*	*$1.08*	*$1.08*
Carbon Tax	$1,885	$2,827	$3,770	$4,712	$5,655	$6,597	$7,540	$7,540	$7,540	$7,540	$7,540	$7,540	$7,540	$7,540	$7,540	$7,540	$7,540	$7,540	$7,540	$7,540
Total Proposed Case	$219,216	$92,891	$93,114	$93,337	$93,561	$93,786	$94,011	$94,238	$94,465	$94,693	$94,922	$95,151	$95,382	$95,613	$95,845	$96,078	$96,311	$96,546	$96,781	$97,017
Net Cash Flow	($120,481)	$6,145	$6,225	$6,305	$6,386	$6,467	$6,548	$6,629	$6,710	$6,791	$6,873	$6,955	$7,037	$7,119	$7,201	$7,284	$7,367	$7,450	$7,533	$7,616
Cumlative Cash Flows	($120,481)	($114,336)	($108,111)	($101,806)	($95,420)	($88,953)	($82,406)	($75,777)	($69,067)	($62,276)	($55,403)	($48,448)	($41,411)	($34,292)	($27,090)	($19,806)	($12,440)	($4,990)	$2,543	$10,159
PRESENT VALUES																				
Base Case Costs	$98,735	$99,036	$99,339	$99,642	$99,947	$100,253	$100,559	$100,867	$101,175	$101,484	$101,795	$102,106	$102,419	$102,732	$103,046	$103,362	$103,678	$103,995	$104,314	$104,633
Proposed Case Costs	$219,216	$92,891	$93,114	$93,337	$93,561	$93,786	$94,011	$94,238	$94,465	$94,693	$94,922	$95,151	$95,382	$95,613	$95,845	$96,078	$96,311	$96,546	$96,781	$97,017
Annual Savings	($120,481)	$6,145	$6,225	$6,305	$6,386	$6,467	$6,548	$6,629	$6,710	$6,791	$6,873	$6,955	$7,037	$7,119	$7,201	$7,284	$7,367	$7,450	$7,533	$7,616
Cumulative Total	($120,481)	($114,336)	($108,111)	($101,806)	($95,420)	($88,953)	($82,406)	($75,777)	($69,067)	($62,276)	($55,403)	($48,448)	($41,411)	($34,292)	($27,090)	($19,806)	($12,440)	($4,990)	$2,543	$10,159

APPENDIX F: SHAW'S 20 YEAR LCCA

Result Metric	Abbr	Value	Units
Net Present Value	NPV	$94,626	
Discounted Payback Period	DPP	13.9	yr
Internal Rate of Return	IRR	13.3%	

Input	Value	Units
Discount Rate	10.0%	
Electric Rate Escalation	0.3%	/ Year
Electric Demand Rate Escalation	0.3%	/ Year
Gas Rate Escalation	0.4%	/ Year
Power Purchase Agreement Rate	$0.160	/ kWh

Assumption	Value	Units
Lighting Incentive Rate	$2.00	/ kWh
Electric Custom Incentive Rate	$0.18	/ kWh
Gas Custom Incentive Rate	$1.25	/ kWh

	1	2	3	4	5	6	7	8	9	10
Year	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033
CASH FLOWS										
Base Case										
Utility Electricty Use Costs	$260,572	$261,287	$262,004	$262,722	$263,443	$264,165	$264,890	$265,616	$266,345	$267,075
Utility Electric Demand Costs	$20,069	$20,124	$20,179	$20,235	$20,290	$20,346	$20,402	$20,458	$20,514	$20,570
Effective Electricity Rate $/kWh	*$0.140*	*$0.140*	*$0.141*	*$0.141*	*$0.142*	*$0.142*	*$0.142*	*$0.143*	*$0.143*	*$0.144*
Utility Natural Gas Costs	$35,891	$36,040	$36,191	$36,341	$36,493	$36,645	$36,798	$36,952	$37,106	$37,260
Effective Natural Gas Rate $/therm	*$1.00*	*$1.00*	*$1.01*	*$1.01*	*$1.02*	*$1.02*	*$1.03*	*$1.03*	*$1.03*	*$1.04*
Carbon Tax	$10,076	$15,114	$20,152	$25,190	$30,228	$35,266	$40,304	$40,304	$40,304	$40,304
Total Base Case	$326,608	$332,565	$338,526	$344,488	$350,454	$356,422	$362,393	$363,329	$364,268	$365,210
Proposed Case										
ECM Implementation Costs	$528,700									
ECM Utility Incentives	($80,675)									
PPA Electricity Costs	$37,902	$37,902	$37,902	$37,902	$37,902	$37,902	$37,902	$37,902	$37,902	$37,902
Utility Electricty Use Costs	$178,146	$178,635	$179,125	$179,616	$180,108	$180,602	$181,098	$181,594	$182,092	$182,592
Utility Electric Demand Costs	$15,985	$16,029	$16,073	$16,117	$16,161	$16,206	$16,250	$16,295	$16,339	$16,384
Effective Electricity Rate $/kWh	*$0.144*	*$0.145*	*$0.145*	*$0.145*	*$0.146*	*$0.146*	*$0.146*	*$0.147*	*$0.147*	*$0.147*
Utility Natural Gas Costs	$35,891	$36,040	$36,191	$36,341	$36,493	$36,645	$36,798	$36,952	$37,106	$37,260
Effective Natural Gas Rate $/therm	*$1.00*	*$1.00*	*$1.01*	*$1.01*	*$1.02*	*$1.02*	*$1.03*	*$1.03*	*$1.03*	*$1.04*
Carbon Tax	$7,514	$11,272	$15,029	$18,786	$22,543	$26,300	$30,057	$30,057	$30,057	$30,057
Total Proposed Case	$723,463	$279,878	$284,319	$288,763	$293,208	$297,656	$302,106	$302,800	$303,497	$304,196
Net Cash Flow	($396,855)	$52,688	$54,206	$55,726	$57,246	$58,766	$60,288	$60,529	$60,771	$61,013
Cumlative Cash Flows	($396,855)	($344,167)	($289,961)	($234,235)	($176,990)	($118,223)	($57,936)	$2,593	$63,364	$124,377
PRESENT VALUES										
Base Case Costs	$326,608	$302,332	$279,773	$258,819	$239,365	$221,310	$204,562	$186,445	$169,934	$154,884
Proposed Case Costs	$723,463	$254,434	$234,975	$216,952	$200,265	$184,821	$170,531	$155,384	$141,584	$129,009
Annual Savings	($396,855)	$47,898	$44,799	$41,868	$39,100	$36,489	$34,031	$31,061	$28,350	$25,876
Cumulative Total	($396,855)	($348,957)	($304,159)	($262,291)	($223,191)	($186,702)	($152,671)	($121,610)	($93,260)	($67,385)

