Palmer Community Microgrid
MassCEC Feasibility Assessment

Task 6 Final Report

June 9, 2020

Prepared by:

Microgrid Institute

in partnership with

S&C ELECTRIC COMPANY
Excellence Through Innovation

Contents

I. Chapter 1: Summary and Recommendations

1.0 Feasibility Assessment Process

The Palmer Community Microgrid Feasibility Assessment was initiated by the Town of Palmer and Thorndike Energy, and executed by a Project Team comprised of staff representing Microgrid Institute and S&C Electric. The assessment addressed all Tasks defined by the Massachusetts Clean Energy Center (MassCEC) for its Community Microgrids Feasibility Assessment program, specifically:

- *Task 1:* Kickoff Meeting and Site Visits: Engaged numerous customers in the project area to learn about site energy loads, systems, priorities, and plans;
- *Task 2:* Site Assessment and Description of Microgrid Characteristics: Analyzed energy load and cost data gathered from customers' utility bills and account records, as well as preliminary inputs from the electric utility serving Pittsfield (Eversource), to establish a preliminary design basis for the Palmer Community Microgrid Project;
- *Task 3:* Preliminary Technical Design and Configuration: Further engaged the utility to gather information about distribution system infrastructure and configuration options, and revised the proposed design to establish a technically feasible microgrid solution;
- *Task 4:* Assessment of Microgrid's Commercial and Financial Feasibility: Identified and assessed proposed business model options for the Project; and
- *Task 5:* Information for Cost-Benefit Analysis: Produced metrics to quantify its likely costs and benefits to various parties – most notably customers, third-party investors, and the utility.

For this Task 6 Final Report, the Project Team updated the information presented in earlier Task Reports, and developed the following summary of outcomes and recommendations. The Team closely collaborated throughout the study process to identify and obtain the required inputs and to focus assessment efforts on factors affecting the feasibility of the Project for prospective development.

1.1 Findings, Observations, and Recommendations

The Palmer Community Microgrid initially was proposed as a wide-area community microgrid that would utilize existing and planned new generation sources to energize a safe power island on a large part of the Town of Palmer in Hampden County. The Palmer area already hosts a substantial amount of existing ground-mounted solar generation capacity, with several new major photovoltaic (PV) power projects proposed for development. The preliminary concept proposed reconfiguring National Grid's distribution system to enable utilizing those PV resources, together with additional new battery storage and gas-fired combined heat and power (CHP) generation, in a community microgrid that would provide resilient power supplies for a large number of local critical electric loads – from senior housing to wastewater treatment facilities.

In consultation with the utility, the Project Team assessed the local distribution system and determined that PV generation in the area is interconnected to multiple distribution feeders served by multiple substations, with no clear way to integrate those resources to form a wide-area microgrid in the Palmer area. The Team assessed several possible approaches to serving critical facilities in smaller zones, and identified two possible microgrid zones for further analysis:

Zone 1 - Police, Emergency Operations, Public Shelters, and Commercial, Industrial, and Residential Loads: New utility switching capacity and control capabilities would enable the utility to form a safe power island on two of its distribution segments. The proposed microgrid would be energized by behind-the-meter (BtM) distributed energy resources (DER) that already exist or are planned for separate development in the project area – including more than 12.5 MW of CHP and energy storage at the Thorndike Mill industrial site. Because these generation assets either already exist or are planned for separate development, they would operate as third-party energy suppliers, providing capacity and energy to microgrid customers on a contract basis. In this way the utility would enable customer-owned local generation to provide resilient energy for critical municipal and industrial facilities and non-critical commercial and residential customers in Palmer, with loads totaling 4.1 MW of average demand (10.9 MW peak).

Zone 2 – Baystate Wing Hospital: In contrast with Zone 1, the Zone 2 proposal would serve only one customer property – the Baystate Wing Hospital campus – forming a behind-the-meter microgrid that would use no utility infrastructure during outages. The proposed Zone 2 microgrid design was based largely on a solar+storage project that Baystate Wing Hospital has planned for implementation. The Zone 2 proposal includes new carport-mounted PV arrays and BESS to enable load sharing among the hospital's existing diesel-fueled standby generation and the proposed new solar+storage resources. The system would combine 800 kW of new PV capacity and 500 kW of new BESS capacity with 1,200 kW of existing diesel-fueled standby generation to serve the hospital campus's approximately 500 kW average / 1.3 MW peak demand.

Task 3 assessments showed that the Zone 1 concept technically could be achieved with switching upgrades on existing utility infrastructure, but it would face practical challenges. Most notably, because the proposed microgrid would rely entirely on third-party owned generation and storage, 100% of the system's capital costs would involve upgrades to existing utility infrastructure, with no generation revenues to offset those costs. As a result, Zone 1 distribution upgrade costs would have to be funded through grants or utility rate-based cost recovery. Also, although the utility initially provided information indicating that the proposed Zone 1 switching configuration technically could work, it later stated it would not contemplate a community microgrid using its distribution infrastructure in the project area.

Despite these findings, the Project Team in Task 4 and 5 continued assessing the Zone 1 proposal with the objective of understanding options and factors affecting the feasibility of utility distribution microgrids designed to serve vital community facilities with local DERs.

Task 3 assessments produced a technically viable Zone 2 design based on the hospital's preliminary solar+storage project plans. Task 4 assessments described the proposed third-party power purchase agreement (PPA) approach for the project, while Task 5 assessments quantified the Zone 2 microgrid's financial cost-benefit potential.

Recommendations: Outcomes from the Palmer Community Microgrid feasibility assessment illustrate that achieving Massachusetts goals for community resiliency, sustainability, and economic development will require regulatory change to facilitate productive collaboration among utilities and the communities they serve, and to enable utility investments in local infrastructure to meet community resiliency priorities.

Particularly with regard to Zone 1, the assessment results show that new standards and policies are needed at both municipal and state levels to enable resilient utility system planning and development at the community level.[1] Such new policies could include:

- Prioritized resiliency planning – At State and municipal levels, define community energy resiliency as an infrastructure function that necessitates high-priority, systematic planning and development;
- Utility community performance standards – Provide performance incentives for utilities to engage communities, integrate community priorities into utility system plans, and invest in infrastructure upgrades that meet resiliency needs identified by communities;
- Utility cost-recovery mechanisms for local resiliency investments – Systemwide utility ratemaking mechanisms should allow general rate recovery for utility investments in infrastructure that enables community energy resiliency powered by local DERs.

With regard to the Zone 2 microgrid proposal, Baystate Wing Hospital's progress on its solar+storage deployment was delayed by a moratorium on new DER interconnections in National Grid's Massachusetts service territory, pending the utility's review of system impacts and upgrade requirements. The Team's assessments showed that deployment delays can have a major impact on cost-benefit potential, because federal investment tax credits (ITC) and other incentives diminish over time. Accordingly, utility interconnection moratoria should be strictly limited by the State to minimize unnecessary delays in renewable energy and energy storage investments.

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[1] Policy actions similar to the Project Team's recommendations are codified in a recent California Public Utility Commission order (Rulemaking 19-09-009, "Decision Adopting Short-Term Actions to Accelerate Microgrid Deployment and Related Resiliency Solutions"). Among other things, the CPUC order requires utilities to improve the transparency and efficiency of microgrid planning and interconnection processes, and to "promote collaborative engagement between large investor-owned utilities and local and tribal governments."

II. Chapter 2: Site Assessment and Description of Microgrid Facilities

2.0 Summary of Task 2 Assessment

2.0.1 Project Goals and Objectives

The Town of Palmer and Thorndike Energy initially proposed the Palmer Community Microgrid to serve several critical community facilities and economic assets throughout the Palmer area (*see Figure 2.2: Palmer Community Microgrid Area Map*). Moreover, a community microgrid in Palmer would strengthen the resiliency of a substantial population in an important regional corridor and adjacent population centers; through the Massachusetts Turnpike and Routes 20, 32, and 181, Palmer is centrally located to provide regional services to Worcester, Springfield, and more than 110,000 people living within 10 miles of Palmer.

The primary goal of the proposed Palmer Community Microgrid is to optimize the use of local energy resources for sustainability and resilience of critical services, while supporting job growth and retention. The Project aims to achieve these goals by pursuing five objectives:

1. Improve resiliency of electricity services for critical community facilities
2. Update power infrastructure to support new and existing employers
3. Optimize utilization of local renewable generation to energize local loads (including during regional outages)
4. Expand storage capacity to better integrate local renewable energy
5. Support National Grid goals, objectives, and compliance obligations re: grid modernization, distribution system capacity and reliability, renewable energy integration, and energy storage.

2.0.2 Alignment of MassCEC Community Microgrids Program Goals

The goals of the Palmer Community Microgrid are in close alignment with MassCEC's Community Microgrid Program goals. Section E details characteristics of the project that address Program goals, and considerations for subsequent Task assessments.

2.1 Site Assessment

2.1.1 Size and scope of the proposed microgrid

To assess the required size and scope of the proposed microgrid, the Project Team performed an inventory of existing and planned buildings and assets for prospective service by the proposed microgrid.

Critical community facilities and assets are distributed across a large area in eastern Hampden County, and are served by multiple feeders energized from various National Grid substations. This geographic distribution of critical assets and distribution infrastructure led the Project Team to analyze various ways of improving resiliency in support of the Town of Palmer's objectives for the Project. The Team explored options including a wide-area microgrid scenario, in which the region's substantial renewable resources could be managed and balanced to maintain resilient energy service for potentially dozens of facilities in the Palmer area (*see "Additional Facilities Assessed," below*). While renewable generation capacity in the area in principle might be more than sufficient to serve dozens of critical facility loads, existing interconnection and distribution configuration creates practical hurdles to this wide-area microgrid approach. Most notably, most of the renewable facilities in the Palmer area are interconnected with the 13.2-kV secondary distribution system, providing energy for numerous residences and other facilities before their output could reach a substation to be switched to serve more critical loads. The lack of extensive distribution automation or advanced metering infrastructure (AMI) in the area rendered this approach technically infeasible.

The team further sought to identify logical clusters of critical facilities that could be served by islanding microgrid systems. After performing iterative assessments of various potential load groups at the customer and facility level, the Team selected seven facilities for detailed load analysis, with the expectation that the system could require as many as four separately islanding zones:

- *Zone 1:* Several facilities owned by the Town of Palmer on separate lots that are adjacent or near one another. These facilities – Palmer Town Hall, Palmer Police Station, Palmer High School, and Old Mill Pond Elementary School, support first response, safety, emergency management, and emergency public sheltering. Existing electric generation resources at the Zone 1 facilities include limited diesel- and natural gas-fired backup generation systems. New resources to serve critical facilities in Zone 1 initially were expected to include solar PV and BESS capacity, as well as distribution system reconfiguration and upgrades to support island-mode microgrid operations.
- *Zone 2:* Baystate Wing Hospital campus, comprising three (3) buildings totaling 243,000 square feet of occupied space on a single lot. Onsite resources include an 800 kW covered-parking PV-plus-BESS (500 kW/1,000 kWh) planned for development by the hospital, to be interconnected behind the facility meters where it will reduce the hospital's utility electricity consumption, demand, and costs. Prospective other new resources to serve the hospital may include solar PV, BESS, and potentially CHP and/or thermal energy storage systems (TES) to support resilient microgrid service and economic benefits for additional hospital loads beyond those served by the planned PV system.
- *Zone 3:* Palmer Wastewater Treatment Plant (WWTP) provides municipal wastewater sanitation for approximately 18,000 residents in the Palmer area. Existing resources at the Palmer WWTP include a 500 kW diesel-fired backup generator. Also the 2.4 MW Norbell Street PV array is located on a nearby property, but it is separated from the WWTP property by Norbell Street and a railroad line. Chapter 3 includes the Project Team's assessments of potential for utilizing output from the Norbell Street array to energize WWTP loads during a regional utility outage. Initial assessments indicated that new resources to serve WWTP loads could include rooftop-mounted PV systems and BESS capacity.
- *Zone 4:* The Palmer Foundry is a 65,000 square-foot, ISO 9001-certified industrial facility that employs approximately 70 skilled workers, working in two shifts per day. Including Palmer Foundry among Palmer Microgrid loads supports the Town of Palmer's objectives for job growth and retention as well as clean energy development. The foundry requires greater energy resiliency to maintain its energy-intensive operations and avoid costly impacts of extended electric outages. Existing resources at Palmer Foundry include approximately 270 kW of ground- and rooftop-mounted PV capacity as well as 100 kW of gas-fired backup generation capacity. New resources to serve foundry loads could include limited additional rooftop-mounted PV systems (approximately 165 kW) and BESS capacity, as well as an additional 100 kW gas-fired generator.

The Project Team also assessed the 200,000-square foot Thorndike Mill industrial redevelopment site, which is expected to house several energy intensive industrial tenants when fully occupied, representing a potential peak demand of approximately 10 MW and annual electric consumption of 70,000 MWh per year. Current loads at the site consume an estimated 500 MWh per year, with a peak demand of approximately 300 kW. These loads are fully met on an annual basis by 1,040 kW of existing hydropower generation, located nearby upstream on the Ware River, and interconnected at the Thorndike Mill site to serve loads behind the meter. Excess production is exported to the National Grid distribution system and monetized under the utility's Small Hydro Tariff. Thorndike Energy has planned several new energy resources at the Thorndike Mill site, which are expected to include approximately 2 MW of rooftop-mounted and covered-parking solar PV capacity with an estimated annual production of 1.9 million kWh, and approximately 10 MW of natural gas-fired CHP capacity, with waste-heat capture systems to serve space heating and industrial thermal loads estimated at approximately 94 MBtu per hour. Thorndike Energy also plans two energy storage systems, flow batteries and flywheel storage systems. Chapter 3 addresses how the microgrid would utilize Thorndike Energy resources, and how those resources also would serve Thorndike Mill loads.

Fig. 2.1: Palmer Community Microgrid Area Map

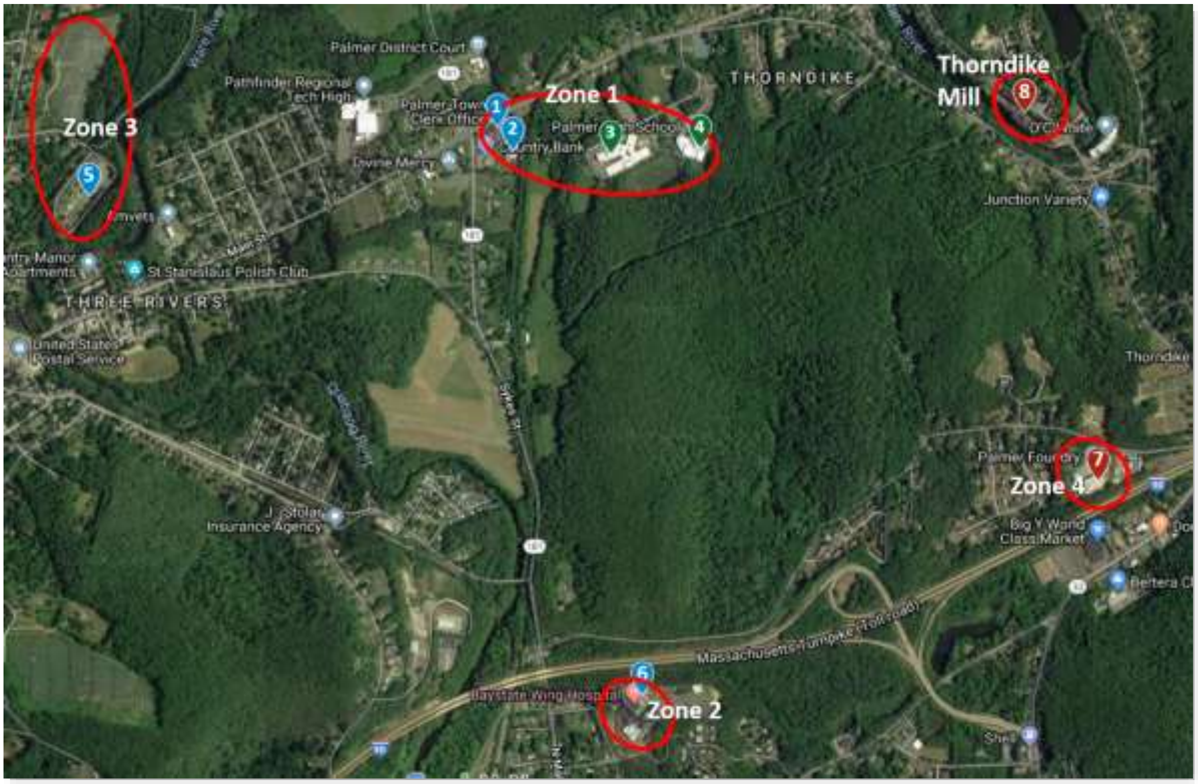


Fig. 2.2: Palmer Community Microgrid Modeled Facilities

Zone	#	Facility	Demand (kW)	Consumption (MWh)	Total Charge	Supply Charge	Demand Charge	Other Delivery Charges
1	1	Town Hall	48	68	$12,465	$5,855	$2,999	$3,610
1	2	Palmer Police Station	52	247	$38,082	$21,418	$4,267	$12,397
1	3	Old Mill Pond ES	136	413	$69,280	$35,800	$12,818	$20,662
1	4	Palmer High School	252	832	$126,620	$72,129	$15,322	$39,169
2	6	Wing Hospital	1,316	4,552	$742,463	$480,455	$60,871	$201,138
3	5	WWTP	302	1,394	$208,554	$120,813	$20,155	$67,586
4	7	Palmer Foundry	1,162	2,823	$2,475,147	$2,277,067	$71,303	$126,777
		Total - Current Loads	**3,267**	**10,329**	**$3,672,610**	**$3,013,536**	**$187,734**	**$471,340**
TBD	8	Thorndike Mill	10,000	70,000				
		Total – Current and Prospective Loads	**13,267**	**80,329**				

Additional Facilities Assessed

As part of the preliminary wide-area microgrid design assessment, the Project Team considered numerous additional facilities that contribute critical and vital services to the Palmer community (*Figure 2.3*). Although including them could support Town of Palmer objectives for the proposed microgrid, these facilities were omitted from the current phase of assessment for various reasons, including the following:

- With a few noteworthy exceptions discussed below, none are located within or near priority facilities identified by the Town of Palmer.
- Owners of some facilities contacted either did not respond to the Team's inquiries or did not timely provide facility data for assessment. Examples include Big Y, Public Petroleum, Pathfinder School, and Palmer Fire Department.
- Converse Middle School has closed, and its future is indeterminate. Working plans for redevelopment as a housing facility diminish its potential use as an emergency public shelter. Additionally, the facility already is equipped with a 150-kW diesel-fired backup generation system and 10,000-gallon fuel tank, which currently supports greater resiliency than either of the two school buildings included in the analysis.
- With regard to the area's several fire stations and the ambulance service, initial assessments showed that providing resilient energy service would not appreciably improve their operability during regional outages. Notably, none of these are residential fire stations, so their energy loads are minimal, and emergency vehicle operations can continue without electricity.

Some of the additional facilities, however, could be reconsidered in later Project phases if adding them would strengthen technical or economic viability. Namely, Zone 1 could, in principle, be extended across Main Street and County Road 181 to include Palmer District Court, Public Petroleum, and/or Pathfinder School. Additionally, Big Y's loads could be substantial enough to merit investment in additional resilient energy resources, and the facility is located near Palmer Foundry, separated only by I-90. However, at this phase of study Big Y declined to provide data for analysis.

