B2Q

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Mr. Shawn Luz
Sustainability Coordinator
City of Framingham
150 Concord Street
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RE: Framingham Energy Resiliency Feasibility Assessment Phase 1

Dear Shawn,

B2Q is pleased to provide this report summarizing our findings from this high-level review of the feasibility of implementing energy resiliency and/or microgrid projects at Memorial Hall and the Police Department Headquarters.

Introduction

The City of Framingham recently completed a community resilience study and workshop, funded by a Municipal Vulnerability Preparedness (MVP) Planning Grant, in an effort to: a) identify climate-related hazards the City faces or may face in the future, including but not limited to flooding, extreme temperatures, and severe weather, b) evaluate potential impacts of these hazards, and c) develop recommendations to mitigate these impacts and improve resiliency. One high-priority recommendation made in the final report is to investigate opportunities to integrate backup power, including green power and battery storage, at critical facilities. In response, the City's sustainability department is exploring options to improve energy resiliency and install distributed energy resources (DERs) at (2) City facilities – Memorial Hall and the Police Department Headquarters (PDHQ).

Facility Descriptions

Memorial Hall

General

Memorial Hall is a 76,453 ft^2, three-story (two above grade, one below grade) brick building located at 150 Concord Street. It was originally built in 1926. The building is primarily comprised of offices for city personnel, such as the mayor, building inspector, town clerk, town treasurer, etc. There are two meeting rooms on the ground level used for medium-sized gatherings and one large concert hall, known as Nevins Hall, on the first floor that is used for special functions.

Mechanical Equipment

The airside mechanical systems include (2) air handling units (AHUs) serving dedicated spaces. AHU-2 provides cooling to the Blumer Room and associated conference rooms on the ground floor, while AHU-4 provides cooling to the Ablondi Room on the first floor. Most of the building is heated and cooled by the Mitsubishi variable refrigerant flow (VRF) system. A few spaces, such as the archive room and planning board, are not connected to the VRF system, but rather are served by a dedicated split air conditioner or heat pump. The server room on the ground floor is served by a Liebert in-row cooler and a wall-mounted Carrier heat pump.

The steam system is comprised of (2) 4,358 MBH HB Smith 28HE Steam Power-Burner boilers. The system supplies steam to perimeter radiators throughout the building, as well as the steam coil in the Nevins Hall AHU.

Memorial Hall has an energy management system (EMS) that controls the AHUs and boilers. The EMS has some control of the Mitsubishi VRF system. Space temperature setpoint, mode of operation, and occupancy schedules for the VRF system may be adjusted via the EMS. Based on our past observations during our energy scoping study, there is no automated, synchronized control between EMS and equipment and VRF equipment (e.g. between radiators and heat pumps in the same room). Most of the radiators in the building have pneumatic actuators and therefore are not on the EMS.

ELECTRICAL INFRASTRUCTURE

Electric service is provided to Memorial Hall by Eversource. The electric service is dedicated to the building and ties in at the 1200-amp main switchboard (MSB) at 208 V in the main electric room. There are approximately 20 – 30 electric panels throughout the building that are fed from the MSB. Of these panels, we observed (3) panels designated as emergency panels indicating that they are served by the backup power system. The backup power system is served by (1) 100 kW Caterpillar diesel generator

POLICE DEPARTMENT HEADQUARTERS

GENERAL

PDHQ is a 42,336 ft^2, three-story brick building located at 1 William H Welch Way. It was originally built in 1908 and renovated in 1994.The original 11,000 ft^2 Police headquarters was located in the historic armory building prior to the addition that constructed the remaining 31,336 ft^2. The expanded headquarters includes a firing range, 20-cell detention area, training facilities, and an exercise/racquetball court.

MECHANICAL EQUIPMENT

The airside mechanical systems serving the Police Station are comprised of (2) air handling units (AHUs) providing ventilation, cooling and heating for most of the Station. AC-1 serves the majority of the building's VAVs and fan powered boxes, while AC-2 primarily serves the holding cells. There are (2) heating and ventilating (H&V) units, HV-1 and HV-2, whose primary function is to provide ventilation and heating for the shooting range and the garage, respectively. There are also (3) split air conditioning units named FX-1/2/3 serving the dispatch and the fitness areas.

The hot water system includes (2) 850 MBH hot water (HW) boilers, referred to as Boiler-1 and Boiler-2, which serves perimeter radiation, VAV reheat coils, and AHU heating coils. The hot water system has (2) 3 hp pumps with constant speed motors. The chilled water (CHW) system consists of (1) 90-ton air-cooled chiller, which serves cooling needs for the AHUs and FCUs. The chilled water system has (2) 5 hp pumps with variable speed motors.

Airside and waterside mechanical systems are controlled with an EMS. AC-1 appears to have packaged controls from the original equipment manufacturer (OEM) and it is integrated into the EMS via BACnet.

The building operates on a 24/7 basis, however, some occupancy schedules are used to turn of select equipment during unoccupied periods.

ELECTRICAL INFRASTRUCTURE

Electric service is provided to PDHQ by Eversource. The electric service is dedicated to the building and ties in at the 1600-amp MSB at 208 V in the basement electric room. Four electric panels and the chiller are fed by the MSB. All of the electric panels are tied to the backup power system, which is served by (1) 250 kW Caterpillar diesel generator.

ELECTRIC DEMAND PROFILES

B2Q obtained actual monthly peak electric demand data for May 2019 through April 2020 from the demand history chart on a sample utility bill. Summer and winter weekday daily demand profiles were estimated based on the equipment sizes and runtime schedules, as well as our experience from analyzing similar types of facilities during past projects.

MEMORIAL HALL

The graph below shows monthly electric peak demand data for Memorial Hall. Monthly demand over the course of the year is relatively consistent, which is atypical. In comparable facilities, electric demand typically decreases with outside air temperature; however, Memorial Hall utilizes electric heat pumps in the winter to provide heat to some spaces, which may be driving demand higher than similar facilities.