	11	12	13	14	15	16	17	18	19	20
Year	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043
CASH FLOWS										
Base Case										
Utility Electricty Use Costs	$267,808	$268,542	$269,279	$270,017	$270,758	$271,501	$272,245	$272,992	$273,741	$274,491
Utility Electric Demand Costs	$20,626	$20,683	$20,740	$20,797	$20,854	$20,911	$20,968	$21,026	$21,083	$21,141
Effective Electricity Rate $/kWh	*$0.144*	*$0.144*	*$0.145*	*$0.145*	*$0.145*	*$0.146*	*$0.146*	*$0.147*	*$0.147*	*$0.147*
Utility Natural Gas Costs	$37,416	$37,572	$37,729	$37,886	$38,044	$38,203	$38,362	$38,522	$38,683	$38,844
Effective Natural Gas Rate $/therm	*$1.04*	*$1.05*	*$1.05*	*$1.06*	*$1.06*	*$1.06*	*$1.07*	*$1.07*	*$1.08*	*$1.08*
Carbon Tax	$40,304	$40,304	$40,304	$40,304	$40,304	$40,304	$40,304	$40,304	$40,304	$40,304
Total Base Case	$366,154	$367,101	$368,051	$369,004	$369,959	$370,918	$371,879	$372,843	$373,810	$374,780
Proposed Case										
ECM Implementation Costs										
ECM Utility Incentives										
PPA Electricity Costs	$37,902	$37,902	$37,902	$37,902	$37,902	$37,902	$37,902	$37,902	$37,902	$37,902
Utility Electricty Use Costs	$183,093	$183,595	$184,098	$184,603	$185,110	$185,617	$186,126	$186,637	$187,149	$187,662
Utility Electric Demand Costs	$16,429	$16,474	$16,519	$16,565	$16,610	$16,656	$16,701	$16,747	$16,793	$16,839
Effective Electricity Rate $/kWh	*$0.148*	*$0.148*	*$0.148*	*$0.149*	*$0.149*	*$0.149*	*$0.150*	*$0.150*	*$0.150*	*$0.151*
Utility Natural Gas Costs	$37,416	$37,572	$37,729	$37,886	$38,044	$38,203	$38,362	$38,522	$38,683	$38,844
Effective Natural Gas Rate $/therm	*$1.04*	*$1.05*	*$1.05*	*$1.06*	*$1.06*	*$1.06*	*$1.07*	*$1.07*	*$1.08*	*$1.08*
Carbon Tax	$30,057	$30,057	$30,057	$30,057	$30,057	$30,057	$30,057	$30,057	$30,057	$30,057
Total Proposed Case	$304,897	$305,601	$306,306	$307,014	$307,723	$308,435	$309,149	$309,866	$310,584	$311,305
Net Cash Flow	$61,256	$61,500	$61,745	$61,990	$62,236	$62,482	$62,730	$62,978	$63,226	$63,475
Cumlative Cash Flows	$185,634	$247,134	$308,879	$370,869	$433,105	$495,587	$558,317	$621,294	$684,521	$747,996
PRESENT VALUES										
Base Case Costs	$141,168	$128,667	$117,272	$106,887	$97,422	$88,795	$80,932	$73,765	$67,233	$61,280
Proposed Case Costs	$117,551	$107,111	$97,599	$88,931	$81,033	$73,837	$67,280	$61,305	$55,861	$50,901
Annual Savings	$23,617	$21,555	$19,674	$17,956	$16,389	$14,958	$13,652	$12,460	$11,372	$10,379
Cumulative Total	($43,768)	($22,212)	($2,539)	$15,418	$31,806	$46,764	$60,416	$72,876	$84,248	$94,626

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