Fig. 2.3: Additional Facilities

Omitted Facility	Address	Vital Purpose
Public Petroleum	2394 Main St	Auto fuel
Converse Middle School	24 Converse St	Emergency public shelter
Palmer Library	1455 N Main St	
Pathfinder Regional Technical High School	240 Sykes St	
Senior Center/Council on Aging	1029 Central St	
CS Industries	13 2nd St	Employment/Economic assets
Maple Leaf Industrial Park	21 Wilbraham St	Employment/Economic assets
Bondsville Fire Department	3174 Main St	Fire service; first response
Palmer Fire Dept	12 Walnut St	
Thorndike Fire and Water District	4064 Church St	
Three Rivers Fire Department	50 Springfield Street	
Three Rivers Fire District	2031 Main St	
Palmer Ambulance Service	4 Shearer St	First response
Palmer Water District	30 Reservoir St	Fresh water service
Big Y Market	1180 Thorndike St	Grocery, pharmacy
CVS Pharmacy	1001 Thorndike St	Pharmacy and essentials

2.1.2 Assessment of Loads, Resources, Infrastructure, and Programs:

a. Electric and heating/cooling loads

The Project Team's Task 2 site assessments focused on the following information and metrics for electric and thermal loads at the microgrid facilities:

- Electricity consumption (kWh) and peak demand (kW) requirements to serve loads defined by facility customers as critical; and
- Heating, cooling, and thermal process system functions and opportunities for energy savings, load modulation, or CHP optionality.

Facilities management staff provided the Project Team with access to data for Task 2 analysis, including energy usage and cost summary data, and questionnaire inputs for facility surveys. Quantitative analysis focused on electric consumption and demand data to produce baseline critical resiliency requirements.

As discussed in *2.1-A* above, electric loads are grouped into discrete zones for assessment (*see Figure 2.5*). No historic load data exists for the Thorndike Mill brownfield redevelopment, so the Project Team assessed energy consumption and demand estimates provided by the property owner.

Fig. 2.4: Palmer Community Microgrid - Electric Load Summary

Period	Demand (kW)	Consumption (MWh/yr)	Total Charges ($/yr)	Supply Charges ($/yr)	Demand Charges ($/yr)	Other Delivery Charges ($/yr)
2017/9	2,691	855	$137,839	$82,392	$16,188	$39,259
2017/10	2,507	796	$245,326	$193,516	$15,069	$36,741
2017/11	2,325	780	$127,440	$76,955	$14,209	$36,275
2017/12	2,471	870	$369,089	$314,320	$14,829	$39,940
2018/1	2,395	802	$337,846	$286,113	$14,419	$37,314
2018/2	2,456	840	$352,332	$298,206	$14,853	$39,272
2018/3	2,356	777	$337,546	$286,160	$14,197	$37,189
2018/4	2,596	782	$321,203	$269,127	$15,573	$36,502
2018/5	2,735	994	$374,920	$314,730	$16,458	$43,732
2018/6	2,864	865	$286,994	$232,057	$17,190	$37,746
2018/7	3,107	1,040	$408,023	$343,458	$18,652	$45,914
2018/8	2,686	928	$374,054	$316,502	$16,095	$41,457
	3,107 max	**10,329**	**$3,672,610**	**$3,013,536**	**$187,734**	**$471,340**

Fig. 2.5: Palmer Microgrid – Zone Loads and Costs

Zone	Annual Peak Demand (kW)	Consumption (MWh)	Total Charges	Supply Charge ($)	Demand Charges ($)	Other Delivery Charges ($)
1	731	2,954	$455,000	$256,015	$55,560	$143,425
2	1,316	4,552	$742,463	$480,455	$60,871	$201,138
3	302	1,394	$208,554	$120,813	$20,155	$67,586
4	1,162	2,823	$2,475,147	$2,277,067	$71,303	$126,777

Fig. 2.6: Zone 1 (Town Hall, Police, Schools) Monthly Electric Load Profile

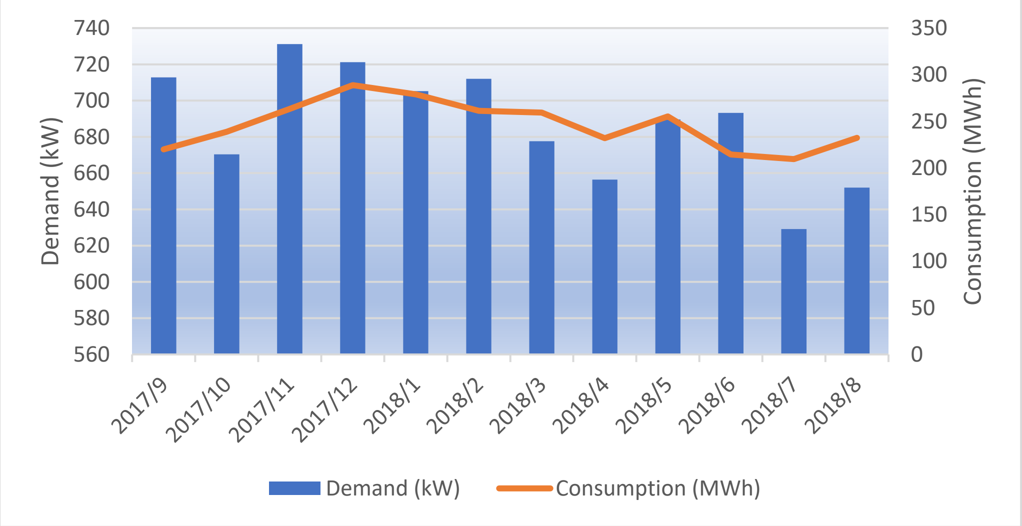


Fig. 2.7: Zone 2 (Wing Hospital) Monthly Load Profile

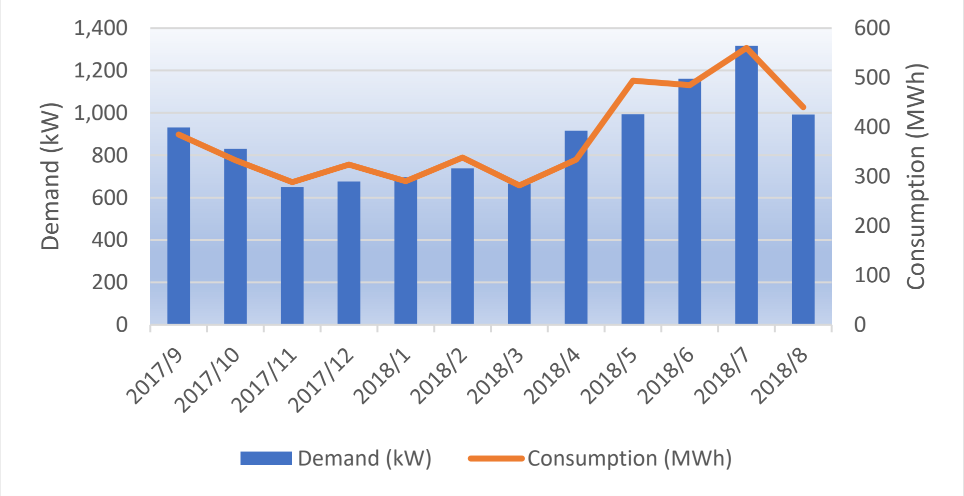


Fig. 2.8: Zone 3 (Palmer WWTP) Monthly Electric Load Profile

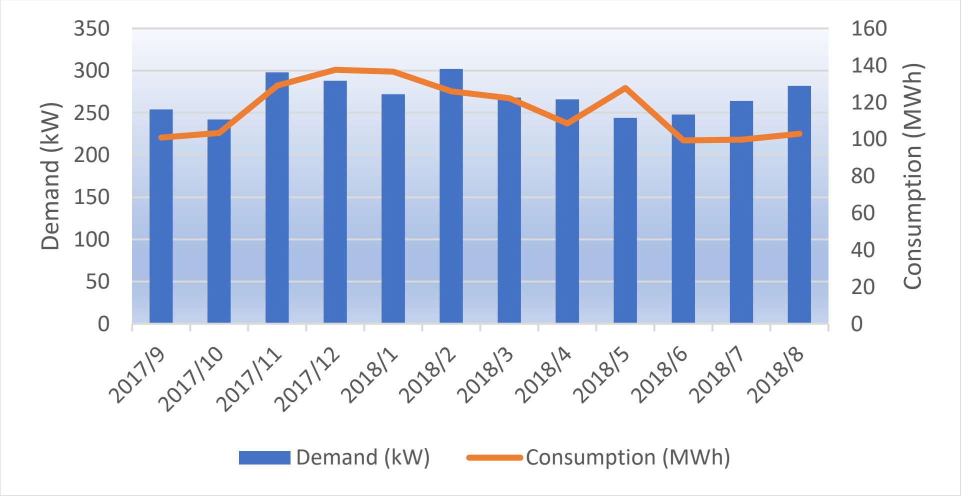
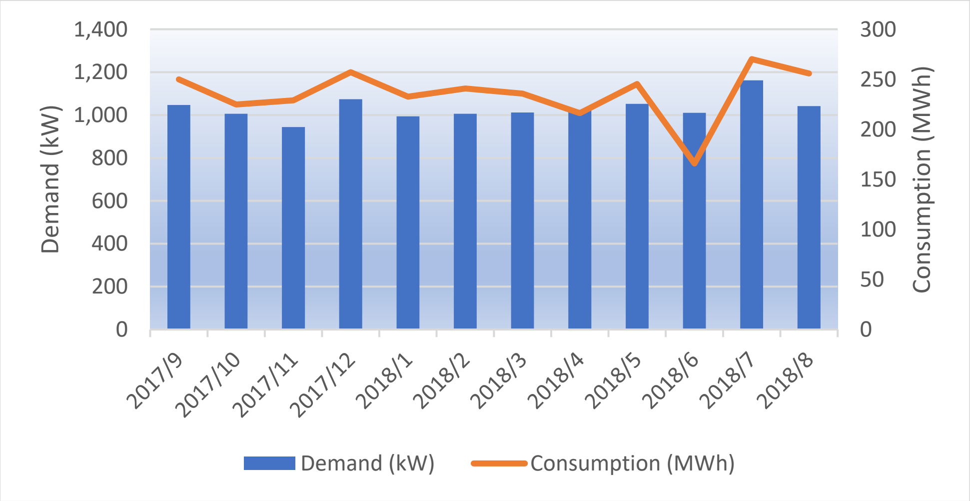


Fig. 2.9: Zone 4 (Palmer Foundry) Monthly Load Profile



b. Generation Resources or other Relevant Technologies

The Town of Palmer's goals for the project support increased reliance on cost-effective renewable energy resources to the greatest practical extent, to reduce reliance on fossil-fueled generation and provide a primary energy resource for microgrid loads.

In the Palmer area, solar and hydroelectric power represent the primary available renewable electric resources. Four hydro facilities owned by Thorndike Energy provide 1,040 kW of generation, while at least 13 large-scale PV facilities provide more than 40 MW of peak solar capacity, with several more in development (*Figure 2.10*). Among these PV arrays, a few are located adjacent to or close enough to microgrid zones to warrant consideration for powering microgrid loads during a regional outage.

Four facilities owned by the Town of Palmer (Police Station, Palmer High School, Old Mill Pond School, and Wastewater Treatment Plant) have approximately $300,000 in annual electricity supply costs offset by remote net-metered solar production listed under the Town's Schedule Z filing with National Grid (*See Figure 2.10*). These net-metering offsets present a challenge to Project viability, by impairing the financeability of new onsite resources to be built to supply those facilities' loads.

Fig. 2.10: Town of Palmer Schedule Z Net Energy Metering Credits

Facility	NEM Credit
Palmer Police Station	$21,208
Old Mill Pond ES	$50,605
Palmer High School	$99,006
WWTP	$13,753
WWTP	$115,070
Total – 5 Accounts	**$299,645**

Existing fossil-fueled standby generation systems in both zones would continue providing backup capacity for facility loads via existing transfer schemes. In Zone 2, the proposed microgrid would integrate existing diesel-fueled standby generation at the hospital.

i. Existing and Planned Renewable Energy Systems:

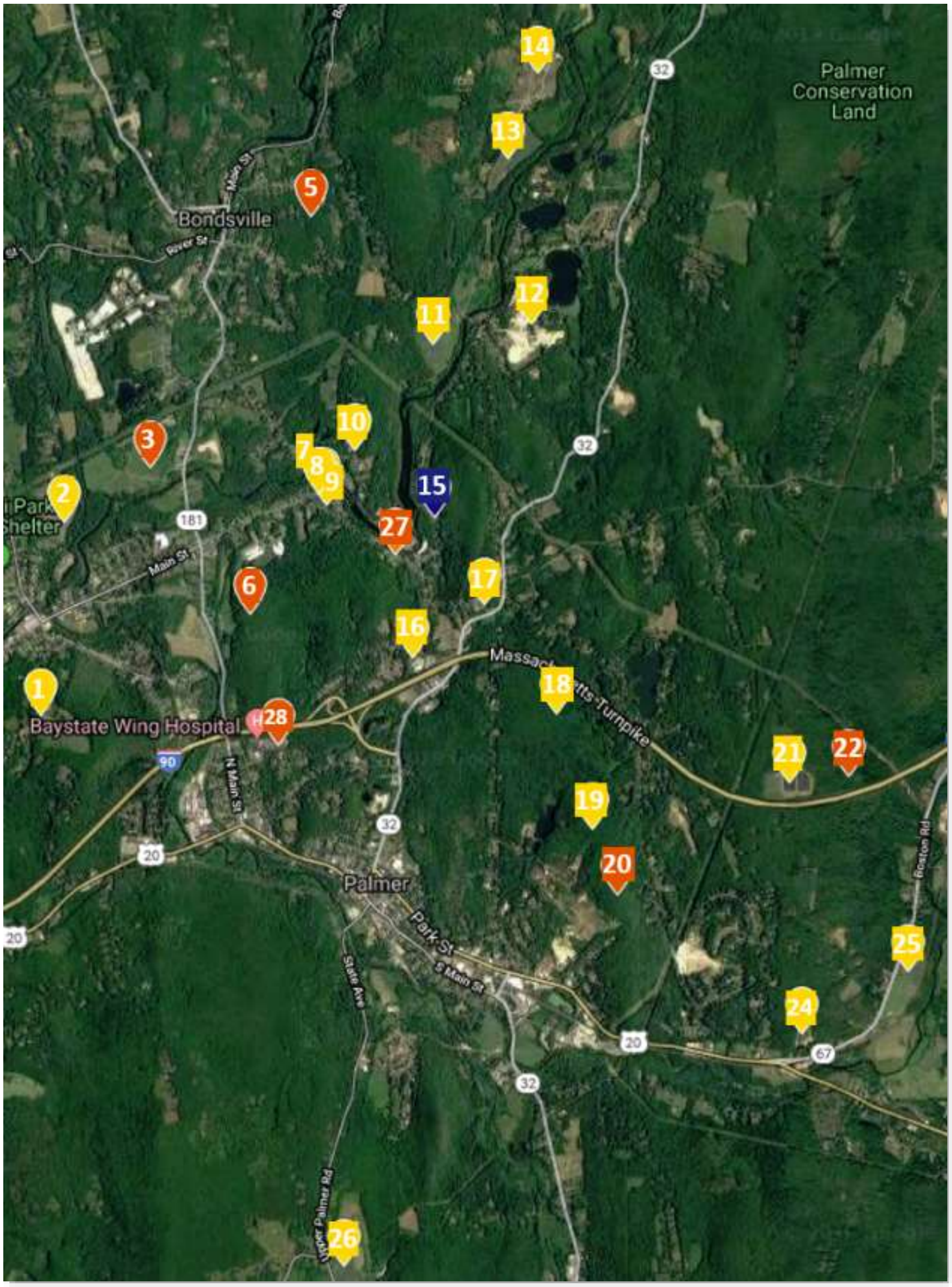
The Palmer area is home to numerous existing and planned renewable generation systems, including more than 40 MW of peak PV capacity, as well as four small hydro generators totaling 1,040 kW of generating capacity, interconnected at the Thorndike Mill site. Additional proposed PV projects include large-scale facilities in the vicinity of the proposed microgrid (*See Figure 2.11*). Most PV facilities in the area are interconnected on three-phase medium-voltage distribution circuits.

Fig. 2.11: Palmer-Area PV and Hydro Generation (Operating and Proposed)

#	Facility	Type	Capacity (kW)	Production (kWh/yr	Status
1	Baptist Hill	PV	4,600	6,072,000	Operating
2	Norbell Street	PV	2,400	3,168,000	Operating
11	Brown Farm	PV	3,000	3,960,000	Operating
12	Borrego Solar - River Street	PV	4,700	6,204,000	Operating
13	Landfill Solar	PV	4,950	6,534,000	Operating
14	Emery Street Airport	PV	4,900	6,468,000	Operating
15	Thorndike Mill	Hydro	1,040	1,056,000	Operating
16	Palmer Foundry Solar	PV	300	396,000	Operating
17	Beaumont Solar	PV	650	858,000	Operating
18	Borrego Solar - Breckenridge St	PV	6,400	8,448,000	Operating
19	Nextamp - Breckenridge Street	PV	5,700	7,524,000	Operating
21	Peterson Road	PV	3,600	4,752,000	Operating
24	Nextsun	PV	890	1,174,800	Operating
25	Draper Farm	PV	1,250	1,650,000	Operating
	TOTAL OPERATING		**44,380**	**58,264,800**	
#	**Facility**	**Type**	**Capacity (kW)**	**Production (kWh/yr)**	**Status**
3	Burgundy Brook Farm	PV	4,980	6,573,600	Proposed
5	States St - Pete St. Jaques	PV		0	Proposed
6	Strzemiemski's Farm	PV	4,980	6,573,600	Proposed
20	St. Woloschuck - Breckenridge St	PV		0	Proposed
22	Peterson Road II	PV		0	Proposed
27	Thorndike Mill	PV	2,000	1,900,000	Proposed
28	Wing Hospital	PV	800	950,000	Proposed
	TOTAL PLANNED		**12,760**	**15,997,200**	

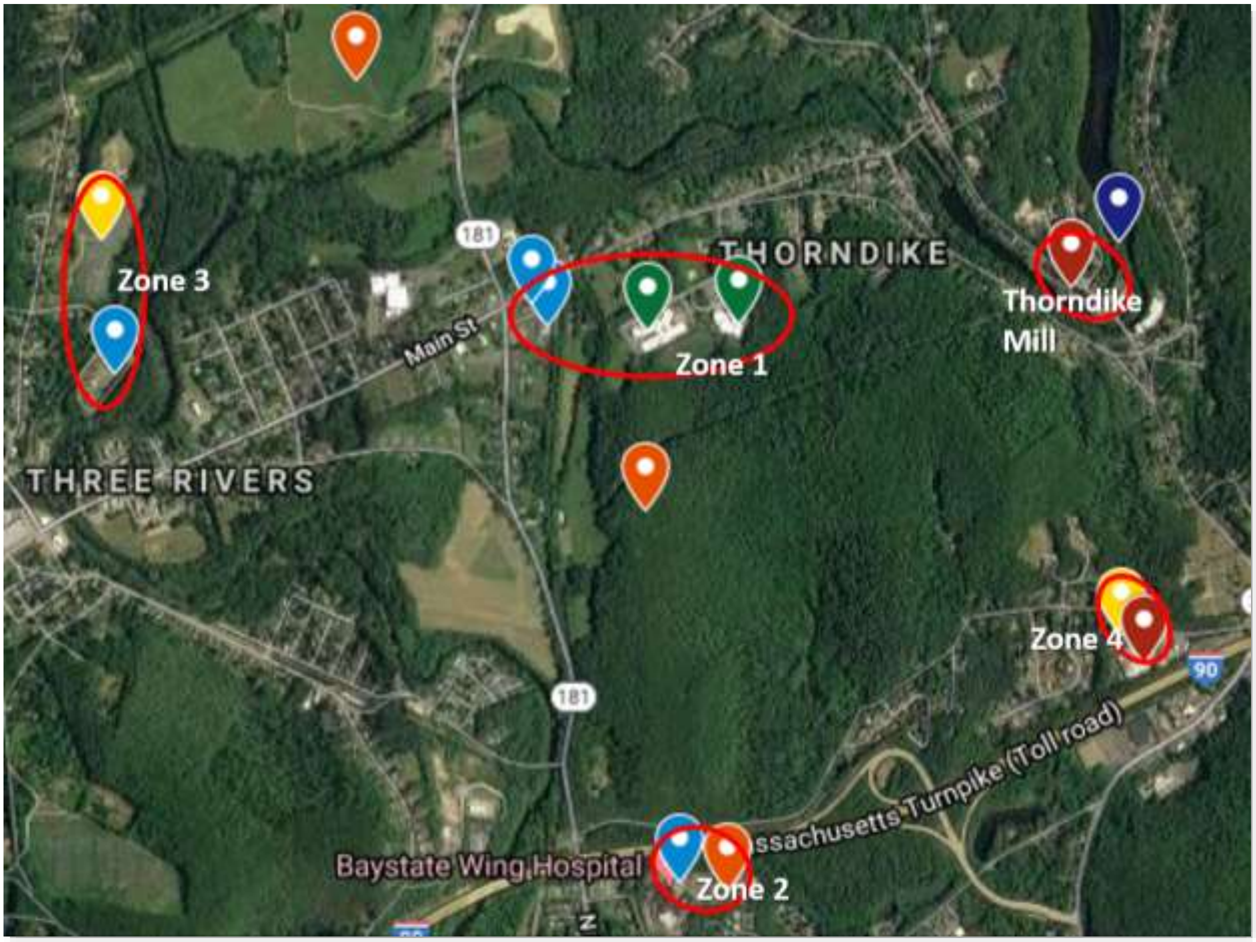
NOTES: Production figures are estimated (1,320 kWh/yr per 1 Watt of PV capacity). List not exhaustive; excludes multiple small private installations (#s 7,8,9,10, and 28 on Figure 2.12) and some pending proposals for large-scale systems (5,20,22, and others).