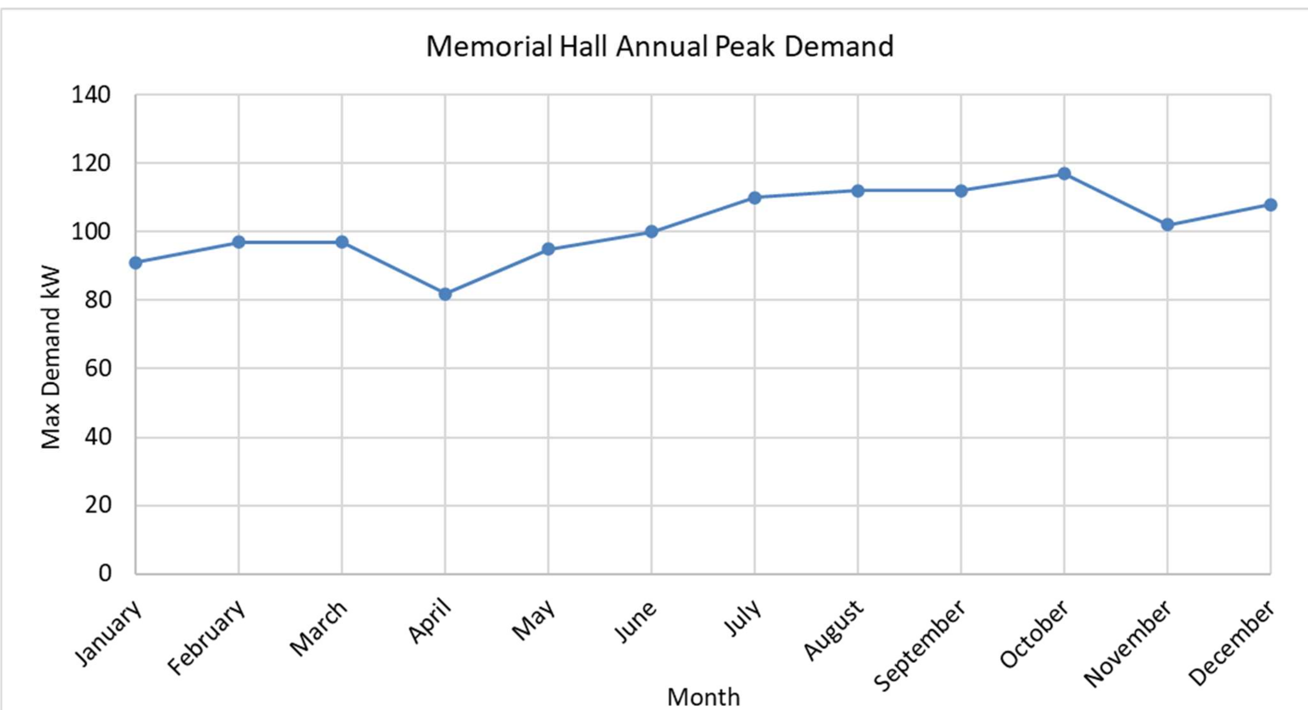

Figure 1: May 2019 – April 2020 monthly peak electric demand for Memorial Hall.

Electric end-use information gathered during our recent scoping study was used to estimate hourly electric demand during a typical day in heating and cooling seasons. The resulting daily demand profiles are captured below in Figure 2. We estimate that electric demand is rather consistent in the summer and winter and is generally highest on weekdays during business hours. Electric demand is expected to decrease overnight and on weekends due to equipment unoccupied setbacks programmed via the EMS.

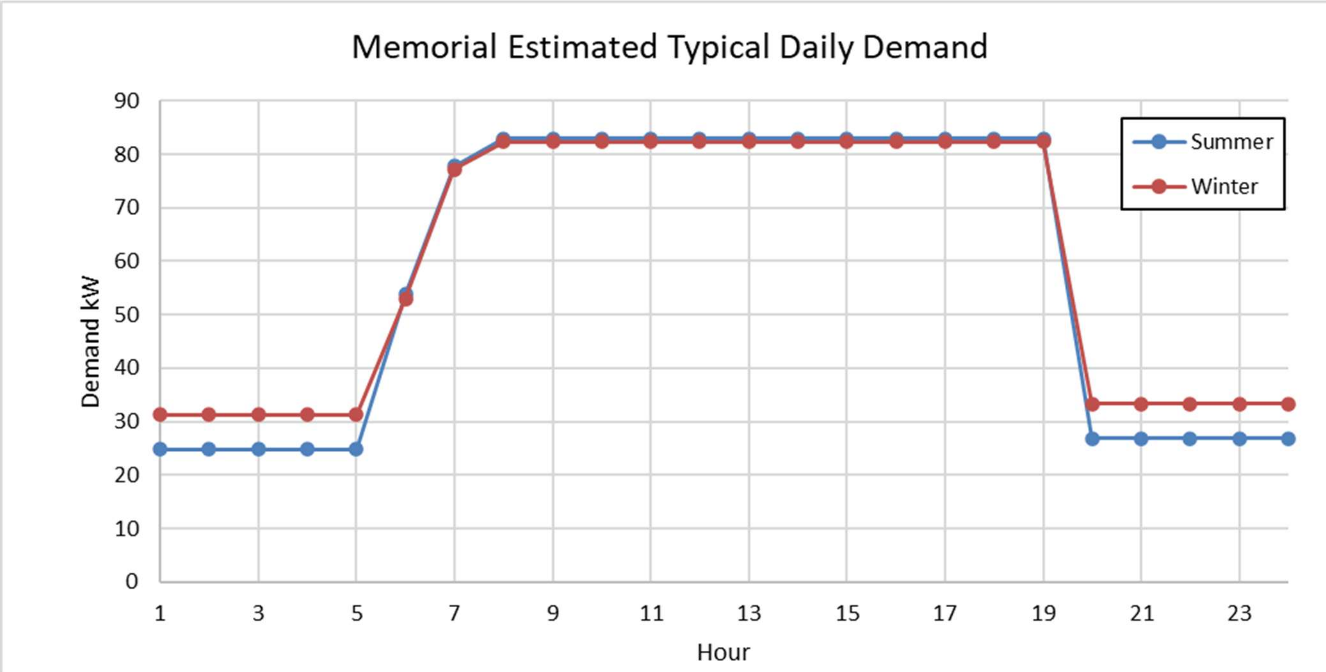

Figure 2: Estimated summer and winter daily electric demand profiles for Memorial Hall.

POLICE DEPARTMENT HEADQUARTERS

The graph below shows monthly electric demand data for PDHQ. Monthly demand is higher during the summer as a result of air conditioning loads, which is typical. The building's base load is relatively consistent at 60 kW during the winter and spring.

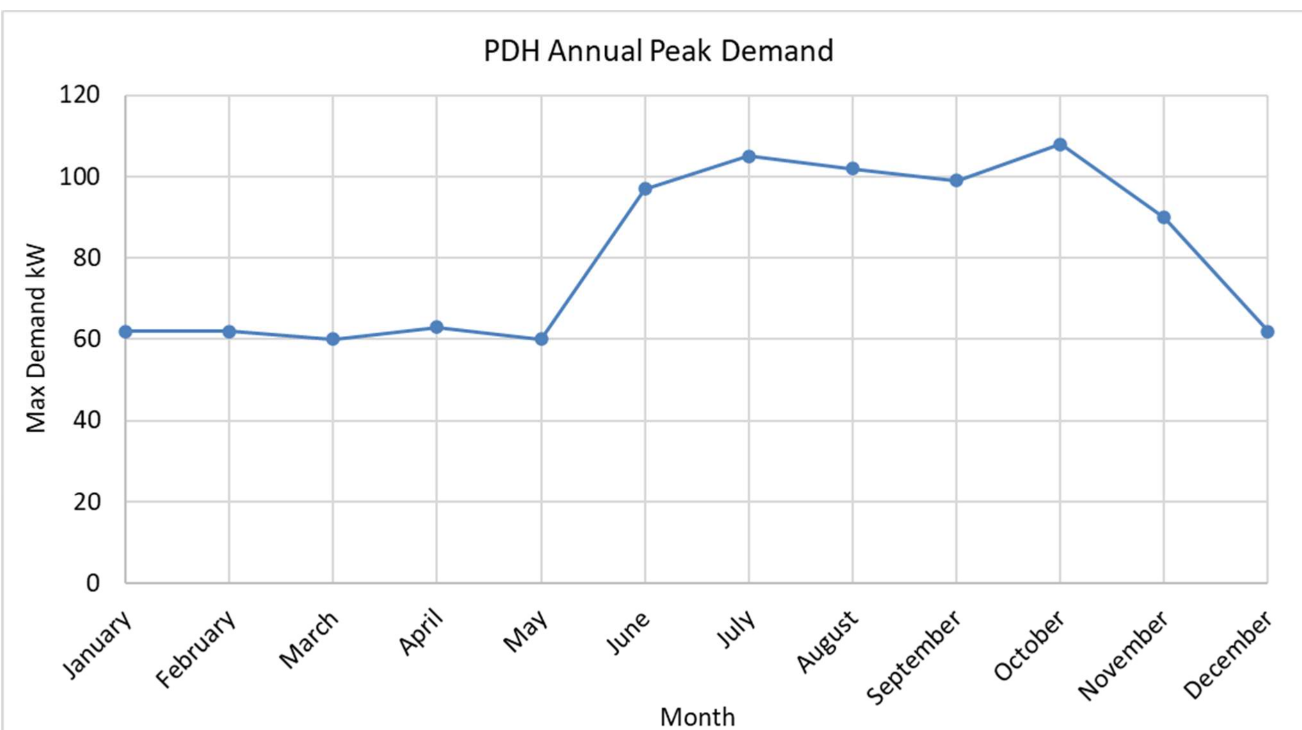

Figure 3: May 2019 – April 2020 monthly peak electric demand for PDHQ.

Electric end-use information gathered during our recent scoping study was used to estimate hourly electric demand during a typical day in heating and cooling seasons. The resulting daily demand profiles are captured below in Figure 4. Mechanical equipment in the building runs 24/7 so demand is relatively consistent throughout the day, with some reductions expected overnight when occupancy is low.

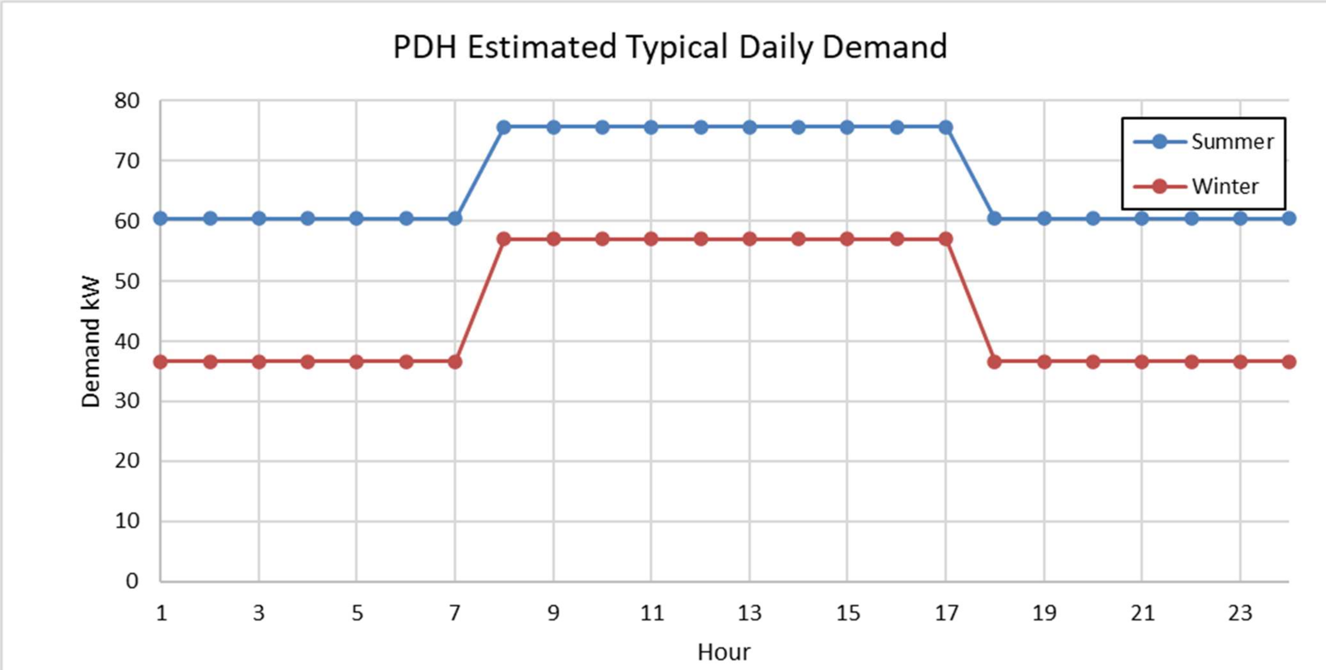

Figure 4: Estimated summer and winter daily electric demand profiles for PDHQ.

VULNERABILITIES, OFF-GRID CAPABILITIES AND GOALS

MEMORIAL HALL

Currently, Memorial Hall is mostly unused during an emergency situation; however, it is home to the City's IT network servers, thus deeming it a critical facility. It is imperative that the servers in the IT room be operational at all times, so the IT equipment as well as the room's dedicated cooling system is connected to an uninterruptible power source (UPS) and the backup power system in case of a utility power outage.

Potential emergency situations involving a utility power outage may include climate-related extreme storms, which are often accompanied by flooding. In case of substantial flooding, the backup power system is not particularly vulnerable to storm-related damage, as the MSB is located on the first floor and the generator is raised a few feet from the ground. It is notable that the City's MVP report did not indicate the area near Memorial Hall or PDHQ as having significant flood risk during a major storm. Although the building may not experience many direct impacts from major storms, the integrity of the utility grid as a whole may be impacted thus resulting in the loss of power to the building. Other potential causes of utility power outages may include severe thunder or snow storms or general equipment failures. Brownouts are also a concern in the area. City staff noted in the past, when the electric demand in the area is high in the summer, they've had to manually adjust equipment operation to keep the building operational despite electricity coming into the building at a low voltage. The City is concerned that the risk of brownouts may worsen over time as new buildings are developed in the area.

The backup power system for the rest of the building consists of (1) 100 kW Caterpillar diesel generator. Upon sensing a loss of utility electric power, the 200-amp automatic transfer switch, ATS-2, will automatically switch from its normal to emergency position. There is a second switch, ATS-1, which is believed to be unused and reserved as a backup. The generator is located outside and is coupled with a 250-gallon storage tank.