Fig. 2.12: Palmer-Area PV and Hydroelectric Facility Locations
(See location references in Figure 2.11)



Chapter 3 addresses the viability of using generation outputs from the area's PV and hydroelectric systems to support microgrid loads. Existing and planned PV systems support electric loads at Wing Hospital and Palmer Foundry, and the hydro resources already serve the Thorndike Mill site. Beyond those exceptions, however, initial assessments show that integrating any of the area's PV systems into the microgrid would require, at a minimum, reconfiguration of interconnection and control systems, which likely will be more practical for some generation facilities than others. The most obvious prospects for integrating existing local PV generation into the microgrid are located at: Zone 1, where two new ground-mounted arrays, 4.98 MW each, are proposed for locations northwest and south from Zone 1; Zone 3, with the nearly adjacent Norbell Street 2.4 MW array; and Zone 4, where Palmer Foundry currently operates a 300 kW PV array.

Fig. 2.11: Renewable Resource Proximity to Microgrid Zones



ii. Onsite PV and BESS Potential: Chapter 3 provides the Team's assessment of new PV and BESS capacity that may be necessary to serve microgrid loads. New solar capacity could involve a combination of ground-mounted and rooftop solar arrays in locations that can supply microgrid loads, either behind facility meters or through National Grid distribution infrastructure. Several of the buildings in all three zones have rooftop capacity for new PV systems. Onsite and community-scale BESS capacity would be required for reactive power and generation shifting to enable grid-forming, balancing, and transitions into and out of safe-island operating modes.

iii. Hydropower Resources: Thorndike Energy owns and operates four synchronous hydroelectric units that are connected behind the meter at the Thorndike Mill development site, with a total interconnected capacity of 1,040 kW. Thorndike Energy anticipates using hydro output to energize onsite industrial loads. Additionally, with reconfiguration and upgrades to the local distribution infrastructure, hydro output and other new planned resources at Thorndike Mill could in principle be used to energize Zone 1 loads, located 0.62 miles to the west. This approach, which is examined further in Chapter 3, would require energizing numerous loads that are not generally defined as critical for community resiliency.

iv. Other Renewable Resources: In addition to solar and hydro resources, the Team reviewed other renewable resource potential in the Project area (including wind, geothermal, and biomass/biogas options). Although onsite solar-thermal and ground-source heat pumping could be viable options for site-specific energy performance improvements, the Project Team determined that such systems are unlikely to contribute to microgrid viability. Also, the Palmer community could consider biomass/biogas options in future Project phases, if cost-effective and reliable fuel sources and technology solutions become available.

During Task 2 assessments, the Team reviewed thermal energy systems, functions, and fuels at the microgrid facilities, and produced the following conclusions regarding thermal requirements and opportunities:

a. *CHP Potential:* Although CHP could be considered in Zone 2, the hospital's planned PV and energy storage systems are found to be sufficient for the assessed energy resiliency objectives of the Project. CHP potential also was considered for Palmer Foundry, and the high intensity of the foundry's thermal loads were determined to be inappropriate for service using CHP.
b. *Existing Energy-Savings Programs:* Many of the microgrid facilities have, within five years, performed energy audits and implemented substantial thermal energy-saving measures, as part of ongoing programs administered by the Town of Palmer and Baystate Health. Most facilities have BEMS in place, but some performance opportunities may remain to be exploited, especially regarding advanced demand-response potential.
c. *TES Potential:* In some circumstances, thermal energy storage systems reduce demand charges and shift peak loads to off-peak periods. In the Project area, TES could be a potential load-management and system energy conservation option for large building thermal loads that could accommodate pre-cooling retrofits or replacements. However, assessments showed that building thermal loads identified for the Project are too limited and inconsistent on a seasonal basis to support economic investment in thermal storage.

2.1.3 Distribution system infrastructure

National Grid owns and operates the local electric distribution system in the Project area. Task 2 assessment of local distribution infrastructure showed that most of the microgrid facilities are served by 13.2 kV overhead secondary distribution lines, energized from the National Grid #503 substation at 9 Fuller Street. The Team's assessments indicate that serving Zone 1 facilities in a safely islanding microgrid would require reconfiguring circuits in the Project area and perhaps installing new underground cables to connect the four Zone 1 facilities in a single electrical system.

Additionally, initial assessments indicate capacity constraints potentially including single-phase distribution lines in some parts of the Project area, which likely will affect potential for interconnecting new PV generating systems on affected segments.

Chapter 3 addresses system design based on detailed distribution system architecture models.

2.1.4 Utility assets including metering and interconnection

Electricity services for facilities included in the microgrid are metered primarily with traditional electromechanical and simple electronic metering systems. This fact leads to two primary consequences for the Project, particularly for Zone 1, which includes four buildings on three separate lots:

a. *No Interval Data:* Assessed electric load data includes monthly total energy consumption (kWh) and monthly peak demand (kW); the lack of advanced metering infrastructure (AMI) means granular interval data is unavailable for the studied facilities. As a result, facility electric load profiles are based on annual month-by-month trends in consumption and demand. Simulated intra-week and intra-day load profiles, based on similar facility load profiles, are provided in Chapter 3 to estimate time-of-day usage and likely system coincident peak demand.
b. *No Remote Disconnect:* Most AMI devices include remote connect/disconnect functionality, but traditional meters do not. As discussed above, the lack of AMI in the Project area limits options for energizing only critical loads on microgrid circuits. This issue primarily affects Zone 1, but it also limits the opportunity to extend other zones to serve facility loads that are not immediately adjacent either geographically or electrically on the National Grid distribution system. Chapter 3 provides the Team's assessments of options for utilizing existing area solar generation to energize circuit segments that serve critical loads, and/or for managing non-critical loads with new automatic switching and control systems that would be installed as part of the proposed Project.

2.1.5 Existing energy efficiency programs

The Town of Palmer and Baystate Health have implemented ongoing energy efficiency and conservation programs for their facilities. Task 2 assessments indicate energy efficiency audits and upgrades have been performed at substantially all facilities within the last five years. Upgrades have included new HVAC systems and lighting replacements with high-efficiency LED systems. Chapter 3 addresses whether additional BEMS or other active load-control technologies may be required to support microgrid functionality.

2.2 Minimum Required & Preferable Microgrid Characteristics

2.2.1 Characteristics and capabilities that are required of the microgrid

Fig. 2.12: Assessment of Program and Project Objectives

MassCEC Program Goal/Objective	Palmer Community Microgrid Goal/Objective
Explore benefits microgrids can offer to Massachusetts energy customers.	The Project is focused on assessing multiple types of benefits for various kinds of customers (government, commercial, and industrial).
Catalyze the development of community microgrids that can:	
Reduce customer energy costs.	Reduce customer energy costs through energy conservation measures and locally owned renewable energy investments.
Reduce GHG emissions.	Reduce GHG emissions through energy conservation measures and by displacing fossil-generated power with clean renewable energy generation.
Increase resiliency of critical facilities and infrastructure.	Improve the resiliency of several critical facilities in Palmer by providing local energy resources and safe-islanding systems to assure continued electric service during regional power disruptions.
Serve at least one, but preferably more, physically separated critical facilities located on one or more properties.	Palmer Community Microgrid includes multiple physically separated critical facilities on multiple properties.
Include clean or renewable energy; diesel fuel may NOT be primary resource.	Exclude diesel fuel as a primary generation resource and reduce diesel consumption by preventing outages that cause dispatch of diesel backup generation.
Include energy efficiency upgrades to minimize new microgrid generation requirements.	Primary opportunities include some remaining LED lighting conversions and prospective upgrades to BEMS technologies. TES was considered and determined unlikely to be economically viable for critical facilities included in the microgrid.
Provide power to critical facilities, for a diverse group of customer and load types.	Palmer Community Microgrid includes multiple critical facilities with differing customer and load types, including municipal first response, EOC, public shelter, inpatient and outpatient medical care, and commercial and industrial facilities.
Resilient to forces of nature that are typical and pose highest risk.	Improve resiliency against regional outages caused by the most prevalent natural threats, including major hurricanes and winter storms affecting the long-distance transmission system. Solutions also may avoid facility impacts from outages caused by disruptions to local distribution service.
Provide one or more distribution system services, such as: Grid capacity support, black-start capability, facilitating renewables integration, etc. Services must be meaningful to the utility.	Support multiple distribution system services, including improvements in grid capacity, reliability, and ability to integrate renewable energy into local energy supplies. The Project Team engaged the utility to identify local grid issues that could meaningfully be supported by microgrid upgrades.

2.2.2 Characteristics and capabilities that are preferable but not required

a. Advanced technologies and designs

During Task 2 assessment the Project Team identified potential to apply distributed automation and AMI technologies in the Project area to enable load management for microgrid resiliency purposes. In addition to new distribution management devices, BEMS upgrades and microgrid signaling may support demand-response and load management for both operational and economic purposes. Chapter 3 addresses technology solutions required to support these and other requirements of the proposed microgrid.

b. Integrates energy storage technologies;

The Project requirements include BESS capacity to support grid forming and modal transitions, as well as reactive power and generation shifting. Project design scope considers a combination of facility-scale and community-scale BESS systems. Additionally, TES systems was considered to support load-management and system energy conservation for large building thermal loads that could accommodate pre-cooling retrofits or replacements. Chapter 3 addresses how energy storage systems are integrated in to the proposed microgrid Project.

c. Integrates relevant technologies designed and/or manufactured in Massachusetts;

Specific technology products have not been considered in the current Project phase. Subsequent phases of Project development would consider specific technology solutions that may be applied to support Project requirements, including those designed and/or manufactured in Massachusetts.

d. Leverages significant third-party investment, including private capital. Project characteristics should be informed by the Project Team's Expression of Interest and viability assessment;

The Project Team anticipates that implementation would require a combination of private third-party investments in new electric generation (primarily solar PV and gas-fired CHP capacity) and BESS capacity, as well as utility investment in distribution system upgrades or reconfiguration. This is consistent with the Project Team's Expression of Interest, which envisioned partnering with National Grid to develop a hybrid utility microgrid – with customer or third-party ownership of generation and storage assets, and utility ownership of distribution system assets.

e. Additional required and/or preferable characteristics, as relevant.

Like any community setting, the Town of Palmer is a dynamic environment, with changes occurring in facilities and services within the Project area. To support quantitative modeling and analysis, the Project focuses on currently known energy requirements. At the same time, however, meeting the proposed microgrid's goals for supporting economic development and employment requires consideration of future-phase development, including at Thorndike Mill.

III. Chapter 3: Preliminary Technical Design and Configuration

3.0 Proposed Microgrid Infrastructure and Operations

Task 3 assessments sought to establish technically viable options for providing resilient energy service for four separate zones described in Chapter 2. Initial assessments yielded the following outcomes affecting the proposed microgrid design for subsequent analysis:

- **Zone 3 Omitted:** The Project Team eliminated the zone that previously had been considered for the Palmer WWTP with prospective reliance on the nearby Norbell St. ground-mounted PV array. Based on distribution system design inputs from the utility, the proposed WWTP zone was determined to be technically infeasible. Specifically, the PV array is interconnected on an overhead feeder (identified as feeder 514L1), while the WWTP is served on a different underground circuit (523L1), with no clear options for reconfiguration. Moreover, the Town of Palmer's electricity purchases for the WWTP are substantially offset by remote net-metered solar production, which effectively forecloses the option to install onsite PV capacity to serve WWTP loads. With no practical way to energize the WWTP from existing nearby renewable sources or pay for new onsite sources, the contemplated WWTP zone was deemed infeasible and omitted from further assessment.
- **Zones 1 and 4 Combined with Thorndike Mill:** As discussed in Chapter 2, the Project Team identified a potential opportunity to serve Zone 1 loads from Thorndike Energy resources located at the Thorndike Mill site. Initial Task 3 assessments, including inputs from the utility, indicated that Thorndike Energy resources also could serve Zone 4 – Palmer Foundry. As a result, the Project Team combined Zones 1 and 4 in a new Zone 1 that would be energized primarily by Thorndike Energy generation and storage.

As a result of these findings, during Task 3 efforts the Project Team revised the Palmer Community Microgrid design to include two separate zones, each capable of forming a safe power island to serve critical facilities and commercial customers in the Palmer area. These two zones are different systems, with different resource options and operating objectives, and as a result they involve distinct infrastructure and operational approaches.

The revised Zone 1 microgrid design would utilize Thorndike Mill resources to provide resilient electricity services for Palmer Town Hall, Palmer Police Station, Palmer High School, and Old Mill Pond Elementary School, and Palmer Foundry. Establishing a safe power island within the National Grid distribution system to serve these facilities from a common source would require the utility to install new and upgraded switching infrastructure on two (2) feeders.

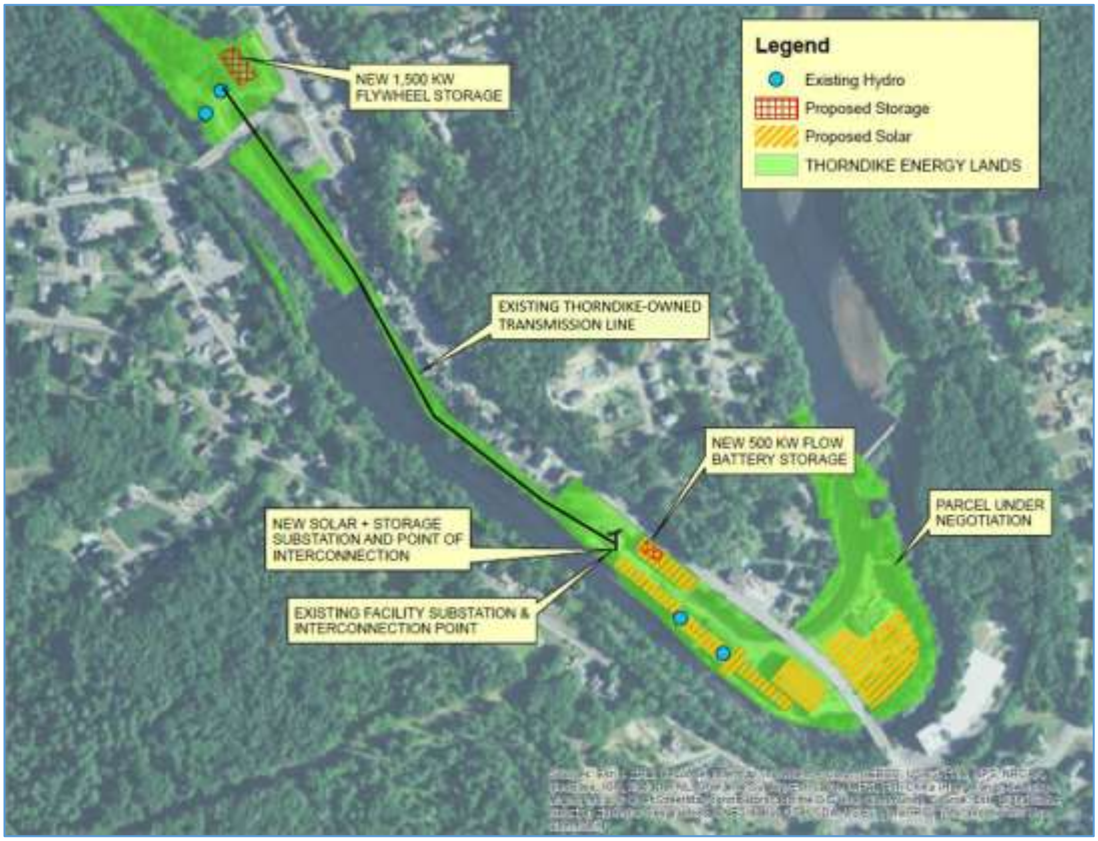
The Project Team also had proposed installing new remote-disconnect devices on numerous non-critical customer loads on the microgrid feeders, to enable the utility to curtail those loads during microgrid islanding. However, the utility rejected that approach and indicated that it would require any proposed microgrid to include generation resources sufficient to serve all loads connected to microgrid circuits.

DERs serving the microgrid either exist already within the footprint of both microgrid zones or are proposed for separate development and construction by critical customers or third-party operators (Thorndike Energy and Palmer Foundry in the case of Zone 1, and Baystate Wing Hospital in Zone 2). Thorndike Energy's existing and proposed resources generally are planned to serve onsite loads during blue-sky conditions at the Thorndike Mill industrial development site, as well as to sell services commercial customers via bilateral agreements and through the ISO New England market. (*See Figure 3.1*). Thorndike Energy DERs include:

- 1,040 kW (nameplate) of existing hydropower capacity;
- 1,900 kW of proposed PV capacity (ground-mounted and covered parking);
- 10 MWe from two (2) proposed natural gas-fired CHP systems – one approximately 1 MW and one 9 MW[2]; and
- 2,000 kW/8,000 kWh energy storage capacity.

Thorndike Energy's proposed storage capacity includes two separate energy storage systems (ESS) to be located at the Thorndike Mills site: a 1,500 kW/6,000 kWh flywheel system and a 500 kW/2,000 kWh vanadium redox flow battery.[3]

Fig. 3.1: Palmer Microgrid – Thorndike Energy Proposed Solar and Energy Storage Systems



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[2] Thorndike Energy proposes to install two separate CHP systems. The first system, approximately 1 MW in capacity (electric and thermal) is expected to be installed sooner than the second, approximately 9 MW system, because it will be needed sooner to serve expected customer loads at the Thorndike Mill site.