Based on conversations with city staff and our observations on site, it is our understanding that a limited amount of equipment is connected to the backup power system via emergency panels behind ATS-2. The steam boilers and associated components are connected to backup power and could continue to operate during a utility power outage. The air compressor in the boiler room used for pneumatic actuators is also on the backup system, meaning heat could be provided to portions of the building, including Nevins Hall, via perimeter radiators during an outage. It does not appear that the AHUs, split air conditioners, or heat pumps throughout the buildings are connected to the backup power system, with the exception of a few miscellaneous air conditioners. Based on limited information, it does not appear that the lights in the building are on the backup power system, with the exception of emergency egress lighting. Based on the rating of ATS-2, we estimate that up to 40 kW of electric load could be connected and powered by the backup power system. Based on the generator's performance ratings, we anticipate that the generator could power the loads connected to the backup power system for 2-3 days, starting with a full tank of fuel. Operation beyond this time is dependent on additional fuel delivery.

Due to the limited amount of equipment tied to the backup power system, the City's current ability to safely occupy the building during an extended power outage is likely limited. Currently, much of the building cannot be heated, cooled, or lit without utility power, and most plug outlets connected to computers and other office equipment cannot be energized. Nevins Hall is heated by steam radiators and could potentially be occupied during the day while the room gets natural light from the windows.

It should be noted that the City is working on securing (2) electric vehicles (EVs) and corresponding charging stations in the Memorial Hall parking lot to add to the City's vehicle fleet. In addition to the two planned charging stations, we understand the City is interested in adding several more charging stations in the future to accommodate an expanding EV fleet to be used by departments housed in Memorial Hall, such as Inspectional Services and the Health Department. In most cases, the charging stations have a dedicated electrical feed from the utility, but if they can be fed from the building's standby power system, then this would allow the City to continue to charge the vehicles during a local grid power outage, thereby increasing the resiliency of the vehicle fleet.

POLICE DEPARTMENT HEADQUARTERS

The PDHQ houses the City's Emergency Operations Center (EOC) and plays a critical role during emergency situations. City personnel, including police, fire, and other officials, use the EOC as a meeting location and command center during all types of emergencies. Potential emergency situations involving a utility power outage may include climate-related extreme storms, which are often accompanied by flooding. In case of substantial flooding, the backup power system is somewhat vulnerable to storm-related damage. While the generator is raised a few feet from the ground and is not particularly vulnerable to flooding, the MSB is located in the basement, which could become damaged and inoperable if standing floodwater gathered in the basement or water rained onto the switchgear. However, it is notable that the City's MVP report did not indicate the area near Memorial Hall or PDHQ as having significant flood risk during a major storm. Although the building may not experience many direct impacts from major storms, the integrity of the utility grid as a whole may be impacted thus resulting in the loss of power to the building. As mentioned in the section above, brownouts are also a concern in the area.

The entire building is connected to the backup power system, which includes (1) 250 kW Caterpillar diesel generator. Based on a report provided by city personnel, the generator was sized to meet the building's peak load in 2014, which was roughly 160 kW, with room for future demand growth. The building's current annual peak demand is 110 kW, so the generator has spare capacity. Upon sensing a loss of utility electric power, the 1,600-amp automatic transfer switch, ATS-1, will automatically switch from its normal to emergency position. The generator is located outside and is coupled with a 500-gallon storage tank.

While the PDHQ is fairly energy resilient, if there were to be a utility power outage, potentially caused by a climate-related emergency event, the building's operation beyond a few days is entirely dependent on additional fuel deliveries. If the building was running on the backup power system at its typical demand level, we anticipate that the generator could power the building loads for 4-5 days, starting with a full tank of fuel. Operation beyond this time is dependent on additional fuel delivery. If the tank becomes empty and fuel deliveries are delayed or unavailable, the building, including the EOC, would lose power completely. Due to the high importance of PDHQ during emergencies, the City is interested in improving the energy resilience of the facility potentially through on-site renewable energy generation and/or battery energy storage.

MOBILE GENERATORS

The City has access to several mobile generators through an agreement with Northeast Homeland Security Regional Advisory Council (NERAC). Based on the inventory provided by the City, several options are currently available including (2) 75-kW, (1) 45-kW, (1) 55-kW, (1) 150 – 210-kW, and (4) "small" mobile generators. During an emergency situation, Memorial Hall and PDHQ may be able to utilize an available mobile generator to power some, if not all, of the loads connected to the backup power systems. Mobile generators add another layer of energy resilience to each facility as they may be available to be used in place of the existing backup generators while waiting for fuel deliveries. Based on available information, it does not appear that the mobile generators could run simultaneously with the building backup generators. City staff have indicated that they would explore the option to install a manual bypass switch for the existing generator to allow for a more seamless swap over to the mobile generator, when enabled. Similarly, electrical infrastructure upgrades would be required if the City intended to run the mobile generator(s) in parallel with the existing backup generator.

ENERGY RESILIENCY SOLUTIONS

DEMAND MANAGEMENT

The existing energy management system at PDHQ may be utilized to reduce HVAC equipment demand and extend runtime during off-grid operations. For example, if the EMS monitored the status of the backup generator, the EMS could command HVAC equipment to follow setbacks when the generator status transitioned to on. To reduce electric demand, zone temperature setpoints may be relaxed, fan and pumps speeds may be reduced, or turned off completely in certain zones, and the chiller could control to a higher chilled water temperature to limit runtime/demand. Alternatively, upon a power outage building personnel could manually setback HVAC equipment via overrides on the EMS if properly trained and staffed.

It is our understanding that limited, if any, airside HVAC equipment at Memorial Hall is currently tied into the backup power system. Therefore, demand management strategies do not presently hold as much value as at PDHQ. If electrical upgrades are pursued to increase the size of the backup power system and integrate additional HVAC loads, then demand management may be a viable strategy. The feasibility of HVAC demand management during off-grid events should be considered in more detail. Note, however, that because the majority of the air conditioning in Memorial Hall is provided by the VRF system, which is distributed throughout the building and fed by many different electrical panels, a wholesale upgrade to the electrical infrastructure would be required to maintain air conditioning during an outage.

Installing advanced lighting control systems may permit lighting demand management strategies, such as dimming or turning off certain lights, during an off-grid event to reduce the load on the generator, thereby extending building operations. It should be noted that this type of retrofit has a relatively high cost, as all of the lights will need to be upgraded to LEDs and each fixture must be wired to the lighting controller. Incentives may be available from Eversource to cover some of the costs. Again, based on the present backup power system, this would be an impactful and cost-effective option for PDHQ only. Lighting control system configurations and feasibility should be considered in more detail. Alternatively, upon a power outage building personnel could manually turn off lights in unoccupied zones to reduce electric demand and extend the generator runtime.

Energy Conservation Initiatives

There are a number of energy conservation initiatives planned for both sites in the near future, such as installing variable frequency drives (VFDs) on fans and installing occupancy sensors, that could reduce annual electric and natural gas consumption by up to 50,600 kWh and 7,100 therms at Memorial Hall and 123,700 kWh and 6,200 therms at PDHQ. This would further improve energy resiliency by extending the potential runtime of the generator, as well as extending the amount of the buildings' loads that can be met by any DERs installed in the future.

Electrical Infrastructure Upgrades

One option to improve energy resiliency at Memorial Hall is to complete electrical infrastructure upgrades to connect more, if not all, of the building to the backup power system. It should be noted that rewiring individual feeds or electrical panels is a significant undertaking, but may be possible. Based on the size of ATS-2, it is unlikely that it has the capacity to support additional loads. If ATS-2 was to be replaced with a larger switch, the existing generator has the capacity to support more loads. The generator is rated for 100 kW, which is below the building's historical 120 kW peak demand, but is likely has enough capacity to power most, if not all, of the building on a typical day. Based on the generator's performance ratings, we estimate that the generator could power 100 kW of load for roughly 1 day, starting with a full tank of fuel. If demand management strategies are deployed or only part of the building is added to the backup power system, the generator may be able to power the building on the order of 2-3 days, starting with a full tank of fuel. Operation beyond this time would be dependent on additional fuel delivery.

If changes are made to the electrical infrastructure to keep more of the building's equipment running during an emergency situation without utility power, the building could potentially play more of an important role to the City, such as a food and supply distribution center or a community gathering and/or shelter place. Specifically, the City has expressed interest in integrating the Mayor's office, the Board of Health, and select meeting spaces into the backup power system; however, we understand that City personnel are able to work remotely when Memorial Hall is not usable. Further, if future EV charging stations are fed from the building's backup power system, then the charging stations may also benefit from electrical infrastructure upgrades and the City could charge the vehicles during a local grid power outage.

Improve Generator System Reliability

Increase Fuel Storage

Another option to strengthen energy resiliency at each site is to increase the size of the diesel fuel storage tanks. Similarly, a third tank could be added on site which could be shared by both buildings. Additional on-site fuel storage would extend equipment runtime during an off-grid scenario and could lessen the buildings' dependence on fuel deliveries. The feasibility of upsizing the existing tanks or installing a third, centralized tank should be studied in more detail if the City is interested.

Upgrades for Seamless Building to Mobile Generator Transition

As discussed above, if the backup diesel generator at either building runs out of fuel and is waiting for a fuel delivery, mobile generators may be available to power some or potentially all of the backup power loads. However, based on discussions with city staff, the current process involves disconnecting all loads from a power source during the generator transition. A potential solution to permit a seamless transition between generators may be installing manual bypass switches on the buildings' existing generator feeds to accommodate the connection to a standalone mobile generator, allowing facilities personnel to flip between sources as needed for refueling or maintenance. The feasibility of this option should be considered in more detail if the City is interested.

Distributed Energy Resources

Integrating DERs at Memorial Hall and PDHQ would improve energy resiliency during a utility grid outage by reducing dependence on fuel deliveries and extending the duration of off-grid building operations using on-site energy assets. Further, during an off-grid scenario all of the electrical loads in the building could be powered while the DERs are actively generating electricity. On-site renewable energy generation and storage also may result in energy cost savings throughout the year and progress the City's sustainability and climate action goals. Potential DER assets include, but are not limited to, rooftop solar photovoltaics (PV), canopy solar PV over parking areas, battery energy storage, wind turbines, and combined heat and power (CHP). On-site DER assets may be utilized individually or be integrated together as a microgrid to serve one building, or potentially several buildings. Based on available billing data, estimated demand profiles, site observations, and discussions with city personnel, we have considered the feasibility of each of the mentioned DER options at a high-level. Table 1 on the following page summarizes potential opportunities and is followed by specific discussions for each DER asset, as well as a microgrid that connects multiple DER assets.

Table 1: Summary of DER feasibility.

	Feasibility	Potential Location	Potential DER Challenges	Potential Multi-Building Microgrid Challenges
Rooftop PV	Likely feasible	• MH	• Structural capacity of the roof to be determined	• Crossing William H Welch Way to integrate DERs into microgrid shared by MH and PDHQ would present regulatory challenges • Utility interconnection approval
Canopy PV	Potentially feasible	• MH Parking Lot	• Snow plow and front-end loader access in the winter • Potential clearance requirements near Union Ave and William H Welch Way • Parking spaces are in high demand – need to preserve as many spaces as possible • Higher construction costs than rooftop PV • Excavation involved – unknown soil conditions/contaminants • If system dedicated to PDHQ, crossing William H Welch Way would present regulatory challenges	
Battery Energy Storage	Potentially feasible	• Outside of MH near alleys • In parking lot next to PDHQ generator	• Space requirements – NFPA code requires outdoor placement 10 feet from buildings and public ways • Parking spaces are in high demand – need to preserve as many spaces as possible	
Wind	Likely not feasible	• Roof • Parking lot	• Space required for a unit large enough to meet scale of building demand • Structural demands for roof-mounted unit • Foundation/sub-surface work required for standalone unit	
CHP	Likely not feasible	• Roof • Parking lot	• Insufficient summer heating demand, CHP would inefficiently waste heat much of the year • No space available indoors and high demand for space in parking lot • Rooftop space would take away capacity of PV if pursued in parallel • Can be too noisy in urban environment if installed outdoors	

ROOFTOP PV

Memorial Hall's roof may be a candidate for rooftop solar PV, pending structural analysis. Potential roof sections to receive solar PV panels are captured below in Figure 5. Due to the varying roof pitches and the dormer windows on both sides of the PDHQ, we do not believe the roof at PDHQ is favorable for installing rooftop solar PV panels. Actual solar PV panel locations, arrangement, and mounting configurations should be determined by an engineer during a future study.

Figure 5: Potential sections of Memorial Hall roof to receive solar PV panels.

Based on typical industry metrics and roof square footage provided by drawings sent by the City, we estimate the roof may be able to accommodate a 110-kW rooftop solar PV system. Based on the estimated daily demand profiles presented earlier in Figure 2, a rooftop PV system of this size may be able to meet the entire building's electric demand during the portions of a day when the system is producing at its rated peak capacity. During a next phase, detailed analyses should be conducted to determine the roof's suitability, as well as the actual system size and annual electricity production.

Note if a rooftop solar PV system was installed individually, it could not produce electricity during an off-grid scenario unless coupled with the backup generator or an energy storage system which can form a grid for the solar PV system to follow.

CANOPY PV

The parking lot behind Memorial Hall and adjacent to PDHQ may be a candidate for a canopy solar PV system, which may extend over several parking rows. Based on the size of the parking area behind PDHQ, we do not anticipate that canopy solar PV will be a cost-efficient option over the area. See Figure 6 below for potential canopy solar coverage areas. Roadways requiring unrestricted vehicular travel, including large front-loaders for snow removal, are indicated with yellow arrows. Actual canopy solar PV panel locations, arrangement, and mounting configurations should be determined during subsequent studies. Possible disruptions to City operations, including snow and trash removal, should also be considered.