[3] Thorndike Energy selected vanadium redox flow batteries instead of other battery chemistry options (*e.g.,* lithium ion or lead acid) for several reasons, most notably that vanadium redox batteries provide a lower life cycle cost of energy, by virtue of a longer service life, lower cost per discharge/recharge cycle, and the ability to discharge completely without degrading battery effectiveness.

The Zone 2 system would enable island-mode capabilities for onsite solar + battery storage (800 kW carport PV, 500 kW/1,000 kWh battery) that Baystate Wing Hospital plans to install. Infrastructure requirements at Zone 2 include interconnection and protection system upgrades to support safe transitions to and from island mode, reconfiguration of onsite power distribution, and new energy controls to manage load sharing among the BESS and standby diesel (1,200 kW) resources. Zone 2 is conceived as a single-campus microgrid, and would not utilize any National Grid distribution infrastructure during island-mode operations.

3.1.1: Simplified Microgrid Diagrams

Fig. 3.2: Palmer Microgrid (Revised Zone 1) - Simplified Single-Line Diagram

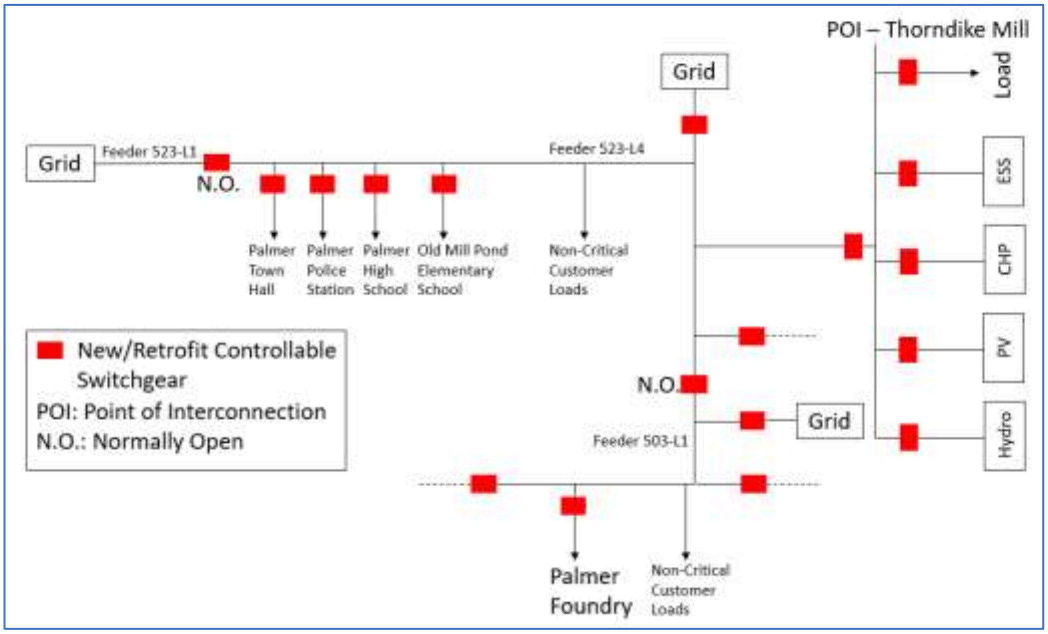
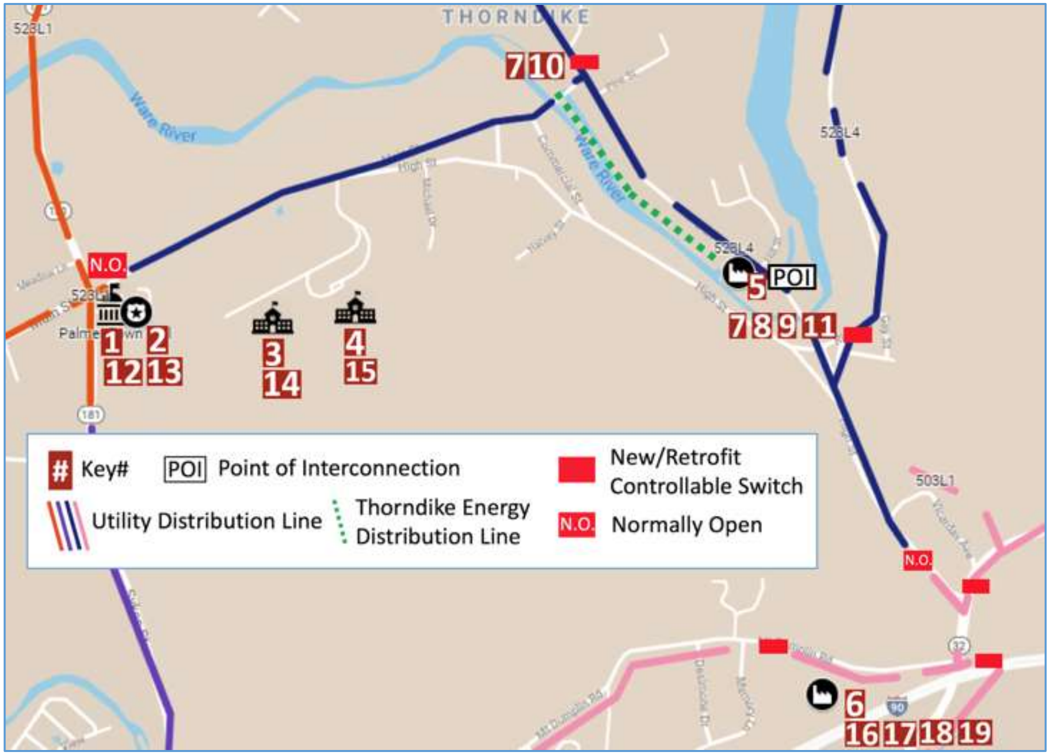


Fig. 3.3: Palmer Microgrid (Revised Zone 1) - Geospatial Overview



Note: Figure 3.3 omits DER interconnection switches illustrated on Figure 3.2.

Fig. 3.4: Palmer Microgrid (Revised Zone 1) - Key to Critical Facilities and DERs

Key #	Facility or Component	Description	Existing or Proposed
1	Palmer Town Hall	Administrative and EOC offices	Existing
2	Palmer Police Station	First response, public safety, EOC	Existing
3	Old Mill Pond School	Emergency public shelter	Existing
4	Palmer High School	Emergency public shelter	Existing
5	Thorndike Mills	Industrial redevelopment site	Existing
6	Palmer Foundry	Industrial site	Existing
7	Hydro	Hydro facilities (1,040 kW)	Existing
8	PV	Rooftop and covered parking (1,900 kW)	Proposed
9	CHP	Gas-fired combined heat and power (10 MWe)	Proposed
10	Flywheel ESS	Flywheel energy storage (1,500 kW/6,000 kWh)	Proposed
11	BESS	Vanadium redox flow battery (500 kW/2,000 kWh)	Proposed
12	Standby Generator	Diesel standby genset (60 kW)	Existing
13	Standby Generator	Gas-fired standby genset (280 kW)	Existing
14	Standby Generator	Diesel standby genset (125 kW)	Existing
15	Standby Generator	Diesel standby genset (125 kW)	Existing
16	Standby Generator	Gas-fired standby genset (100 kW)	Existing
17	Standby Generator	Gas-fired standby genset (100 kW)	Proposed
18	PV	Ground-mounted PV array (270 kW)	Existing
19	PV	Ground-mounted PV array (165 kW)	Proposed

Fig. 3.5: Palmer Microgrid (Zone 2) - Simplified Single-Line Diagram

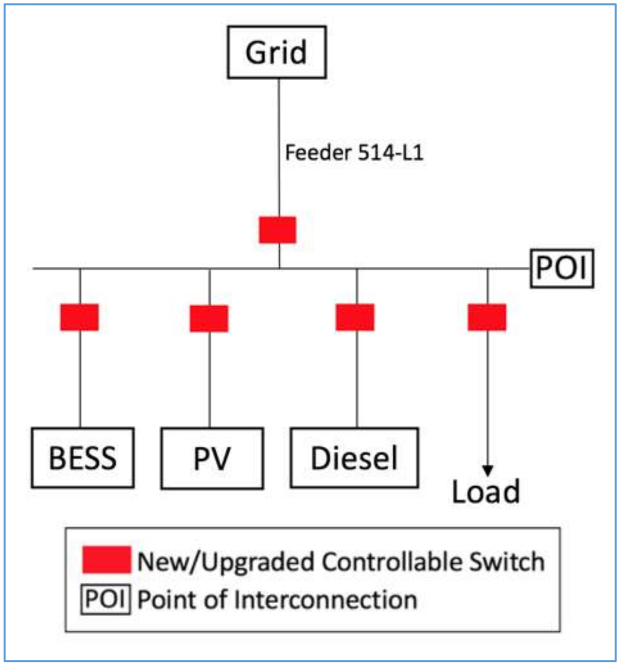


Fig. 3.6: Palmer Microgrid (Zone 2) - Geospatial Overview

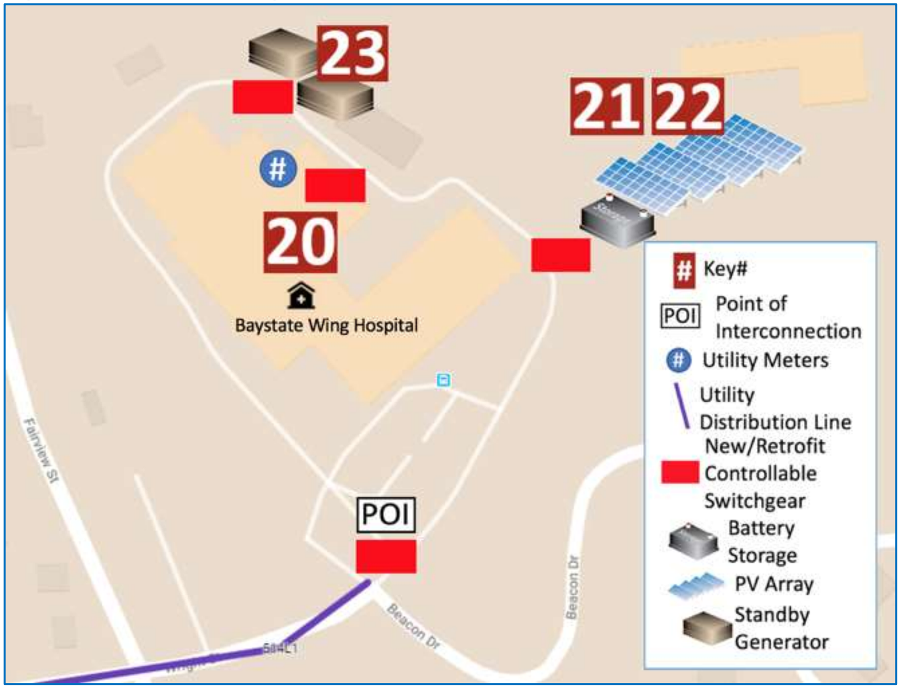


Fig. 3.7: Palmer Microgrid (Zone 2) - Key to Diagrams (Figs. 5-6)

Key #	Facility or Component	Description	Existing or Proposed
20	Baystate Wing Hospital	Hospital, emergency care	Existing
21	PV	Covered parking PV (800 kW)	Proposed
22	BESS	Battery energy storage (500 kW/1,000 kWh)	Proposed
23	Standby Generators	Diesel standby gensets (1,200 kW)	Existing

3.1.2: Microgrid Operations – Normal and Emergency Modes

Under normal conditions, the primary function of the two proposed microgrid zones would be to monitor and log the status of microgrid systems. During emergency conditions, including when normal electric service is interrupted, the microgrid would enter island-mode operations and maintain resilient power supplies for microgrid loads. Utility-owned and -operated microgrid controllers in each zone would accomplish safe-islanding functions as described in "3.5.4 – Microgrid Operation," below.

3.1.3: Interconnection and Protection Systems

Zone 1 of the Palmer Community Microgrid would create a safe island within the National Grid distribution system by signaling existing and new switches (*noted in Figures 3.2, 3.3, and 3.4, above*) to isolate segments serving the microgrid loads. Bi-directional protection schemes implemented on the utility system's protective devices would selectively detect and isolate a fault on the network during normal operating modes. Zone 1 is conceived as a utility distribution microgrid, and all controls, signaling, and switching capabilities would be controlled by National Grid.

Interconnection and protection systems for third-party owned generation and storage would be defined by the configuration of those systems, outside the scope of this assessment. Thorndike Energy ESS and dispatchable CHP capacity would be configured to support both onsite power service as well as grid forming on the microgrid when it enters island mode. At a minimum, reverse power protection on Thorndike Energy's points of interconnection with circuit breakers and protective relays would prevent unintentional power flows during normal and island-mode operations.

In addition, any other third-party/customer-owned PV resources in Zone 1 must be equipped with dedicated breakers and protection and control measures such as over/under frequency and voltage detection on interconnection couplings to sense an unintended outage and isolate the PV systems from the utility distribution system according to the IEEE 1547 standard.

Zone 2 of the microgrid would isolate the Wing Hospital campus from the utility distribution system at the service entrance, and would not utilize any utility infrastructure during island-mode operations. Once isolated, the existing Wing Hospital circuit would serve as a microgrid bus that can be energized locally using BESS and distributed PV resources proposed for development on the hospital campus. Reverse power protection will be provided on the microgrid's point of interconnection by a circuit breaker and protective relay to prevent power injection into the utility distribution system during grid-connected operation.

The Zone 2 interconnection system would include dedicated breakers and protection and control measures, such as over/under frequency and voltage detection on interconnection couplings, to sense an unintended outage and isolate Zone 2 from the utility distribution system according to IEEE 1547 and 2030 standards. Zone 2 BESS will be configured to support grid forming on the microgrid bus. Bi-directional protection systems would be implemented on all protective devices in order to selectively detect and isolate network faults when the microgrid is operating in grid-connected and islanded modes.

Control functionalities to support transitions to and from islanded mode are described in greater detail in "3.5.3: Microgrid Operation," below.

3.1 Load Characterization

3.2.1 Description of Loads Served by the Microgrid

Zone 1 of the Palmer Community Microgrid is designed to enable resilient electricity service for critical and non-critical community loads on two National Grid feeders, coded 503-L1 and 523-L4, which include:

- Building-wide electricity loads at four (4) critical community facilities (Town Hall, Police Station, and two schools);
- Industrial loads at Palmer Foundry; and
- Various non-critical residential and commercial loads connected to the proposed microgrid circuits.

The six critical facilities' electric loads are predominately daytime loads, involving regular five-day weekly business hours, plus 24-hour/7-day heating, ventilation, and air conditioning (HVAC) and second-shift industrial process loads. The remaining non-critical community loads, representing dozens of homes and commercial facilities, were not modeled in detail during Task 2 analysis, but their theoretical maximum peak demand is estimated on the basis of circuit loading information provided by National Grid.

DERs that would serve Zone 1 microgrid loads would be designed and developed to serve prospective industrial loads during blue-sky conditions at Thorndike Mill, including 24-hour lighting, HVAC, and pumping associated with indoor agriculture.

Zone 2 of the Palmer Microgrid is designed to serve critical and emergency loads in both the new and old wings of Baystate Wing Hospital. Loads in the old wing are primarily daytime loads, Monday through Friday each week, while loads in the new wing include 24-hour emergency medical and inpatient care services.

Fig. 3.8: Palmer Microgrid Load Summary

Zone	Facility	Load Type	Peak Demand (kW)	Average Demand (kW)†	Annual Consumption (kWh)
1	Palmer Town Hall	Commercial	48	18	67,560
	Palmer Police Station	Commercial	52	20	247,160
	Old Mill Pond School	Commercial	136	51	413,200
	Palmer High School	Commercial	252	95	832,400
	Palmer Foundry	Industrial	1,162	439	2,823,322
	Thorndike Mill	Industrial	300	113	500,000
	Zone 1 Total Critical Load		1,950	737	4,883,642
	Additional non-critical customers	Various (peak demand estimate based on circuit loading data)	8,960	3,387	NA
	Zone 1 Peak Load (Max)		10,910	4,124	NA
2	Zone 2 - Baystate Wing Hospital	Commercial	1,316	497	4,551,600

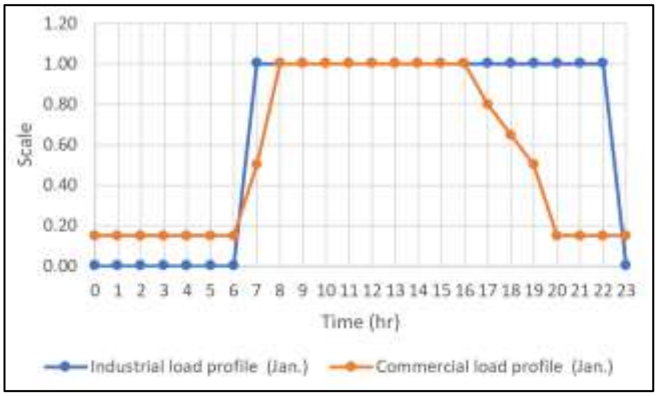
†Average demand estimated as a factor (0.378/1.0) of monthly peak, which is the only demand data available for the studied loads.

3.2.2 Hourly Load Profile

Available metering data for the critical loads studied included only monthly consumption and peak demand information. The Project Team used HOMER Pro software to model hourly loads based on HOMER's library of representative load profiles. The Team selected profiles for typical commercial, light industrial, and office loads, and then scaled those profiles on the basis of actual peak demand values obtained from utility monthly metering data.

The proposed Palmer Microgrid critical loads were modeled as industrial loads and commercial loads for system modeling in HOMER Pro. Palmer foundry was categorized as an industrial load and the four facilities in the Town Hall cluster were categorized as commercial loads. These category definitions were based on the facilities' monthly facility load profiles, facility uses, and engineering judgements. Figure 3.9 illustrates the HOMER industrial and commercial loads used for this study.

Fig. 3.9: HOMER Pro Load Profile Template



The hourly load profile templates were scaled to match the actual critical load demand (kW) of the month and slightly modified to best match the actual energy consumption (kWh) of the critical loads for each month. The actual demand and consumption values are the aggregation of demand and consumption of facilities within each load category derived from utility bills from six of the seven facilities assessed. Thorndike Mill loads were omitted from the load profile because onsite loads at the site (including current and prospective future tenants) are not among critical loads defined for microgrid service. During normal operating conditions, Thorndike Mill tenants generally will purchase energy services from Thorndike Energy's proposed generation systems, thereby supporting cost recovery for generating assets that are required to serve critical microgrid loads. During utility outages, onsite loads either will be curtailed, or will be served by other onsite resources according to separate service agreements with Thorndike Energy.

Also, the non-critical microgrid loads were omitted from the load profile, because detailed load data were unavailable. The Project Team estimated from circuit-loading data that the peak demand for these non-critical loads totals 9 MW, to verify that the proposed system has ample generating capacity to serve both critical and non-critical loads.

Figures 3.10 and 3.11 illustrate the Palmer Microgrid's average daily critical load profile for each month of the year.