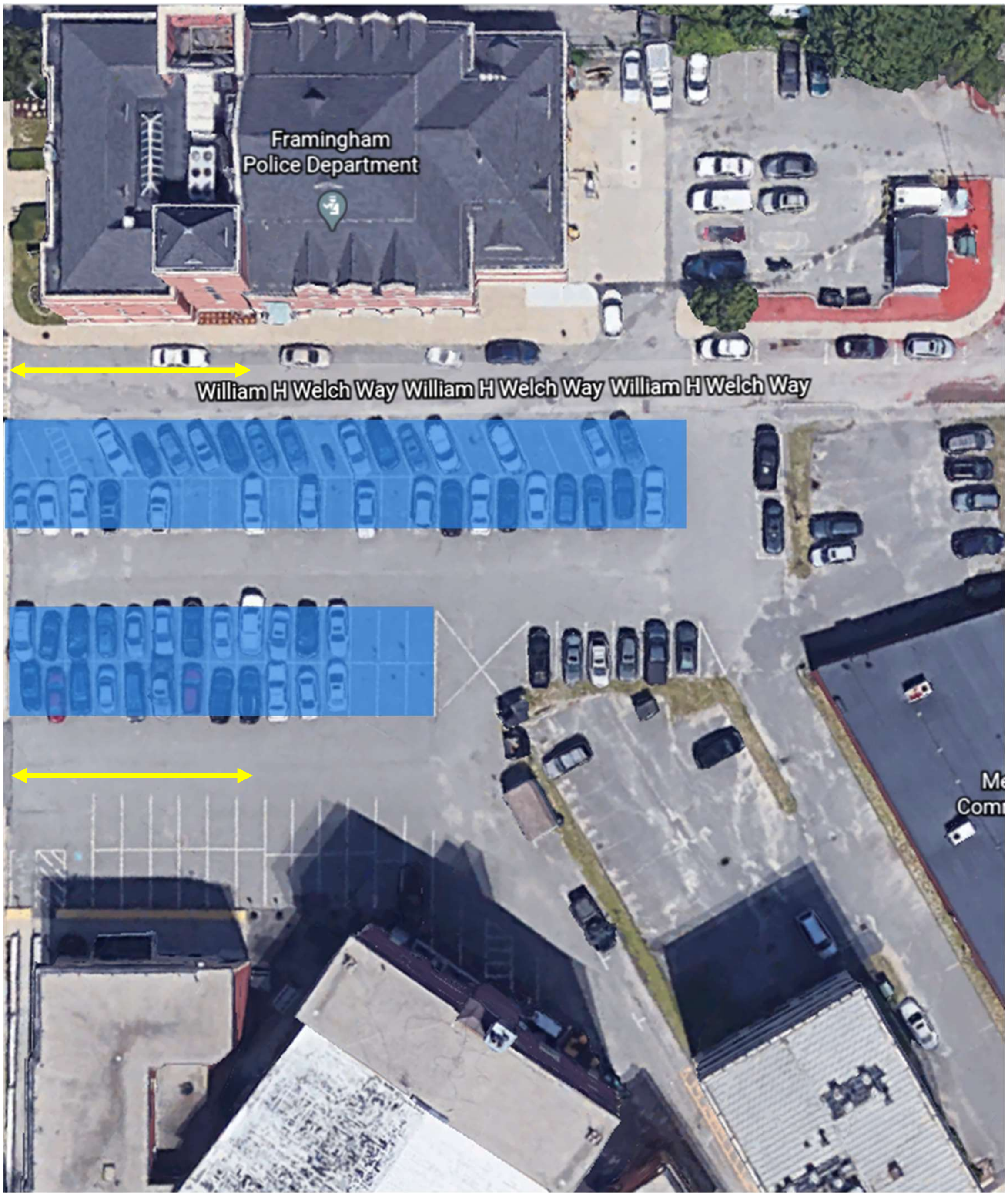

Figure 6: Potential parking lot sections compatible with canopy PV systems.

Based on typical industry metrics and the estimated square footage of the parking areas shown above, we estimate the parking lot may be able to accommodate a 110-kW canopy solar PV system. Based on the estimated daily demand profiles presented earlier in Figure 2, a canopy PV system of this size may be able to meet the electric demands of either building during the portions of a day when the system is producing at its rated peak capacity. If rooftop PV was installed on and dedicated to serve Memorial Hall, a canopy system over Memorial Hall's parking lot could potentially be dedicated to PDHQ. However, regulatory hurdles involved in crossing William H Welch Way, which is a public way, present significant, though not insurmountable challenges that need to be considered in more detail. During a next phase, detailed analyses should be conducted by an engineer to determine the parking lot's suitability, required clearances from roadways, and the actual system size and annual electricity production. Further, an environmental engineer may need to be engaged to consider the soil quality and potential excavation hurdles in the area.

Note if a canopy solar PV system was installed individually, or with rooftop solar PV only, it could not produce electricity during an off-grid scenario unless coupled with the backup generator or an energy storage system which can form a grid for the solar PV system to follow.

Battery Energy Storage

Battery energy storage systems (BESS), including lithium-ion batteries, can be coupled with on-site renewable energy generation to store excess electricity production, which may be discharged later when energy generation does not meet building demands. Alternatively, the BESS could charge from the utility grid, as well, potentially in preparation for an off-grid event. Additionally, the BESS may be used to participate in utility demand response programs, such as Eversource's Daily Dispatch program, to earn monetary incentives for discharging energy during the summer when the grid may be stressed. Currently, the incentive rate for the Daily Dispatch program is $200 per average kW reduction per summer.

Energy storage systems can be utilized during off-grid scenarios to black start on-site solar PV systems. The BESS and solar PV systems may operate together to power connected building loads when utility power is unavailable to supplement the capabilities of the existing backup diesel generator and potentially extend safe building operations and occupancy. Depending on the system configuration, these assets may be able to work in series or parallel to the existing generators.

Battery storage solutions are available for both indoor and outdoor installation, depending on the system size and fire safety requirements. Based on limited spare space observed in the buildings and anticipated fire safety concerns, an outdoor BESS may be the preferred option to consider. Note that the National Fire Protection Agency (NFPA) has developed specific codes for outdoor battery installations to promote safe operation. Notably, batteries installed outdoors must meet enclosure requirements and maintain a minimum of 10 feet of clearance between buildings and roadways. These requirements should be reviewed in detail to fully understand the requirements of installing a BESS at these sites. Locations that may meet code requirements are indicated in red in Figure 7 below, but need be further evaluated.