Fig. 3.10: Palmer Microgrid (Revised Zone 1) – Daily Critical Load Profile

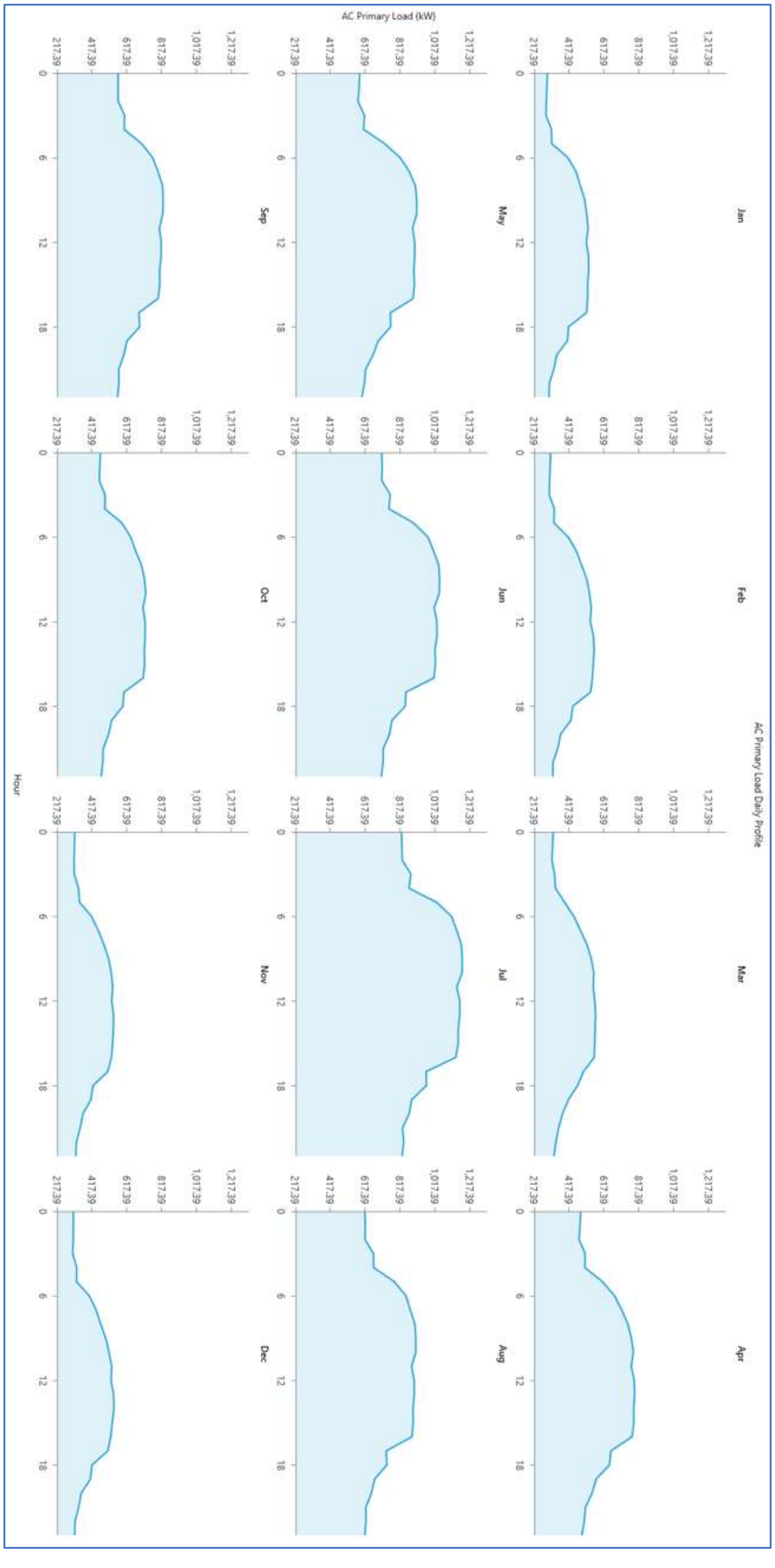
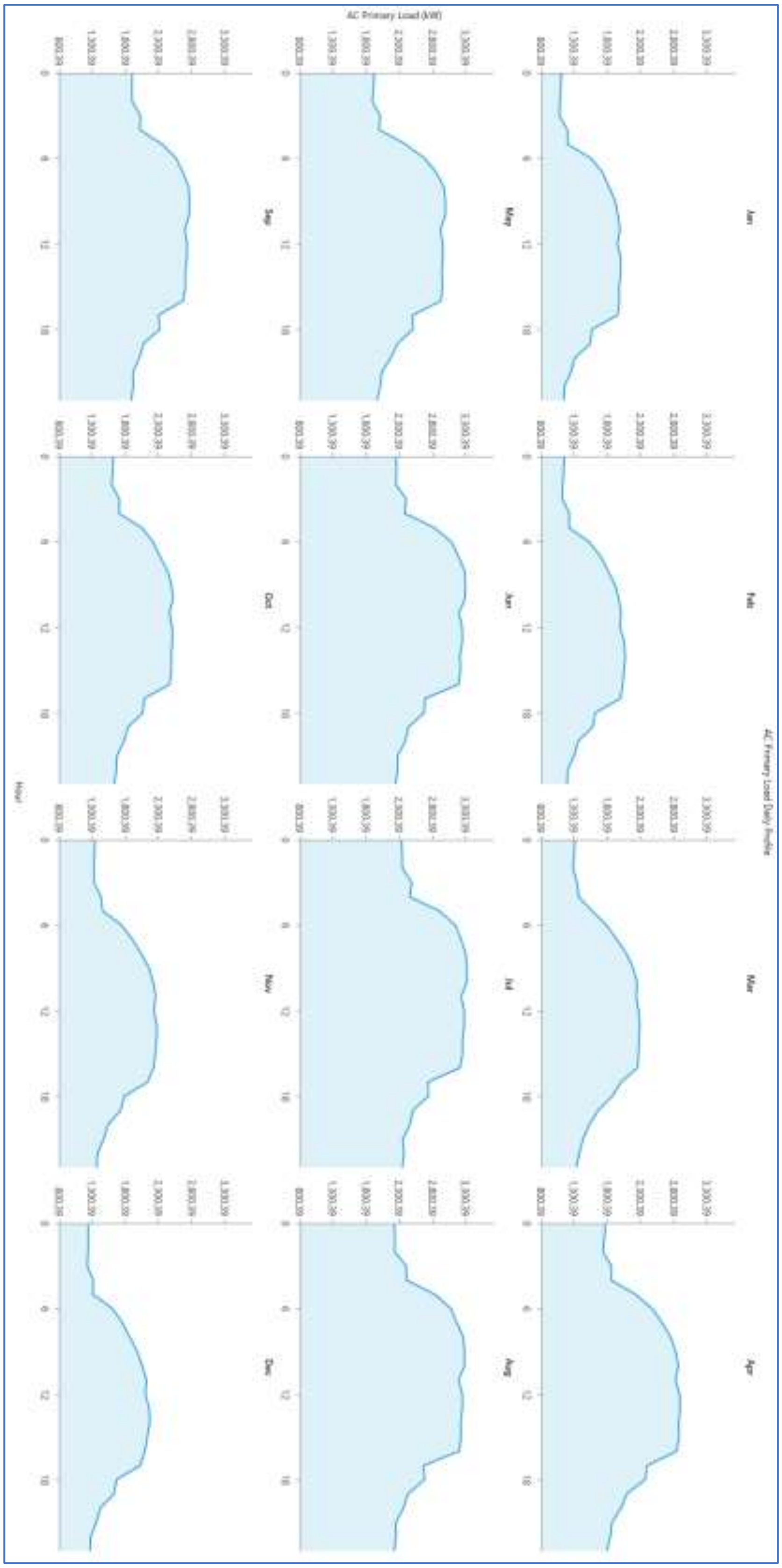


Fig. 3.11: Palmer Microgrid (Zone 2) – Daily Critical Load Profile



3.2 Distributed Energy Resources Characterization

The proposed Palmer Microgrid design relies on third-party and customer-owned solar PV, hydroelectric, BESS, natural gas-fired CHP, and diesel-fueled standby generation systems in locations as summarized in Figure 3.12.

Fig. 3.12: Thorndike Energy DER Summary

Facility	PV - Existing (kW AC)	PV - Proposed (kW AC)	Hydro - Existing (kW AC)*	BESS - Existing (kW)	BESS - Proposed (kW)	CHP - Proposed (kW)	Standby - Existing (kW)	Standby - Proposed (kW)	Diesel Storage (gal.)
Palmer Town Hall	0	0	0	0	0	0	60	0	100
Palmer Police Station	0	0	0	0	0	0	280	0	NA
Old Mill Pond School	0	0	0	0	0	0	125	0	5,000
Palmer High School	0	0	0	0	0	0	125	0	550
Palmer Foundry	270	165	0	0	0	0	100	100	NA
Thorndike Mill	0	1,900	1,040	0	2 MW/8 MWh	10,000	0	0	NA
Zone 1 Total	**270**	**2,065**	**1,040**	**0**	**2 MW/ 8 MWh**	**10,000**	**690**	**100**	**5,650**
Baystate Wing Hospital	0	800	0	0	500 kW/ 1 MWh	0	1,200	0	4,000
Zones 1 and 2 Total	**1,070**	**2,065**	**1,040**	**500**	**2.5 MW/ 9 MWh**	**10,000**	**1,890**	**100**	**9,650**

3.3.1 DER Adequacy to Meet Demand

The generation sources specified to support the revised Zone 1 (totaling 13.4 MW[4] comprised of PV, hydro, ESS, and CHP plus 790 kW of standby diesel and natural gas-fired capacity) are adequate to serve 100 percent of loads on the relevant feeders (503-L1 and 523-L4, totaling about 9 MW) – including both critical loads modeled for the project (1.9 MW theoretical coincident peak demand; 737 kW average demand) and other non-critical loads that National Grid indicated also would have to be served by the proposed microgrid rather than being curtailed as originally proposed by the Project Team. Thorndike Energy anticipates providing premium power services to some industrial customers at the Thorndike Mill site in the future, which may result in additional onsite capacity being specified for those loads. The total proposed generation would be more than adequate to support critical and non-critical microgrid loads in all foreseeable scenarios.

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[4] Most of the revised Zone 1 DERs would interconnect with National Grid's 523 feeder network, which is served by the T2 transformer at the Thorndike #523 substation. This T2 transformer has a summer normal rating of 47.8 MVA, and currently hosts 20 MW of distributed generation. In principle, transformer T2 currently has adequate capacity for the proposed new Thorndike Energy DERs, but that capacity likely will diminish over time as other DERs are approved for interconnection on the 523 feeder network.

Given the expected sufficient DER capacity to support Zone 1 loads, the Project Team determined that BEMS upgrades and other efficiency measures would not be required for the proposed microgrid to support community resiliency objectives. Nevertheless, microgrid controls should be specified and configured with functionality to support direct control of customer loads for microgrid islanding and balancing. The microgrid controls would signal BEMS and interruptible load controllers to reduce or curtail non-critical loads. The same BEMS and load controllers would also enable customers to save energy costs by shifting loads in response to critical peak pricing conditions and DR events.

In Zone 2, the microgrid would integrate both the new solar+storage resources (800 kW PV+500 kW/1 MWh BESS) plus the hospital's existing 1,200 kW of diesel-fueled standby generation. These resources are more than adequate to meet the approximately 1,300 kW of Zone 2 peak demand in all foreseeable conditions.

Specific designs for proposed DERs would be defined by third-party energy suppliers including Thorndike Energy and Palmer Foundry. Resilient energy capacity and supply would be secured for microgrid service through long-term agreements with Thorndike Energy. Palmer Foundry's interconnected PV is expected to be consumed by onsite loads.

3.3.2 Resiliency of DERs to Natural Forces

-and-

3.3.3 DER Fuel Sources

Zone 1 DERs are powered by three different energy sources – solar, hydro, and natural gas – creating significant energy security and redundancy to address a wide variety of outage scenarios. Natural gas and diesel-fueled standby generation systems would be left in their current automatic transfer switched (ATS) configuration. Zone 2 DERs are powered by solar energy and diesel fuel. Diesel-fueled resources would be integrated into the hospital's solar+storage microgrid.

Renewable resources considered for the Project are variable and not dispatchable for grid-forming purposes. Thorndike Energy's hydro production is subject to seasonal variance, with generators shutting down when water levels on the Ware River are very low. Onsite hydro and PV would operate in net-metered configuration during grid-connected operations, and would support ESS recharging and serve a portion of microgrid loads during island-mode operations.

The specified DERS would be designed to withstand severe weather conditions that typically affect the project area.

Thorndike Energy resources are expected to be sited in flood-prone areas near the Ware River.[5] Any flood protection measures would be implemented by Thorndike Energy as part of its design and development of the DERs at its location.

Snow cover would not be expected to have a substantial effect on PV output, given the angled orientation of panels and the tendency for PV panels to heat up with even minimal solar irradiance and shed snow quickly in almost all snow conditions.

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[5] See *Town of Palmer Hazard Mitigation Plan:* http://www.pvpc.org/sites/default/files/Palmer_HazMitPlanUpdate2016_final.pdf

3.3.4 DER Capabilities

The Thorndike Energy proposed 2 MW/8 MWh of energy storage and 10 MWe of CHP capacity would serve as the prime sources of capacity to support all required Zone 1 island-mode operations, including black starting, following dynamic loads, and serving partial or full loads on the microgrid.

Zone 2 DERs (1,300 kW of PV and BESS plus 1,200 kW of standby diesel) are capable of supporting 100 percent of the hospital's managed loads (1,316 kW peak; 497 kW average) in both the new and old wings of the hospital. Under the current standby ATS configuration, cooling loads are supported at a limited capacity for the new hospital wing only. Cooling capacity is not considered critical in the old wing, which primarily provides outpatient care services, in contrast with the new wing, which includes an emergency medical department, surgical operating theatres, and 74 inpatient beds. Accordingly, actual critical loads requiring resilient energy service are less than the metered peak or average loads.

Utility-owned and -operated microgrid controls and distributed controls in both zones would operate resources to manage voltage and frequency, dispatching generating capacity to maintain service during island-mode operations. Ride-through capabilities would enable uninterrupted service during voltage and frequency events, and would manage resynchronization upon grid restoration, consistent with IEEE and utility standards. Also, to the degree customer facilities and critical loads are equipped with BEMS and direct load controls, the microgrid controls would signal those devices to manage peak demand and total consumption during islanding events, particularly during transitions from grid-connected to islanded operating modes.

3.3 Electrical Infrastructure Characterization

As illustrated in Figure 3.1, Palmer Microgrid Zone 1 would operate on two utility feeders, identified as feeder 523-L4 and feeder 503-L1.

To operate the microgrid in islanded mode, the utility would disconnect non-microgrid circuits using existing and upgraded isolating circuit breakers. Several existing switches and circuit breakers must be upgraded to enable the utility microgrid control system to open circuits and form an intentional power island on segments of both feeders 523-L4 and 503-L1 in the event both are affected by an outage upstream on the transmission or distribution system. (*Refer also to "Sec. 3.5 Microgrid and Building Controls Characterization"*). In addition to these isolating circuit breakers, a controllable tie switch must be installed to connect feeder 523-L4 to 503-L1, enabling the Palmer Foundry (*See Figure 3.1*) to be energized by the microgrid. In addition to the foundry, additional critical customer loads could – assuming the addition of adequate generation capacity – be included in the microgrid in future phases with new switchgear upgrades on feeder 503-L1 enabling power flows to National Grid customers located across the I-90 Massachusetts Turnpike to the south. Such loads include grocery, pharmacy, fuel supply, and other vital community assets.

The electrical infrastructure serving the project area is not resilient to natural forces that pose direct threats in the project area – namely high winds, severe winter weather, and physical damage. The project team considered the possibility of installing underground infrastructure to serve microgrid loads, and determined that buried cable for 2-1/4 miles of 13.2-kV distribution line would be cost-prohibitive, likely exceeding $5 million. Therefore, the proposed microgrid Zone 1 would rely on the existing above-ground distribution infrastructure, with pole-mounted or pad-mounted switches installed to enable island-mode operations.

Much of the local distribution system traverses wooded areas. A modest increase in utility maintenance (primarily in more frequent tree trimming and repair of damaged distribution infrastructure) could improve the affected overhead lines' resiliency against local outage threats. Nevertheless, overhead lines cannot be considered resilient against the most common local causes of utility outages. The proposed microgrid's most important resiliency benefit therefore involves protecting the community's critical assets against long-duration outages affecting regional system operations. Examples include extended transmission system outages caused by Superstorm Sandy, interconnect-level faults such as the 2003 Northeast blackout, and physical or cyber assaults on central power generation or high-voltage transmission systems.

Figure 3.13 describes how the proposed microgrid would support various operating capabilities.

Fig. 3.13: Proposed Microgrid Capabilities

Capability	Comment
Automatically connecting to and disconnecting from the grid	Yes (Achieved with isolation circuit breakers such as S&C Vista Underground Distribution Switchgears)
Load shedding schemes	No
Blackstart and load addition	Yes (Refer to section above)
Performing economic dispatch	No
Performing load following	Yes (DERs controlled to inject into the microgrid only enough power to meet the primary loads)
Demand response	No
Storage optimization	No (Since the BESS is used only to support resiliency objectives, and the BESS operates at voltage mode with frequency reference, and PV operates at current mode, no optimization is required. PV would serve the load as much as possible, and the rest of the demand is served by CHP and BESS based on droop control functionality.)
Maintaining frequency and voltage	Yes (Achieved with CHP)
PV observability and controllability; forecasting	Yes (achieved with advanced microgrid control functionality)
Coordination of protection settings	Yes
Selling energy and ancillary services	Yes (Thorndike Energy's generation systems are specified to sell energy services to onsite customers, microgrid customers, and other customers through the New England ISO market)
Data logging features	Yes

3.4 Microgrid and Building Controls Characterization

The Palmer Microgrid design would apply microgrid master control systems capable of detecting grid reference voltage and signaling utility switches, load breakers, and DER controllers. Microgrid control systems would monitor loads and provide load-dispatch signaling via customer BEMS and direct load controls where applicable – particularly in Zone 2, where the hospital's existing BEMS would be signaled to support microgrid control functionality .

3.5.1 Microgrid Control Architecture

Microgrid control systems would monitor and signal the dispatch of all distributed energy resources during island-mode operations, including PV, hydro, BESS, and CHP, as well as automated circuit breakers, protective relays, metering systems, and BEMS and direct load controls. Control systems in both zones would be managed and operated by the utility via a custom user interface, which would visually illustrate the microgrid and provide real-time equipment data, system alarms, and historical data. Zone 1 microgrid control systems and distributed telemetry and controls would communicate through utility communication systems, while Zone 2 systems would utilize secure onsite communication networks.

Each microgrid could be controlled by three integrated control systems (Layers) as follows:

- Layer 1: Device-level control

This layer consists of controllers and sensors that provide direct, fast control of each device, *e.g.,* the CHP system controlling active and reactive power output to maintain nominal frequency and voltage. In addition to DER controllers, switch controllers and protective relays are considered as integral to the equipment in this layer. The Layer 1 protective devices would be responsible for protection of the DER assets and the distribution system and would interpret and execute commands issued by Layers 2 and 3, if the device determines that it is safe both for the DER and the system to do so.

- Layer 2: System-level control

This layer consists of an automation controller platform or Real-Time Automation Controller (RTAC). This controller would connect to the Layer 1 control devices and other sensing devices as required to determine system status and would issue commands to devices based on the desired operating state of the system. This Layer would be responsible for issuing general system commands to each Layer 1 device such as opening/closing circuit breakers and dispatching battery storage system.

- Layer 3: Grid operator control

This layer consists of SCADA controls issued by the utility operations center after evaluating the overall system conditions. This Layer would communicate directly with the Layer 2 control platform to enact system control. This layer would enable microgrid control by the utility.