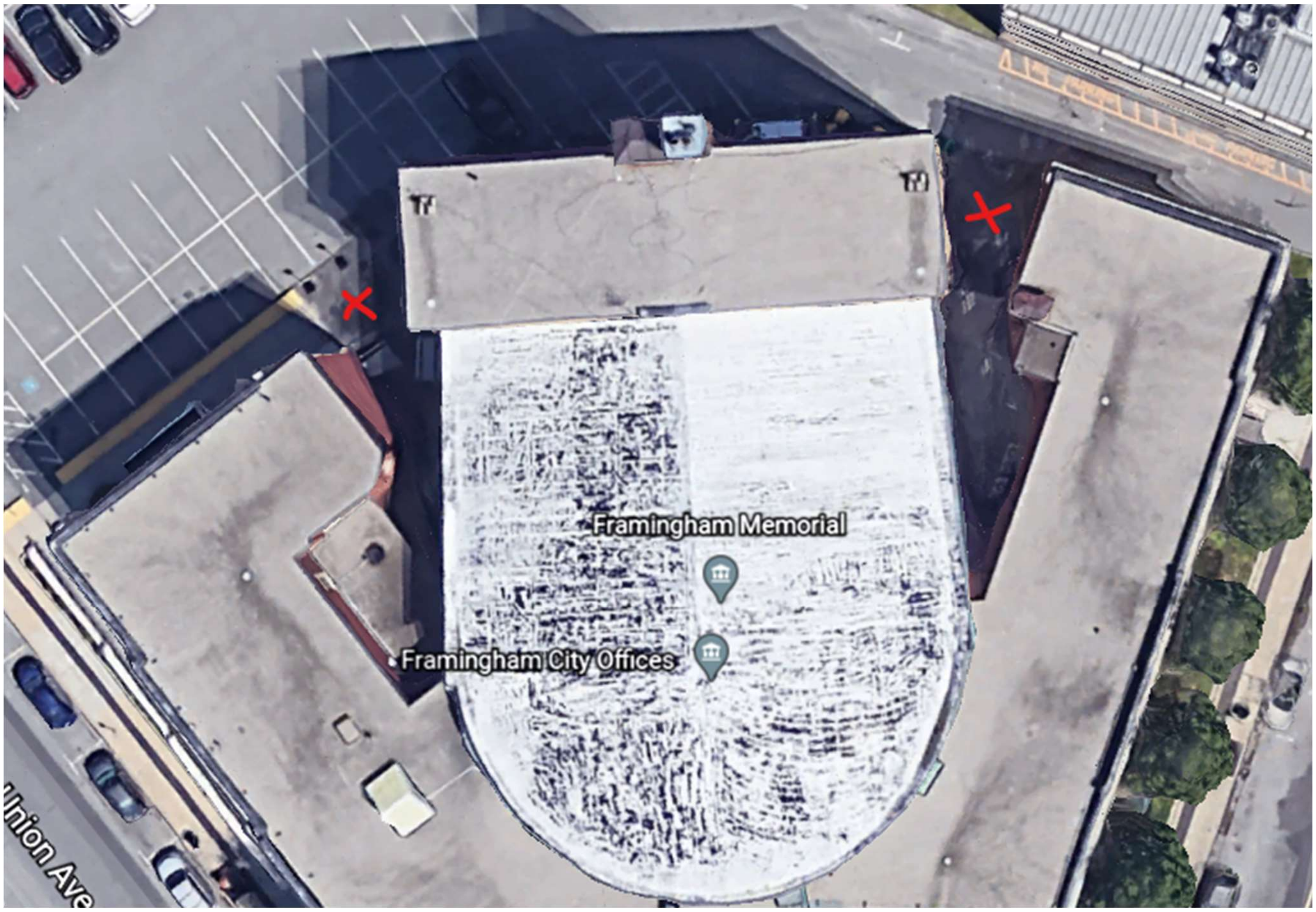

Figure 7: Potential outdoor BESS locations at Memorial Hall.

The area near the shed behind PDHQ was observed during our site visit as another potential location for a battery; however, it does not appear to be a feasible location due to NFPA clearance requirements, as it is directly adjacent to two public roads. Also, city personnel mentioned the possibility of placing the battery at other nearby, but not adjacent, City-owned property, such as the condemned Danforth Museum School. Although the feasibility of this scenario has not been vetted in detail, we do not anticipate it will be practical as the property located in between this parcel and PDHQ is not owned by the City.

Based on the estimated average demand values of Memorial Hall and PDHQ, potential BESS inverter ratings could be in the range of 160 kW to 230 kW, if one BESS is to be connected to both buildings and expected to power all electric loads in each building during an off-grid event. The BESS inverter size could likely be reduced if it were dedicated to only one building or the other. Optimal inverter sizes as well as storage capacities should be studied in more detail in subsequent phases, with the City's resiliency goals in mind. Feasibility analyses should consider the value of resiliency to the City in order to understand the costs and benefits of varying amounts of energy storage. As the facilities' energy storage duration goals (i.e. power all loads in both building for 2 hours) increase beyond the existing backup energy sources, the battery size and cost will increase as well.

WIND TURBINE

Based on the location of the buildings in consideration, we do not believe installing wind turbine(s) on site as a renewable energy resource is a viable option for these sites. Although small wind turbines targeted towards urban environments exist, such as vertical axis turbines, these options typically provide much smaller electrical output relative to solar PV installed in the same space and the small wind turbines can create some structural challenges, depending on their size, due to the lateral forces they exert on the building shell. Therefore, we believe that solar PV may be a better on-site renewable energy generation option. However, the feasibility of small on-site wind turbines could be considered in more detail during future studies.

CHP

A combined heat and power system, sometimes referred to as cogeneration, is comprised of a fuel-driven prime mover, such as a gas turbine or reciprocating engine, a generator driven by the prime mover, and a heat recovery system. Typical fuel-fired generators, such as diesel engine, are only approximately 30% efficient in converting the fuel energy to electrical energy. By incorporating the heat recovery system, however, the system efficiency can rise as high as 60 – 70%, thereby increasing the return on investment and potentially qualifying for utility incentives.

In the size range applicable to these two facilities, the two most common CHP options would be reciprocating engines and microturbines. Memorial Hall would likely require a microturbine because it is difficult and inefficient to generate steam with a reciprocating engine and Memorial Hall's only non-electrical heating use is its steam system. Microturbines, however, are less efficient on the whole compared to reciprocating engines and may not reach minimal efficiency thresholds to qualify for utility incentives in this application.

The PDHQ on the other hand would be a candidate for a reciprocating engine system because of its existing hot water infrastructure. In the case of both buildings, both have relatively low summer thermal loads to which to direct the CHP's recovered heat. We understand that neither building's existing boilers run during the summer, for reheat or process heating. The only potentially useful way to take the CHP's heat during the summer would be for domestic hot water, which is a relatively small load. Given this scenario, the CHP could either be sized (1) smaller so that the design heat output is equal to the domestic hot water, though this would limit the electrical capacity to have a small impact on resiliency or (2) the CHP could simply reject its recovered heat to atmosphere during much of the year, though this significantly limits the efficiency of the system and likely disqualifies it from obtaining utility incentives. While we understand the City's focus is primarily on resiliency at this time, rather than on the payback of the potential CHP project itself, allowing the CHP system efficiency to fall so low can significantly limit the marginal value of the heat recovery system itself, in which case it may be advisable simply to install an additional generator without heat recovery and possibly with a higher level air permit to allow for a greater number of annual run hours or run hours in non-emergency scenarios.