3.5.2 Locations of Microgrid and Building Controls

Zone 1 microgrid supervisory controls would be located at a National Grid distribution control center, and Zone 2 microgrid controls would be located in the hospital electrical control room associated with onsite solar+storage and standby generator systems. Existing BEMS and load controls in both zones would remain in current locations, and any new load controls would be located in each building’s electrical control room as applicable. Major loads in the hospital will be controlled via existing or upgraded BEMS.

3.5.3 Existing and New Controls

In order to develop the proposed Zone 1 control platform, several existing switches must be upgraded. Tie-switches between feeders 523-L1, 523-L4, and 503-L1, as well as eight other switching and circuit-break locations on these feeders, must be upgraded or replaced to enable remote operation. These switches and isolating circuit breakers are labeled in red on Figure 3.1. Retrofits to enable remote operation include the addition of battery charger, battery packs, voltage and current sensors, RTUs such as SEL-2411 Programmable Automation Controller, and communication devices, at a minimum.

Another set of new control devices required for the microgrid design are the DER control devices. In general, CHP systems and PV, hydro, and BESS inverters would be equipped with automation controllers. For load control, the Zone 2 microgrid would interact with existing BEMS, upgraded or replaced as necessary to support monitoring and indirect control of building loads by the microgrid control system.

3.5.4 Microgrid Operation

Zone 1: Upon loss of grid, the Zone 1 microgrid control system would seek to establish a safe island within the National Grid distribution system by taking the following steps:

A. Signaling the actuation of switches at several points on two (2) distribution feeders, labeled in red in Figure 3.2. Switches would open circuits to prevent power flows from the microgrid onto adjacent segments, and a controllable tie switch would connect feeder 523-L4 to feeder 503L1 to allow energizing the Palmer Foundry with Thorndike Energy sources.
B. Execute a black start of the microgrid by dispatching available Thorndike Mill generating capacity (ESS, CHP, PV, hydroelectric). Once reference voltage and frequency is established on the microgrid, any other grid-tied PV systems connected to microgrid feeders would automatically reconnect and inject power into the distribution system in accordance with IEEE 1547 interconnection standards.
C. Monitor voltage, frequency, and phase angle, and signal DER controllers, BEMS, and direct load controls to respond as needed to correct any deviations.
D. Upon restoration of normal grid service, the microgrid would signal controllable DER breakers to open, shutting down the microgrid. It would open the switch at the microgrid point of interconnection and signal distribution operators confirming that the microgrid feeders are no longer energized, allowing operators to close the tie switches at the microgrid boundary and restore normal utility service in the project area.

Zone 2: Upon loss of grid, the Zone 2 microgrid control system would:

A. Signal interconnection breakers to open;
B. Initiate grid forming by signaling the storage system inverters to energize the common bus;
C. Close the breakers on the critical and emergency loads, within the maximum capacity of the storage system inverters;
D. Signal PV inverters to start injecting power into the common bus and share a part of the load with BESS depending on the available generation from PV;
E. Monitor BESS state of charge (SoC) for the low set point. When the SoC approaches the proper margin with the low set point, signal the PV inverters to inhibit and stop operating;
F. Signal standby generator controllers to initiate startup and synchronize to the common bus with the storage reference voltage to share the load with BESS;
G. Signal the PV inverters to start operating and injecting power into the common bus to share the load with the BESS and generator;

H. When SoC reaches the low set point, drop all the loads except emergency load and ramp up/down the generator output to serve the emergency load. At this point, any PV generation would be stored in BESS;

I. Upon restoration of utility service, the microgrid would signal controllable DER breakers to open, shutting down the microgrid. It would open the switch at the microgrid point of interconnection and signal utility distribution system controllers confirming that the microgrid feeders are no longer energized, allowing the utility to close the tie switches at the microgrid boundary and restore normal utility service to the hospital.

3.5.5 Island Contingency Generation Management

In Zone 1, in the case of failure of the Thorndike Energy CHP systems, or failure of ESS during a peak-loading event, the microgrid would shut down because the Thorndike Energy's dispatchable DERs function as the voltage and frequency reference for the microgrid electric system. In the case of PV or hydro contingencies, because these generation resources function as current sources, the net load served by the CHP and BESS would increase (in the BESS case if additional charge in the battery is available).

In Zone 2, in the case of failure of the BESS, the microgrid would shut down because the BESS would function as the voltage and frequency reference for the microgrid electric system. In event of microgrid shutdown for any reason, standby generator controls would restore service on critical circuits, either by starting the generators or ramping up their output to support critical loads that were being served by the BESS.

3.5.6 Resiliency of Microgrid and Building Controls

Microgrid controls in both zones would be installed in interior above-ground locations that are protected from natural forces affecting the project area.

3.5 3.6: Information Technology (IT)/Telecommunications Infrastructure Characterization

3.6.1 IT Infrastructure Description

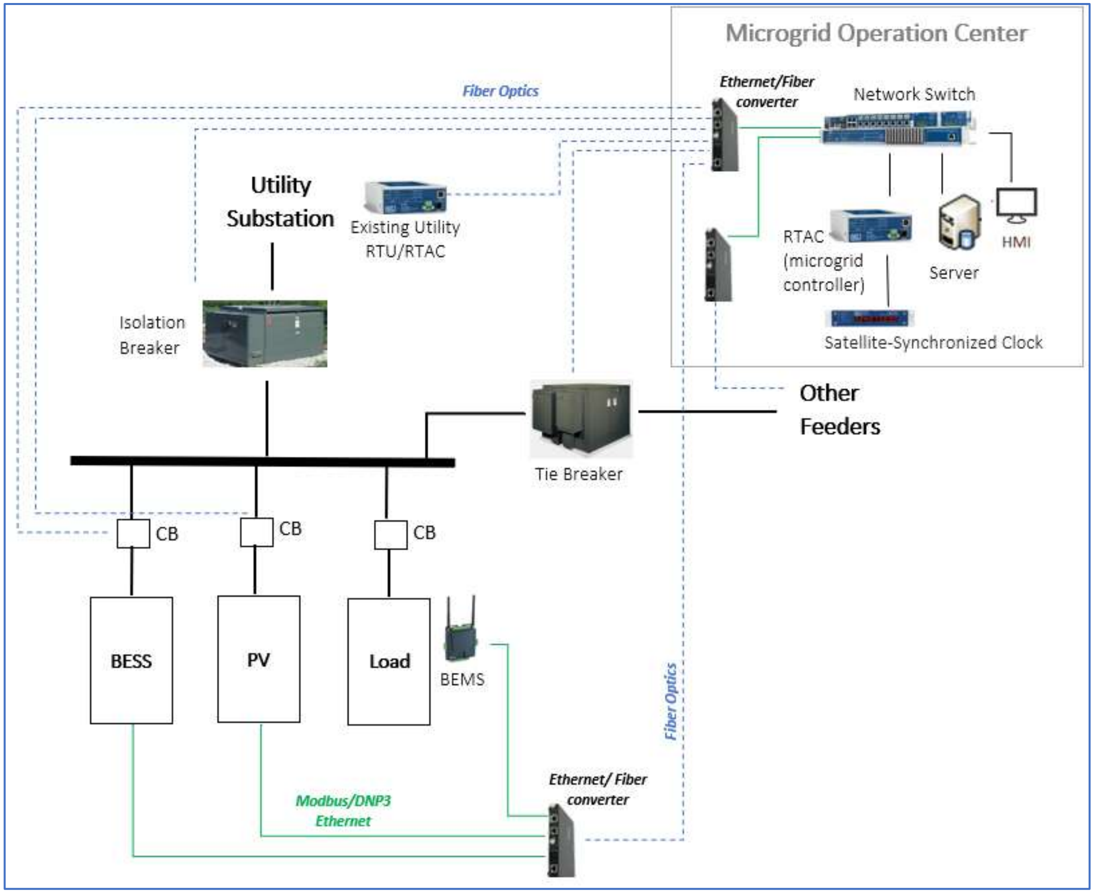
The microgrid control system would use both hardware and software systems to monitor and control microgrid components. Communications between the microgrid relays, microgrid controllers, DERs, loads, and SCADA devices would be integrated into existing utility communication systems where applicable. Where existing utility communication systems are unavailable or unsuitable, new fiber-optic communications network systems are recommended. Microgrid devices and controllers would report to the microgrid controllers via SCADA protocol of Modbus or Distributed Network Protocol (DNP3) over the communications network. The microgrid controller would issue commands to the DERs, BEMS (at Zone 2), and relays via the same network. Fiber-optic transceivers would be required to make conversions among fiber and ethernet connections in the network. Devices would be connected through fiber-optic media rather than radio-based communication media to provide resilient and secure communication. To implement forecast-based operating protocols, the microgrid or RTUs would require connectivity with reliable sources of real-time locational weather data.

The communication between microgrid devices would be performed via proprietary, encrypted protocols and secure networking. Communications with human-machine interfaces (HMI) also would be encrypted. Server architecture would support log collection and time synchronization functions.

3.6.2 IT and Telecommunications Infrastructure

Figure 3.14 presents a conceptual IT and telecommunications infrastructure on the simplified equipment layout diagram.

Fig. 3.14: Conceptual IT and Telecommunications Infrastructure



3.6.3 Utility Communication

Utility microgrid communication systems would be designed for monitoring or future expansion purposes. A fiber optics-based communication platform can be used to interconnect the utility remote terminal units (RTU) and real-time automation controllers (RTAC) to the utility microgrid controller. Usually, this communication channel from layer 3 to layer 2 control is designed for grid-connected mode of operations, such as to implement economic dispatch or demand response objectives. It also would support microgrid operating mode transitions, and coordination of protection systems. During islanded mode, the microgrid automatically detects loss of grid source and the utility microgrid controller can directly work with layer 1 devices and controllers.

3.6.4 IT and Telecommunications Infrastructure Resiliency

Resilient networks are characterized by providing and maintaining an acceptable level of service when facing failures and faults, which affect their normal operation. The communication infrastructure considered for the Palmer Microgrid is a conventional hierarchical design.

Communication between layers of the controllers could be made more resilient with multiple communication paths. An alternative communication network to address the issue of the resiliency and reliability is the distributed architecture. A distributed architecture uses a community of controllers, which eliminates the traditional master controller concept. At any time, only one controller functions as the lead controller to ensure safe operations. Should that controller become unavailable, the system would sense the loss and would automatically reconfigure the microgrid to maintain operations. This approach eliminates the single point of failure and provides optimum redundancy under adverse conditions providing resiliency.

IV. Chapter 4: Assessment of Microgrid's Commercial and Financial Feasibility

4.0 Summary

The Palmer Microgrid Zone 1 and 2 proposals include investments in systems to assure resilient energy service for critical public services in the Town of Palmer. The two zones differ substantially from each other, and so they involve different ownership models and feasibility factors.

As proposed, Zone 1 would add switching capacity and control capabilities to enable utilizing segments on two National Grid distribution lines to form a safe power island during system outages. The proposed microgrid project would rely on behind-the-meter DERs that already exist or are planned for separate development in the project area.

In Zone 1, the proposed scope and consequently the potential benefits for Palmer-area residents diminished from the initial project proposal. The project team – comprised of Thorndike Energy and the Town of Palmer – had asked the utility (National Grid) to consider reconfiguring its distribution network to enable formation of a wide-area utility distribution microgrid. As initially conceived, the microgrid would support a wide variety of critical community loads by integrating existing, planned, and prospective future local solar generation with proposed new energy storage and CHP capacity, together with control systems to curtail non-critical loads during outage events. The utility rejected this approach as being technically infeasible, given the locations of existing solar systems and the vulnerability of overhead infrastructure serving much of the Palmer area. It also asserted that any proposed system must serve all connected facilities rather than curtailing non-critical loads as originally conceived.

The Project Team assessed options for scaled-back microgrid zones, and ultimately omitted all of the originally considered low-income housing, fire-response, and water treatment facilities, as well as pharmacy, grocery, and other commercial facilities, leaving only the Palmer Police Station, Palmer Town Hall, two school buildings, and the Palmer Foundry to be served by the proposed utility distribution microgrid. Additionally, prospective customers at the Thorndike Mill industrial development site would be served by onsite resources, including during utility outages to the degree Thorndike Energy provides firm capacity to support their loads.

With many vital loads omitted, the Zone 1 proposal offers less community benefit than originally envisioned, and therefore may attract less community interest in supporting development. Further, the remaining loads in the down-scaled zone would bear a high burden for recovering any incremental microgrid costs that must be passed directly to customers. Finally, although the utility initially provided information suggesting the proposed Zone 1 switching configuration could work, it later indicated it would not contemplate a community microgrid using its distribution infrastructure in the project area. Nevertheless, the proposed Zone 1 business model is assessed to support understanding of options and factors affecting the feasibility of utility distribution microgrids to serve vital community facilities.

Unlike the proposed Zone 1 system, Zone 2 is proposed for development entirely on the Baystate Wing Hospital campus, and would use no utility infrastructure during island-mode operations. The proposed Zone 2 microgrid is based on the design concept for a system that Baystate Wing Hospital has planned for implementation. This system envisions installing new carport-mounted PV arrays and BESS to enable load sharing among the hospital's existing diesel-fueled standby generation and the proposed new solar+storage system. Baystate Wing Hospital hopes to implement the project when National Grid lifts a moratorium it imposed on distributed solar energy development in its Massachusetts territory.

In general, outcomes from the Palmer Microgrid feasibility assessment illustrate that achieving Massachusetts goals for community resiliency, sustainability, and economic development would require continued progress to remove regulatory barriers to innovation and to encourage productive collaboration among utilities and the communities they serve. Additionally, the assessment results support consideration of new standards and policies at both municipal and state levels. Such new policies could include updated planning methodologies and cost-recovery mechanisms to support investments in community energy resiliency.

4.1 Commercial Viability – Customers

Contractor shall describe the commercial terms/relationship between participants in the microgrid project, products expected to be produced by the microgrid and arrangements for sharing of benefits by addressing the following:

a. Identify the number of individuals affected by/associated with critical loads should these loads go unserved (e.g. in a storm event with no microgrid).

- How many people are employed at the project facilities?

The critical facilities identified for microgrid service employ approximately 1,123 people on a full-time equivalent basis.

- How many clients (customers, etc.) are served by those facilities on a daily basis?

The critical facilities serve nearly 2,500 direct clients per day, representing secondary clients numbering in the tens of thousands.

Figure 4.1 itemizes the employee and client metrics provided by each critical facility. Note that these figures exclude other non-critical customers served by the utility's distribution segments in Zone 1.

Fig. 4.1: Palmer Microgrid Facilities – Individuals Affected

Zone	Facility	Employees (FTE)	Clients* Served/ Day
1	Palmer Town Hall	23	110
1	Palmer Police Station	45	75
1	Palmer High School	32	500
1	Old Mill Pond School	363	1,063
1	Palmer Foundry	75	50
2	Baystate Wing Hospital	585	686
	TOTAL	**1,123**	**2,484**

**In addition to daily clients served at Palmer Police Station, the facility's employees support law enforcement and first response for Palmer's population of 12,000. The clients at Palmer High School and Old Mill Pond School are students. At Baystate Wing Hospital, the clients are patients (inpatient and out-patient). Palmer Foundry's clients include large corporations as part of a supply chain serving customers numbering in the many thousands.*

b. Identify any direct/paid services generated by microgrid operation, such as ancillary services, or indirect benefits, such as improved operation, to the utility or ISO New England.

The microgrid and the resources dedicated to serving it would be configured to provide distribution ancillary services. DERs proposed for separate development by Thorndike Energy would be designed and operated to reduce onsite customer energy costs, and may be dispatched to support ancillary services and demand response (DR) capacity. In particular, flywheel storage systems planned by Thorndike Energy could provide reactive power supplies.

Additionally, either microgrid zone could, in principle, be operated as a DR resource in the same way the utility would manage any similarly sized interruptible load. The utility could signal for the microgrid to disconnect and enter island-mode operations, treating the microgrid as a single dispatchable load. However, doing so may cause localized disruption that in most situations likely would outweigh the benefits of DR via microgrid islanding.

c. Identify each of the microgrid's customers expected to purchase services from the microgrid.

Zone 1: Critical-load customers include the Town of Palmer (Town Hall, Police Station, Palmer High School, and Old Mill Pond School) and the Palmer Foundry. Additionally, the distribution segments used to form the microgrid also serve several dozen residential and small commercial customers.

Zone 2: Baystate Wing Hospital is the sole customer.

d. Identify other microgrid stakeholders; what customers will be indirectly affected (positively or negatively) by the microgrid?

As noted, in addition to the identified critical load customers and their daily users, the distribution segments used to form the microgrid also serve several dozen residential and small commercial facilities, whose occupants would benefit from assured electricity service during utility outages originating outside the microgrid boundary.

More broadly, a community microgrid in Palmer would strengthen the resiliency of an important regional corridor and population center. Through the Massachusetts Turnpike and Routes 20, 32, and 181, Palmer is centrally located to provide regional services to Worcester, Springfield, and more than 110,000 people living within 10 miles of Palmer. Improving energy resiliency for critical services provided in both Zones 1 and 2 would positively affect those customers by minimizing the effects of long-duration utility outages, improving public health and safety, and accelerating recovery in the aftermath of disruptive events such as hurricanes and winter storms affecting western Massachusetts.

Finally, the project would support the Town of Palmer in its commitment to resiliency, sustainability, and renewable energy investment, as part of the Town's efforts to attract and retain businesses and employers. The project supports development of renewable resources that would offset fossil-fueled electricity consumption and contribute to local experience and expertise with clean and resilient energy systems.

e. Describe the relationship between the microgrid owner and the purchaser of the power. Indicate which party/customers will purchase electricity during normal operation and during islanded operation. If these entities are different, describe why.

In the proposed Zone 1 model, the utility would own and operate distribution infrastructure used to form the microgrid, and would contract with Thorndike Energy to provide generation and storage capacity and energy to serve microgrid customer loads during island-mode operations.

In Zone 2, Baystate Wing Hospital would own and operate all microgrid infrastructure, and would contract with a third party to build, own, and operate the required onsite DERs and microgrid controls. The hospital would pay for DER costs through a power purchase agreement (PPA) with the third-party owner.

During normal grid-connected operations, the microgrid customers in both Zones 1 and 2 would continue purchasing electricity supplies from the utility. In Zone 1, outputs from Thorndike Energy's generation and storage systems[6] would be purchased by the company's onsite industrial customers, bid into the ISO New England market, or both. In Zone 2, new PV and BESS are proposed for installation and operation behind the meter to substantially reduce the hospital's utility demand and consumption during normal operations.

f. What are the planned or executed contractual agreements with critical and non-critical load purchasers?

New contractual arrangements may include the following:

Thorndike Energy-National Grid Agreement: Under the proposed model, National Grid would be expected to enter one or more agreements with Thorndike Energy to purchase capacity and energy supplies from its existing and planned generation and storage systems.

Utility Tariff: In principle, a new utility tariff for Zone 1 microgrid customers could be developed to allow National Grid to recover reasonable and necessary capital and operating costs associated with required upgrades to utility-owned infrastructure, and to pass through to customers the costs of purchasing capacity and energy from Thorndike Energy. However, project stakeholders including the Town of Palmer regard resiliency upgrades on the utility system as being equivalent to other utility investments in system reliability and safety. Accordingly, the Town has indicated that it would not support a project that required the Town or other customers in the community to pay any additional costs for resilient service. As a result, a special microgrid tariff was deemed infeasible for the project, and all incremental costs would have to be covered by the utility using general rate-base funds and external financing.

Third-Party DER PPA: In Zone 2, Baystate Wing Hospital would enter power purchase agreement (PPA) with the third-party owner of the proposed onsite DERs and controls. The hospital would continue to finance operations and maintenance of its onsite electric infrastructure and standby generation from its operating budget.

g. How does the Project Team plan to solicit and register customers (i.e. purchasers of electricity) to be part of their project?

In Zone 1, the assessed project was designed primarily to serve two utility customers – the Town of Palmer and Palmer Foundry.[7] It also would include sufficient firm capacity to serve all other loads connected to utility distribution segments that would be isolated to serve the Town and the foundry. All are current customers of the utility, and so no onboarding would be necessary. The utility could, in principle, offer service-level guarantees with additional fees to help recover the costs of assuring resilient service.

The assessed Zone 1 design could readily be expanded to support additional commercial customers located immediately across the Massachusetts Turnpike from the Palmer Foundry, and served by the

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[6] Thorndike Energy's DERs are proposed for development and financing separately from the microgrid, but their outputs would be available to support microgrid loads during island-mode operations.

[7] Thorndike Mill's prospective industrial customers would be engaged separately by the site owner, and contracted to purchase energy services as part of lease agreements. Thorndike Mill customers were not included among critical loads for the study, because those customers were prospective at the current phase of study, and so load and energy cost information was not available. To the degree Thorndike Mill customers require resilient energy service, Thorndike Energy would provide capacity not reserved for serving the microgrid's other customers.

same utility feeder as the Palmer Foundry. The utility would be expected to engage any additional customers and arrange firm capacity to serve their loads, prospectively with resources from Thorndike Energy or other third-party owners.

As noted, Thorndike Energy's onsite customers would be acquired through the process of development and leasing at the Thorndike Mill industrial site.

In Zone 2, the proposed system design and business model would not support serving additional customers. Consequently, additional customer onboarding is not contemplated for Zone 2. Notably, however, control and communications systems for the proposed microgrid could readily be configured and extended to include additional DERs, including generation, storage, and load controls, enabling the system to be expanded to support changing hospital requirements in the future.

h. What other energy commodities (such as steam, hot water, chilled water) will the microgrid provide to customers?

Project objectives are defined address electric loads only. However, Thorndike Energy separately would provide process heat to a variety of prospective onsite industrial customers at Thorndike Mill.

3.6 Task 4.2 – Commercial Viability - Value Proposition

Contractor shall describe the value the microgrid is expected to provide directly to its participants, to the community at large, to the local electric distribution utility and to Massachusetts by addressing no less than the following questions:
a. What benefits and costs will the community realize by the construction and operation of this project?

Zones 1 and 2 generally are very different approaches and so they are characterized by different benefits and costs. Shared characteristics are assessed separately from benefits and costs that are distinct to each zone.

Benefits (Both Zones):

Resiliency, higher operating uptime, improved public safety: The proposed microgrid would reduce disruption to critical public services and economic assets from short-duration outages, and would increase the operability of those services during long-duration outage events.

Local renewable energy production value: The proposed microgrid would support the addition of substantial new PV generation capacity, and these new renewable assets would be integrated into a resilient energy system with BESS capacity. Moreover, the BESS capacity could be expanded in the future to extract greater value from renewable resources by increasing potential battery autonomy and storing more energy for use during high-demand periods.

Reduced carbon footprint: PV generation proposed to serve the microgrid can be expected to displace utility-supplied power responsible for approximately 2.3 million kg (2,535 tons) of CO_2e per year, or approximately 50,700 tons over the 20-year lifetime of the proposed PV assets.

Reduced diesel consumption: Systems proposed for both zones would reduce diesel consumption and extend time to refueling. In Zone 1, the system would serve to defer startup of diesel-fueled standby generation during utility outages by dispatching PV and cleaner gas-fired generation. In Zone 2, it would reduce diesel consumption by enabling the use of solar energy during outages.

Greater energy cost stability: Proposed DERs – especially PV but also to some degree the proposed CHP systems – would displace consumption of utility-delivered electricity that is subject to periodic price changes (usually upward).

Benefits (Zone 1 only):

Ancillary services and resources: The proposed system would help support Thorndike Energy's investment in local energy storage capacity that would provide substantial ancillary services to the utility and ISO New England, including reactive power and demand response capabilities.

Utility distribution microgrid R&D: The proposed system would provide the utility with experience designing, deploying, and operating a utility distribution microgrid that relies on customer DERs to energize local microgrid segments during a regional outage.

Utility-community collaboration: Developing the proposed system would provide the utility with an opportunity to collaborate with the Town of Palmer and other local stakeholders to improve energy resiliency for critical community facilities, and to maximize the value of local solar generation.

Economic development: The project would support development of advanced resilient energy services to attract and retain a diverse range of high-value employers in the community.

Benefits (Zone 2 only):

Reduced customer demand charges with DERs: The PV and BESS capacity specified for the microgrid would substantially reduce Baystate Wing Hospital's demand for utility-supplied energy, and would reduce customer demand charges by reducing peak utility power consumption during daytime periods.

Costs (Both zones):

DER services and utility bill offsets: In Zone 1, Thorndike Energy will incur capital costs and operating costs associated with the Thorndike Mill onsite DERs (proposed for separate financing), and onsite customers will incur costs for purchasing services from those DERs. In Zone 2, the hospital would incur costs for energy capacity and supplies provided by the third-party DER owner, with corresponding utility bill offsets expected to yield net energy cost savings.

Costs (Zone 1 only):

Utility infrastructure investment costs: If the utility were to develop the project, it would incur costs for switching upgrades and controls to enable forming a safe power island on the microgrid distribution segments, as well as ongoing operations and maintenance (O&M) costs.

Utility rate recovery of incremental microgrid costs: To the degree the utility included investments for the proposed system in its rate base, the utility would recover costs through slightly higher monthly customer bills. Any grants or external funding to support grid modernization would first be applied to reduce net costs for general rate recovery.

Costs (Zone 2 only):

Project development and management costs: The hospital may incur costs for project development and management, in the form of labor hours for customer scope associated with microgrid project development. Any third-party or utility development and management costs would be included in other capital costs.

b. How would installing this microgrid benefit the utility (e.g. reduce congestion or defer upgrades)? What costs would the utility incur as a result of this project?

The microgrid would directly benefit the utility in at least four ways. It would:

- Provide direct experience with the design and implementation of a resilient microgrid system within the utility distribution system;

- Provide direct experience in collaborating with municipal and private customers to optimize renewable DERs to support local resiliency;
- Support utility operational and investment goals regarding renewable resources, grid modernization, and environmental and climate mitigation; and
- Support the addition of BtM energy storage and load-management functionality to reduce the potential impact of new PV generation on the distribution system in the project area.

The utility would incur costs for upgrading switches to enable remote controllability for isolating the microgrid segments from the utility distribution network, and it would incur costs for securing firm power capacity and supplies to energize the microgrid during a regional outage.

c. Describe the proposed business model for this project. Include an analysis of strengths, weaknesses, opportunities and threats (SWOT) for the proposed business model.

The proposed project relies on a hybrid business model that combines utility financing and ownership of microgrid infrastructure and controls with customer (or non-utility third-party) ownership and financing of renewable generation, BESS, and BEMS. Implementation of the Palmer Microgrid project using the proposed model would be affected by the following SWOT factors:

Strengths:

1. The model would facilitate customer investments in local PV and energy storage assets.
2. The model is comparatively simple and would avoid complex procurement and contracting structures.
3. The proposed Zone 1 system demonstrates how existing utility distribution systems can be reconfigured to use local DERs for microgrid islanding.
4. The proposed Zone 2 system demonstrates a replicable approach for small campuses like hospitals to integrate solar energy and storage assets in a microgrid with existing fossil-fueled standby generation.

Weaknesses:

1. The utility has indicated it will not support development of a community microgrid using its infrastructure in the project area.
2. To the degree microgrid customers would bear substantial costs for utility distribution system upgrades, the project partners would decline to support the project. Grants or general rate-base financing for utility distribution system resiliency upgrades would address this weakness.
3. Current regulatory policies in Massachusetts lack clarity on energy storage and grid modernization, creating uncertainties for initiatives like the proposed microgrid that could support State objectives. Most notably, depending on how they are to be financed, owned, or used, infrastructure upgrades might not qualify for state incentives for energy storage or grid modernization.

Opportunities:

1. Customer investments in PV would produce benefits in terms of both economics and resiliency, as opposed to non-microgrid PV, which is inoperable during a utility outage and provides no resiliency benefits.

2. The proposed project gives the utility an opportunity to collaborate with the Town of Palmer and local customers to support long-range planning objectives and goals for energy resiliency, sustainability, and economic development, and to optimize the local use of renewable DERs on the utility's distribution system.
3. The proposed Zone 1 system would create modernized resilient clean energy systems to attract and retain employers in the project area.
4. The proposed Zone 2 project provides an opportunity for Baystate Wing Hospital to demonstrate its vision and leadership in development of resilient and sustainable energy systems for critical public safety.
5. Implementing the proposed project would help inform the master planning efforts of the Town of Palmer as it seeks to guide land use and development decisions in ways that are consistent with the Town's goals for resiliency and sustainability.

Threats:

1. An ongoing utility freeze on new solar PV interconnections in the project area creates an ongoing uncertainty about potential for developing resilient renewable energy systems. The utility recently proposed $62 million in transmission and distribution system upgrades in the Palmer area to better accommodate new solar DER proposals.[8]
2. To the degree state regulation and utility planning and cost-recovery policies disregard or de-prioritize state or community goals for resiliency and climate adaptation, utilities and DER developers will continue investing in systems that are not optimized to meet local requirements. These sub-optimal investments assets impede progress toward resilience and sustainability by limiting customers' options and encouraging duplicative investments in standby systems that are inefficient and unsustainable.

d. Are there any characteristics of the site or technology (including, but not limited to, generation, storage, controls, information technology (IT), automated metering infrastructure (AMI), other) that make this project unique?

The system is intended to rely on commercially available and warranted technologies integrated in standard configurations.

One novel aspect of the proposed Zone 1 system involves forming a utility distribution microgrid on segments of two feeders (523L4 and 503L1), both served by the same substation. The proposed approach includes control flexibility, enabling microgrid formation on segments of the 523L4 feeder but not the 503L1 feeder if an outage affects the former and not the latter.

e. What makes this project replicable? Scalable?

The proposed Zone 1 system demonstrates an approach that is scalable both in terms of technical systems and customers. Zone 2 demonstrates scalability for technical systems and loads, but not customers.

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[8] *Central and Western MA Cluster Study and ASO Study Update,* National Grid, Dec. 5, 2019 https://ngus.force.com/servlet/servlet.FileDownload?file=0150W00000ETOty

Scalability in the Zone 1 area is limited by the configuration of the existing utility distribution system as well as by the proximity of critical loads requiring resilient electric service. However, the basic Zone 1 approach of installing remote switching capabilities at key points in the distribution system is inherently replicable and scalable, to the extent system design and configuration supports it. Additionally, with appropriate dispatchable DER capacity and distribution switching capabilities, the utility could readily expand the microgrid boundary to include additional customer facilities.

The Zone 2 approach of isolating a single-owner campus and forming a safe intentional island using onsite energy resources and controls is readily replicable and scalable. The Zone 2 business model is designed to serve the host customer only. A different ownership approach and business model would be required for a system intended to serve multiple customers.

f. What is the purpose and need for this project? Why is reliability/resiliency particularly important for this location? What types of disruptive phenomena (weather, other) will the microgrid be designed for? Describe how the microgrid can remain resilient to disruption caused by such phenomena and for what duration of time.

The microgrid investments proposed in Zones 1 and 2 would strengthen the resiliency of energy services for critical community facilities in an important regional population center, transportation corridor, and commercial and industrial development area. Improving energy resiliency for critical services provided in both Zones 1 and 2 would improve community resiliency by minimizing the effects of long-duration utility outages, improving public health and safety, and accelerating recovery in the aftermath of disruptive events such as hurricanes and winter storms affecting power transmission systems serving western Massachusetts.

The microgrid is designed to provide sustainable and resilient energy service for critical loads during long-duration outage scenarios, involving such events as hurricanes, derechos, and severe winter weather that can damage both local and regional grid infrastructure.

In Zone 1, the proposed system would support resiliency against long-duration outages by utilizing PV, hydro, energy storage, and gas-fired CHP resources to energize distribution segments that serve critical facility loads. The proposed system includes sufficient dispatchable generation resources (storage and CHP) to support microgrid islanding indefinitely. The Zone 1 system design is intended to improve resiliency against outages caused by faults outside the microgrid boundary – primarily regional outages affecting high-voltage transmission systems. The project team considered alternatives to improve resiliency against local faults (*e.g.,* installing new underground infrastructure, including about two miles of underground cable), and determined the capital costs would be excessive for a project of the proposed scope. Additionally, the proposed islanding control scheme would necessitate black starting the microgrid segments, making the approach less useful for addressing brief service interruptions caused by local faults.

In Zone 2, the proposed system would support hospital loads in island mode for both brief and extended periods of time by dispatching onsite dispatchable resources (diesel and BESS), and integrating PV outputs to reduce diesel consumption and extend time to refueling the hospital's 4,000 gallons of onsite diesel storage. The Zone 2 system design would protect Baystate Wing Hospital against both local outages affecting utility distribution lines as well as regional outages affecting transmission systems.

Both systems would be designed for resiliency against localized flash flooding events of the kind that occasionally affect the project area. In Zone 1, the utility's pad-mounted switching systems are vulnerable to extreme flash floods and sustained flooding. The utility could improve resiliency against flooding by replacing these systems with submersible switches at a substantial added cost. However, Thorndike Energy's generation and storage systems are proposed for siting in low-lying areas near the

Ware River, and so DERs required to energize the microgrid may be unavailable during extreme flooding conditions.

g. Describe the project's overall value proposition to each of its identified customers and stakeholders (including, but not limited to, the electricity purchaser, the community, the utility, the suppliers and partners, and Massachusetts).

Both microgrid zones would produce value for customers and the community in multiple ways:

- Increasing public safety by improving energy resiliency for critical facilities in the Palmer area.
- Enabling utilization of local renewable and gas-fired CHP generation during utility outages.
- Reducing diesel fuel consumption and related emissions.

Developing the proposed microgrid would support local and State goals for sustainable energy development and community resiliency improvements.

The project would provide the utility with direct experience implementing an advanced microgrid in its western Massachusetts distribution system, and developing business processes to facilitate collaboration with municipal and private customers to optimize use of DERs to support local resiliency.

In addition to enhancing the resiliency of critical services in an important community, the project would benefit the Commonwealth by advancing goals for renewable energy integration and grid modernization. The project supports grid modernization with improvements in resiliency and reliability. Local experience executing these improvements would support the Town of Palmer's economic development objectives.

h. What added revenue streams, savings, and/or costs will this microgrid create for the purchaser of its power?

In Zone 1, Thorndike Energy would incur capital costs and operating costs associated with installation and O&M of its proposed DERs. The project also would generate revenues for Thorndike Energy through sales of resilient energy capacity and supplies to the utility.[9]

If the utility were to proceed with the Zone 1 upgrades as a rate-base investment, then utility customers would incur slightly higher monthly billed costs, to recover the utility's costs for resilient energy capacity and supplies, and for installing and operating new infrastructure not financed by other sources.

In Zone 2, Baystate Wing Hospital would incur capital and operating costs associated with all microgrid systems.

Customers in both microgrid zones would save costs by avoiding lost productivity during utility outages. Additionally, in Zone 2 the hospital would save annual electricity costs by offsetting utility purchases with onsite solar PV production and storage. The hospital also would reduce fossil fuel consumption and costs by integrating solar energy to displace diesel consumption during utility outages.

i. How does the proposed project promote state policy objectives (e.g. RPS, Global Warming Solutions Act)?

The proposed project would promote state policy objectives in several ways:

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[9] Alternatively, Thorndike Energy could contract directly with customers to provide resilient energy capacity and energy supplies, but this approach may be impractical given the utility's requirement that all customers in the microgrid area would have to be served during a utility outage.

- Facilitating development and optimizing integration of approximately 2,700 kW of new solar PV capacity and 2,500 kW of energy storage capacity;
- Supporting generation of solar electricity that displaces grid power responsible for producing 2.3 million kg (2,535 tons) of CO_2e per year, or approximately 50,700 tons over the lifetime of the proposed PV assets; and
- Demonstrating community energy resiliency solutions for potential replication by other Massachusetts communities.

j. How would this project promote new technology or technologies developed or manufactured by Massachusetts-based companies (including, but not limited to, generation, storage, controls, IT, AMI, other)? What are they?

Products referenced as part of Task 3 system conceptual design and modeling are intended as examples of commercially available technologies, and not as pre-approved equipment for specification. Advanced engineering design and procurement scope for the proposed project may include preferences for Massachusetts-based vendors.

3.7 Task 4.3 – Commercial Viability - Project Team

Address the following in describing the structure of the Project Team and the roles, strengths and resources of its members and other necessary partners:

a. Describe the current status and approach to securing support from local partners such as municipal government, community groups, residents, and other relevant stakeholders.

Utility: National Grid provided data and other inputs to support the study process. The nature of the Zone 1 microgrid proposal requires the utility to take a leading role in development. Accordingly, the utility's role would include engaging other members of the project team. During Task 3 assessment, however, the utility indicated it would not support a community microgrid using its distribution system in the project area.

For Zone 2, Baystate Wing Hospital would be expected to engage the utility to execute an interconnection agreement.

Municipal Government: The Town of Palmer has supported the project throughout the study process. Outcomes of the current feasibility assessment would influence the Town's interest in pursuing the Zone 1 project through community energy and sustainability planning and development processes. The Town of Palmer maintains ongoing engagement with National Grid, through which it would support a process to develop a workable framework for collaboration.

Baystate Wing Hospital: The sole Zone 2 customer expressed intent to pursue capital improvements at the hospital substantially similar to the proposed project. These improvements are delayed pending results from the utility's study of transmission and distribution system capacity to accommodate new solar development in its Massachusetts service territory.

DER Owners: If the utility decided to proceed with the Zone 1 project as proposed, then the utility would engage local owners of DERs – most notably Thorndike Energy, but also Palmer Foundry and other customers that own DERs – to enter agreements through which the utility would secure the firm and variable generation, storage, and demand response capacity and energy needed to serve microgrid-connected customer loads.

Community Groups and Residents: The Town of Palmer maintains ongoing engagement with local community groups and individuals, through which it would sustain interest and support for the proposed project. If the project were to proceed, additional community engagement efforts likely would include a public outreach campaign and informational meetings.

b. What role will each team member (including, but not limited to, applicant, microgrid owner, contractors, suppliers, partners) play in the development of the project? Construction? Operation?

Applicant: For Zone 1, Thorndike Energy would host new DERs including PV, CHP, and energy storage systems, alongside its existing hydro systems. In Zone 2, Baystate Wing Hospital would be the sponsor and sole customer, and would host DERs including carport-mounted PV and BESS.

Utility: In Zone 1, the utility would be the microgrid developer and owner. The utility would procure, install, own, operate, and maintain the microgrid's switching and distribution infrastructure and control systems.

Contractors: Various contractors would be involved in the project, including consultants to facilitate collaboration among microgrid stakeholders; and microgrid contractors to support system engineering, procurement, civil engineering, system installation, configuration and integration, and O&M.

Suppliers: Suppliers of microgrid technologies and services would be selected during project procurement phases, consistent with applicable Massachusetts public procurement law.

Additional team members may include providers of legal, regulatory, and financial services to support project structuring, permitting, and financing.

c. Are public/private partnerships used in this project? If yes, describe this relationship and why it will benefit the project.