If option (1) is considered, a 60-kW microturbine is expected to be the smallest available size for Memorial Hall, which is lower than the estimated average demand of the building. Similarly, small reciprocating engines are available in the 68 – 110-kW range which may be considered for PDHQ, but also may not be able to meet the building's typical electric demand. Therefore, we conclude that a CHP system would likely not provide as much of a resiliency or return on investment benefit as would some of the other DERs discussed in this report.

Integrated Microgrid

Two or more of the DERs discussed above can be tied together into a microgrid to serve Memorial Hall, PDHQ, or both. Based on feedback from the City, connecting a microgrid to both buildings is attractive to the City as a way to improve the resiliency of both buildings. This is especially true for PDHQ, since the DERs discussed thus far appear to be more feasible if placed at Memorial Hall and its surrounding property. Based on the high-level system size estimates presented above, the combined solar PV capacity of both a rooftop system on Memorial Hall and a canopy system over the main parking lot could be approximately 220 kW, which at peak production may be capable of meeting the electric demands of both buildings. If the solar PV system is also coupled with a BESS or CHP system, the potential electric output of the integrated system would increase further. Connecting solar PV generation with a voltage source such as a BESS improves the facilities energy resiliency during off-grid scenarios. The BESS could black start the solar PV systems and both assets could discharge together to meet the buildings' electrical load independently of, or potentially in parallel to, the backup diesel generators, when the solar PV system is operating, thus reducing each building's dependence on their diesel generators and fuel deliveries. At night when the solar PV system is unavailable, excess energy stored in the BESS could be discharged and/or the backup diesel generator could operate. In all cases, a System Supervisory Controller could be utilized to synchronize the operation of the DERs during both grid-tied and off-grid modes. The feasibility of a microgrid at one or both facilities should be evaluated in further detail during a follow-up feasibility analysis.

It is noteworthy that obtaining a utility interconnect agreement for microgrids typically involves numerous impact studies and documentation reviews by the utility which can be a time-consuming process. Further, the complexity of integrating a microgrid behind two meters, as well as regulatory hurdles involved in crossing William H Welch Way, which is a public way, present significant, though not insurmountable challenges that need to be considered in more detail.

The City has also expressed interest in exploring a public-private microgrid partnership with VTT Property Management, who owns several buildings along Union Ave and Concord Street across the street from Memorial Hall. This option is attractive to the City as it encourages community collaboration and development while also accessing more building roofs for additional solar PV systems to increase the overall system output. There are many uncertainties associated with a system of this complexity, including regulatory hurdles to cross multiple public ways and interconnect systems behind multiple meters owned by different entities. It is unclear at this time whether these challenges are surmountable and feasibility of potential partnerships should be considered in more detail if the City is interested. If successful, however, this project could be a prestigious accomplishment of community engagement and resiliency that would serve as a model for other peer communities.

CONCLUSIONS AND NEXT STEPS

To summarize, the PDHQ is currently relatively energy resilient. The entire building is connected to the backup power system and is expected to remain operational for several days if running on the existing diesel generator with a full tank of fuel. Further, the generator has spare capacity to accommodate future demand growth. If the generator ran out of fuel before grid power returned, mobile generators could be deployed to extend building operations while waiting on a fuel delivery. In order to extend the generator runtime on a single tank of fuel, a follow-up study may be considered to investigate potential demand management strategies to reduce electric demand during off-grid operations and/or expanded backup fuel storage. Another strategy to improve energy resiliency and sustainability is the addition of onsite energy resources. Although the building and parcel of land it resides on is generally not conducive to adding DERs such as rooftop PV or battery storage, a canopy solar PV system over the parking lot adjacent to Memorial Hall could potentially be tied to PDHQ, if regulatory challenges to cross the public way between them can be overcome.

Memorial Hall currently has limited energy resiliency and would be a challenge to house occupants during an extended off-grid scenario. However, it may be a good candidate for several DERs, including rooftop solar PV, canopy solar PV, and battery energy storage that could increase its resiliency and the opportunity to use it during an emergency, off-grid event. If these DERs are pursued, they could be more impactful from a resiliency perspective if coupled with electrical infrastructure upgrades to connect more building loads to the backup power system. However, the addition of onsite renewable energy sources without electrical upgrades may still be beneficial to the City as it may assist the City's progress in meeting sustainability and climate action goals. Further, solar PV and energy storage could potentially be tied together to form a microgrid to serve both Memorial Hall and PDHQ during grid-tied and off-grid operations. The feasibility of this option should be considered further based on the City's interests.

As a next step, the City should further consider the value of achieving greater resiliency at these facilities. Installing distributed energy resources and upgrading electrical infrastructure can be costly and the value of resiliency at these facilities should be carefully assessed by the City prior to pursuing further. If the City decides to move to the next step, a deeper feasibility analysis should be conducted, which should include, at a minimum, an investigation of Memorial Hall's roof structural capacity for solar PV. Other things to be considered are the potential battery locations deemed acceptable by the City's fire department and/or other code officials, as well as the technical and political feasibility of adding a solar PV canopy over the parking lot.

We also think it may be wise of the City to consider the feasibility of pursuing upgrades and on-site DERs at other City-owned buildings which may be better suited to host occupants or vital emergency operations during a grid outage. In our experience, buildings with large spaces, such as gymnasiums, cafeterias, or auditoriums typically found in schools, suitable for sheltering many people are ideal locations for community warming/cooling shelters during an emergency situation. Other qualities that make a building favorable for off-grid operations include having a central HVAC system controlled by a building automation to permit demand management to conserve energy. Also, pursing an off-grid capable microgrid at a building with existing electrical infrastructure tying most if not all building loads to the backup power system may be significantly cheaper and less complicated than at a building with minimal optional standby loads, such as Memorial Hall. Lastly, a site with existing or planned onsite renewable energy resources, such as rooftop or canopy solar PV systems, may have advantages when selecting a site to use during off-grid scenarios.

City personnel mentioned that several schools and a senior center are presently used as shelters during emergency situations. When utility power is not available, the sites' backup power systems are supplemented by portable diesel generators to operate the facilities off-gird. These facilities may be candidates for energy resiliency enhancements and on-site DERs that the City may want to consider further to achieve more resilient emergency shelter operations.

The City may consider pursuing grant opportunities, such as an MVP Action Grant, to help fund further microgrid feasibility analysis for these or other City facilities. The Massachusetts Clean Energy Center (CEC) and Department of Energy Resources (DOER) have also initiated grant opportunities in the past. State or federal grant opportunities may also arise to provide aid for microgrid feasibility studies and/or construction.

We would be happy to meet with you to discuss any questions or comments you have on the above information. Thank you for the opportunity to work with you on this effort.

Sincerely,

Joseph Bliss

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