The project does not envision formalizing a P3 corporate entity. However, public and private entities would collaborate, as described above, to finalize system design, operational plans, and financial arrangements that support their organizational objectives for participating in the project.

d. For identified Project Team members (including, but not limited to, applicant, microgrid owner, contractors, suppliers, partners), what are their qualifications and performance records?

Applicant: The Town of Palmer is the municipal government of Palmer, Massachusetts, which is comprised of four separate villages – Depot Village, Thorndike, Three Rivers, and Bondsville. The Town government delivers public services for a community of approximately 12,000 people, including departments managing such functions as police, public works, schools, emergency management, and natural resources conservation. The Town of Palmer has initiated and executed sustainable energy projects, including solar PV plants on brownfield redevelopment sites.

Owner: The microgrid would utilize distribution infrastructure owned by National Grid, which serves more than 3 million customers in New England. National Grid has collaborated with the Town of Palmer and other Massachusetts municipalities on locally beneficial projects, including siting and interconnection of several solar power arrays in the Palmer area.

Contractors and Suppliers: In Zone 1, no contractors or suppliers have been identified for project implementation. All contractors and suppliers would be selected through compliant procurement processes to ensure they bring exemplary qualifications and performance records. For Zone 2, Baystate Wing Hospital selected a supplier to install the proposed PV and BESS, but the project is delayed pending the outcome of National Grid's assessments of T&D capacity in its Massachusetts territory. The hospital declined to reveal the name of the supplier or to provide detailed information about the proposed system or agreement.

Partners: The feasibility assessment was led by Microgrid Institute with subcontractor S&C Electric. Prospective participation of each in future project progress has not been established and would be subject to applicable procurement processes and compliance obligations.

e. Are any of the contractors and suppliers identified? If yes, who are they, what services will each provide and what is the relationship to the applicant? If no, what types of team members will be required and what is the proposed approach to selecting and contracting?

For Zone 1, no contractors or suppliers have been identified for potential project implementation. For Zone 2, Baystate Health Systems declined to reveal the name of the supplier it selected to install its proposed solar+storage system. If either or both zones proceed with development, team members would include:

- Consultants to facilitate project development, procurement, and collaboration among microgrid stakeholders;
- Technical contractors to support system engineering, civil engineering, installation, configuration, integration, and O&M;
- Suppliers of microgrid technologies and services, including PV, BESS, standby generation, distributing switching, and microgrid controls; and
- Providers of legal, regulatory, and financial services to support project structuring, permitting, and financing.

All contractors and suppliers would be selected through compliant procurement processes to ensure they bring exemplary qualifications and performance records.

f. Are any of the project financiers or investors identified? If yes, who are they and what is their relationship to the applicant? If no, what is the proposed approach to securing proposed financing? Will other members of the Project Team contribute any financial resources?

Financing partners have not been identified for either proposed project zone.

Financing would be required for three primary asset groups, each of which may require more than one type of financing partner or structure.

1) *PV systems:* In each zone, investments would be treated like any other onsite renewable energy asset, likely including tax-benefit financing for generating assets to be owned and operated by third-party solar developers, with costs recovered through PPAs.

All of the PV systems in both zones would be integrated behind customer meters to directly meet electricity capacity and supply requirements. In Zone 1, Thorndike Energy's proposed PV assets would be financed primarily on the basis of cost recovery from tenants at the Thorndike Mill industrial redevelopment property, and potentially wholesale customers in the ISO New England market. In Zone 2, the solar investments would be financed by a third-party developer with costs recovered through a PPA with the hospital.

2) *Utility Infrastructure:* The Zone 1 system would require upgraded utility switching and communications capabilities. If the utility were to proceed with the project, it would be expected to finance, own, and operate the switching infrastructure and controls, and it would arrange financing

via the channels available to investor owned utilities in Massachusetts. Likely funding sources include:

  a) Utility capital expenditures to be recovered through general rates, with approval from the Massachusetts DPU;
  b) Grants and incentive financing for grid modernization and technology demonstration investments from the State of Massachusetts; and
  c) Utility revenue bonds for a portfolio of utility system investments (to achieve a better scale proposition for raising capital).

The Zone 2 system would not require any utility infrastructure investments, except as required for interconnection safety and protection systems identified during project engineering and permitting phases.

3) *Dispatchable DERs and Controls:* Zone 1 would be energized by a group of energy storage systems, CHP systems, and PV systems proposed for development on the Thorndike Mill site, as well as existing hydro systems at the site. Thorndike Energy would finance its capital and operating costs on the basis of energy service agreements with Thorndike Mill industrial tenants, with excess output exported for sale in the ISO New England market.

In Zone 2, Baystate Wing Hospital would be expected to enter an energy services agreement with a third-party owner of the proposed PV and BESS assets. Project capital and O&M costs likely would be recovered through monthly utility bill offsets.

g. Are there legal and regulatory advisors on the team? If yes, please identify them and describe their qualifications. If no, what is the proposed approach to enlisting support in this subject area?

The feasibility assessment team includes legal and regulatory advisors, most notably Microgrid Institute Counsel Michael Zimmer. Mr. Zimmer is an energy industry attorney with more than 40 years of experience. He has national and international experience in serving energy/utility projects in 35 states and over 20 foreign countries during his legal career. However, he is not admitted to practice in Massachusetts and so his guidance in the project is comprised of general consultative support and not legal advice.

During future project phases, inside and outside counsel would be expected to support customer activities associated with installing onsite renewable generation and executing contracts for microgrid service. Additionally, the Town of Palmer likely would engage counsel to address issues related to procurement of assets and services. Critical roles of counsel include providing guidance on updating regulatory policy to support further needs of the Town and its stakeholders, as well as to resolve legal uncertainties.

Task 5: Information for Cost Benefit Analysis

Develop and provide the information required to support an independent evaluation of project costs and benefits for this stage of analysis.

V. Chapter 5: Information for Cost-Benefit Analysis[10]

5.1 Facility and Customer Description

Describe all facilities that will be served by the microgrid. For each facility, indicate: Rate class to which the facility belongs; Economic sector to which the facility belongs; Whether multiple ratepayers are present at the facility; Whether there will be any financial criteria for prospective customers; Average annual electricity demand (MWh) and peak electricity demand (MW); Percentage of the facility's average demand the microgrid would be designed to support during a major power outage; In the event of a multi-day outage, number of hours per day, on average, the facility would require electricity from the microgrid; Quantified value of resiliency for each facility that would receive electricity from the microgrid during an outage.

As described in Chapter 3, the Palmer Microgrid feasibility assessment focused on two separately islanding zones, each of which would be financed and designed independently to serve different operating objectives.

The proposed Palmer Community Microgrid would include two separate zones, each capable of forming a safe power island to serve critical facilities and commercial customers in the Palmer area. These two zones are different systems, with different resource options and operating objectives, and as a result they involve distinct infrastructure and operational approaches.

Zone 1 would provide resilient electricity services for facilities in locations identified as potentially separate zones in earlier project phases:

A. *Town Hall Cluster:* Palmer Town Hall, Palmer Police Station, Palmer High School, and Old Mill Pond Elementary School;
B. *Thorndike Mill:* Industrial and commercial development properties; and
C. *Palmer Foundry:* Industrial manufacturing site

The Zone 2 system would serve the 74-bed Baystate Wing Hospital campus, including emergency medical and surgical care.

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[10] Chapter 5 information is supplemented by data contained in "Palmer Microgrid Task 5 Cost-Benefit Workbook.xlsx" (Z1 and Z2).

Fig. 5.1-A: Palmer Microgrid Facility and Customer Description

	Palmer Town Hall	Palmer Police Department	Thorndike Mill	Palmer Foundry
Zone	1			
Rate Class	Small commercial			
Economic Sector	City services		Commercial & industrial	
Multiple Ratepayers?	No		No	No*
Financial Criteria	Yes, established in energy service agreement			
Annual Avg. Electricity Consumption (kWh)	67,560	247,160	500,000*	2,823,322
Peak Demand (Annual) (kW)	48	52	300	1,162
Average Demand (kW)	18	20	113	439
% of Avg. Demand Supported by Microgrid	100	100	0 - 100*	100
Avg. Hours/Day of Microgrid Reliance	24	24	24	24
Resiliency Value	Up to 24 hours/day of continued services			

** Figure 5.1 annual consumption represents prospective future load at Thorndike Mill that would be served with onsite resources during blue-sky operations. During outages, future Thorndike Mill tenants would be served by firm capacity established to meet their load requirements.*

Fig. 5.1-B: Palmer Microgrid Facility and Customer Description

	Old Mill Pond School	Palmer High School	Other Non-Critical Customers	Baystate Wing Hospital
Zone	1			2
Rate Class	Commercial	Commercial	Residential, Commercial	Commercial
Economic Sector	School	School	Various	Medical services
Multiple Ratepayers?	No	No	Yes	No
Financial Criteria	Yes – established in microgrid energy service agreement		No – Utility ratepayers	No – sole customer is sponsor
Annual Avg. Electricity Consumption (kWh)	413,200	832,400	NA	4,551,600
Peak Demand (Annual) (kW)	48 kW	52 kW	8,960	3,700 kW
Average Demand (kW)	18 kW	20 kW	3,387	1,410 kW
% of Avg. Demand Supported by Microgrid	100	100	100	100
Avg. Hours/Day of Microgrid Reliance	24	24	24	24
Resiliency Value	24 hours/day of continued critical services w/load management			Reduced consumption of diesel (~9 MMBtu/hr)

New dispatchable resources (ESS or generators) may be integrated into either microgrid zone in future phases of Project expansion, to provide additional resilient capacity and support greater reliance on renewable energy, and in Zone 1 to serve future industrial loads at Thorndike Mill.

5.2 Characterization of Distributed Energy Resources

Describe the DERs the microgrid would incorporate, including for each: Energy/fuel source; Nameplate capacity; Estimated average annual production (MWh) under normal operating conditions; Average daily production (MWh/day) in the event of a major power outage; For fuel-based DER, fuel consumption per MWh generated (MMBtu/MWh); Amount of onsite fuel storage capacity.

The Zone 1 microgrid would rely on solar, energy storage systems, and gas-fired CHP resources to support foreseen daytime loads, with nighttime loads supported by CHP generation. Existing standby generation systems would remain in place, in their current ATS-switched configuration, and would not be integrated into the microgrid.

The Zone 2 microgrid would rely on solar, energy storage systems, and diesel-fired standby generation resources to support foreseen daytime loads, with nighttime loads supported by diesel generation. Existing diesel standby systems would remain in place, with their interconnection and control systems reconfigured to enable energizing the microgrid.

Fig. 5.2-A: DER Operating Characterization – Palmer Microgrid Zone 1

DER	Thorndike Energy ESS	Thorndike Energy CHP	Thorndike Energy PV	Thorndike Energy Hydro	Palmer Foundry
Type / Fuel	Flywheel and VRFB	Natural Gas	Carport and rooftop solar	Small hydro	Rooftop solar
Capacity	2 MW / 8 MWh	10 MW	2,065 kW	1,040 kW	435 kW
Existing or Proposed	Proposed	Proposed	Proposed	Existing	Proposed
Fuel Storage	NA				
Annual Production (MWh/yr)	NA	87,600	2,601	3,365	542
Daily Production (MWh/day)	NA	240	7.12	9.22	1.48
Fuel Consumed (MMBtu/day)	NA	3.475	NA	NA	NA

Fig. 5.2-B: DER Operating Characterization – Palmer Microgrid Zone 2

DER	PV	ESS	Standby Generation
Type / Fuel	Carport PV	NA	Diesel
Capacity	800 kW	500 kW	1,200 kW
Existing or Proposed	Proposed	Proposed	Existing
Fuel Storage	NA		4 days
Annual Production (MWh/yr)	1,015	NA	NA
Daily Production (MWh/day)	2.781	NA	NA
Fuel Consumed / day (MMBtu)	NA	NA	NA

5.3 Capacity Impacts and Ancillary Services

Contractor shall provide estimates of the following services/value the microgrid is expected to provide, as applicable: Impact of the expected provision of peak load support on generating capacity requirements (MW/year); Capacity (MW/year) of demand response that would be available by each facility the microgrid would serve; Associated impact (deferral or avoidance) on transmission capacity requirements (MW/year); Associated impact (deferral or avoidance) on distribution capacity requirements (MW/year); Ancillary services to the local utility (e.g., frequency or real power support, voltage or reactive power support, black start or system restoration support); Estimates of the projected annual energy savings from development of a new CHP system relative to the current heating system and current type of fuel being used by such system; Environmental regulations mandating the purchase of emissions allowances for the microgrid (e.g., due to system size thresholds); Emission rates of the microgrid for CO2, SO2, NOx, and PM (emissions/MWh).

As indicated in Figure 5.4, demand response (DR) and other grid-services capacity technically is constrained by the maximum output capacity of the ESS and inverters, but in practical terms that capacity is reserved to meet the resiliency objectives defined for microgrid operation. As discussed in earlier phases of study, the customers' objectives for the CPDM prioritized increasing customer energy resiliency and reducing fossil fuel consumption during outages. ESS capacity was sized to meet minimal microgrid requirements to support a stable transition to islanded operating mode. Supporting that objective means the currently specified storage would not be sufficient to support substantial DR or other ancillary services.

Fig. 5.4: Palmer Microgrid Capacity Impacts and Ancillary Services

	Zone 1	Zone 2	Notes
Peak load support (MW/yr)	14,065	1,300	Includes PV, ESS, and CHP; excludes diesel standby generation and seasonal hydro
DR Capacity - Technical (MW)	2	0.5	ESS capacity
DR Capacity – Practical (MW)	2	0	
Transmission Capacity Impact (MW)	2	0	
Distribution Capacity Impact (MW)	0	0	
Ancillary Services to the Utility	0	0	
Environmental Regulations	NO_X and CO limits; Streamlined Comprehensive Plan Application for CHP	Emergency gen compliance limits	
Emissions Rates (kg/MWh)	CO_2: 170.2 SO_2: 1 NO_X: 6,315 PM: 0	CO_2: 766.4 SO_2: 1.9 NO_X: 0.42 PM: 0.02	

5.4 Project Costs

Provide the following cost information for the microgrid: Fully installed costs and engineering lifespan of all capital equipment; Initial planning and design costs; Fixed operations and maintenance (O&M) costs ($/year); Variable O&M costs, excluding fuel costs ($/MWh); Maximum amount of time each DER would be able to operate in islanded mode without replenishing its fuel supply; and Amount of fuel the DER consume during this period.

Fig. 5.5: Palmer Microgrid Project Cost

	Zone 1	Zone 2	Notes
Capital Cost (including tax credits)	$567,907	$2,660,907	
Financing Cost	$122,067	$511,000	Estimates based on MassDevelopment bond rate tracker and Bankrate.com
Total Financed Cost	$689,974	$3,171,907	
Project Lifespan	25 years	25 years	
Fixed O&M ($/year)	(negligible)	(negligible)	
Variable O&M ($/MWh)	(negligible)	(negligible)	
Max Operating Time w/o Refueling	NA	109 hours	Zone 1 CHP fueled by natural gas pipeline

Zone 1 estimated costs include microgrid controls and distribution system upgrades only, and are assumed to be financed using 10-year corporate bonds with a 4% interest rate. Proposed new generation and energy storage systems are expected to be financed and owned independently from the microgrid, and so are treated the same as existing rooftop and other PV systems in the microgrid area. Associated DER services costs (to customers) and revenues (to the third-party owner) are factored in the MassCEC benefit-cost analysis workbook (*See Attachment*).

Zone 2 estimates in Figure 5.5 assume PV and ESS costs are financed by a third-party developer using tax incentive financing, with a 5-year term and 7% interest rate. Capital costs account for 20% reduction in PV and ESS costs, assuming 2021 10% federal investment tax credit plus equivalent 10% depreciation benefit. Remaining Zone 2 costs are assumed to be financed using 10-year corporate bonds with a 4% interest rate.

Tax credits may be greater if the project begins construction earlier than 2022, or if current tax credit sunset dates are extended. Additional external financing through grants or state legislative budget allocation also would reduce financing costs.

5.5 Current Costs to Maintain Service During a Power Outage

For each facility the microgrid would serve, describe its current backup generation capabilities, if any.

The Zone 1 microgrid would *not* integrate any of the standby generation currently installed any of the project facilities. Figure 5.6 nonetheless includes estimated costs of operating the standby generators for comparison purposes. The Zone 2 microgrid would integrate the existing 1,200 kW of diesel generation at Baystate Wing Hospital.

In a scenario where neither microgrid assets nor standby generation is available, none of the microgrid facilities could be operated, and would require evacuation and relocation of critical services. In Zone 1, emergency costs if standby power is unavailable are characterized as lost industrial productivity and major disruptions to Town of Palmer business, including public sheltering capacity, first response, law enforcement, 911 emergency dispatch, and management of emergency and recovery operations. Zone 2 emergency costs are based on an estimated evacuation cost of $1,000 per patient at full capacity (74 beds). In Zone 2, costs of standby power are based on diesel-only operation at 70% load for 24 hours.

Fig. 5.6-A: Palmer Microgrid Zone 1 - Costs to Maintain Service during Outages

Standby Generator	Town Hall	Police Station	Palmer High School	Old Mill Pond School	Palmer Foundry
Fuel Type	Diesel	Natural Gas	Diesel	Diesel	Natural Gas
Capacity (kW)	60	280	125	125	200
Fuel Storage	100	NA	550 gals.	10,000 gals.	NA
Avg. Load Factor during Outage (%/nameplate)	70%	70%	70%	70%	70%
Avg. Daily Production during Outage (kWh/day)	1,008	4,704	2,100	2,100	3,360
Fuel Used during Outage (MMBtu/day)	11	58	23	23	41
One-Time Costs	None	None	None	None	None
Daily Non-Fuel Costs	Negligible	Negligible	Negligible	Negligible	Negligible
Emergency Costs w/Standby Power ($/day)	$318	$588	$662	$662	$420
Emergency Costs w/o Standby Power	Disruption to critical public services		Lost sheltering capacity (~2,500); potential damage to facilities		Business losses totaling $50,000 or more

Fig. 5.6-B: Palmer Microgrid Zone 2 - Costs to Maintain Service during Outages

Standby Generator	Wing Hospital
Fuel Type	Dual fuel (Diesel and #2 fuel oil)
Capacity (kW)	1,200
Avg. Load Factor during Outage (%/nameplate)	70%
Avg. Daily Production during Outage (MWh/day)	20.16
Fuel Used during Outage (MMBtu/day)	217
One-Time Costs	None
Daily Non-Fuel Costs	Negligible
Emergency Costs w/Standby Power ($/day)	$5,907
Emergency Costs w/o Standby Power	Evacuation costs up to $74,000; Loss of critical services

5.6 Services Supported by the Microgrid

For critical facilities, including those that provide fire, emergency medical, hospital, police, wastewater, or water services, estimate the population serviced by each facility and describe how a power outage would impact each facility's ability to provide services. If possible, estimate a percentage loss in the facility's ability to serve its population during a power outage, relative to normal operations (e.g., 20% service loss during a power outage), both when the facility is operating on backup power and when backup power is not available.

Town of Palmer critical facilities in Zones 1 and 2 provide services that are accessible to more than 110,000 people living within 10 miles of Palmer.

Fig. 5.7: Services Supported by the Microgrid

	Zone 1	Zone 2
Population Served	110,000	110,000
Service Lost during Outage w/Standby Power	50%	0%
Service Lost during Outage w/o Standby Power	100%	100%

-END REPORT-