

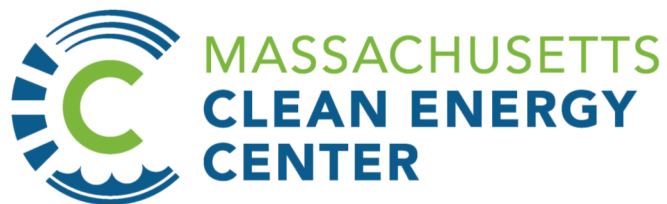
Microgrids – Benefits, Models, Barriers and Suggested Policy Initiatives for the Commonwealth of Massachusetts



Prepared by



Supported by



February 3, 2014

Copyright © 2014, KEMA, Inc.

This document, and the information contained herein, is the exclusive, confidential and proprietary property of KEMA, Inc. and is protected under the trade secret and copyright laws of the United States and other international laws, treaties and conventions. No part of this work may be disclosed to any third party or used, reproduced or transmitted in any form or by any means, electronic or mechanical, including photocopying and recording, or by any information storage or retrieval system, without first receiving the express written permission of KEMA, Inc. Except as otherwise noted, all trademarks appearing herein are proprietary to KEMA, Inc.

Table of Contents

1.	Executive Summary.....	1-1
2.	Introduction	2-1
3.	Microgrids	3-1
3.1	What is a macrogrid, a microgrid and how do they work together?.....	3-1
3.2	Electricity generation and storage	3-2
3.3	Isolation from the macrogrid.....	3-3
3.4	How is a district energy system different from a microgrid?.....	3-5
4.	Benefits of DER and microgrid systems	4-1
4.1	What are the separable benefits of DERs and microgrids?.....	4-1
4.2	Improved reliability	4-4
5.	What are other states and countries doing about microgrids?	5-6
6.	Business models that will enable microgrids	6-1
6.1	Distribution company microgrid	6-1
6.1.1	Distribution company microgrid – ownership and participants	6-1
6.1.2	Distribution company microgrid – benefits	6-2
6.1.3	Distribution company microgrid – complexity, challenges, regulatory suggestions ..	6-2
6.1.4	Distribution company ownership example - SDG&E Borrego Springs, CA.....	6-3
6.2	Single-user microgrid.....	6-3
6.2.1	Single-user microgrid – ownership and participants.....	6-3
6.2.2	Single-user microgrid – benefits.....	6-3
6.2.3	Single-user microgrid – complexity, challenges and regulatory suggestions	6-4
6.2.4	Single-user example – The Santa Rita Jail Microgrid, Dublin, CA.....	6-5
6.3	Hybrid microgrid	6-5
6.3.1	Hybrid microgrid – ownership and participants	6-5
6.3.2	Hybrid Microgrid – benefits	6-6
6.3.3	Hybrid microgrid – complexity, challenges and regulatory suggestions	6-6
6.4	Multi-user (non-utility) microgrid	6-7
6.4.1	Multi-user microgrid – ownership and participants.....	6-7
6.4.2	Multi-user microgrid – benefits.....	6-7
6.4.3	Multi-user – complexity and challenges.....	6-7
6.4.4	Example of a Multi-user Microgrid – Burrstone Energy Center, Utica, NY.....	6-9
6.5	Section conclusion	6-9
7.	Development costs and operational challenges of microgrids.....	7-1
8.	Smart grid technologies that enhance microgrid operation	8-1
9.	Policy and regulatory issues	9-1
9.1	Climate policy: adaptation and mitigation.....	9-1
9.2	Regulatory issues affecting distributed energy resources.....	9-2
9.3	The utility franchise	9-2
9.4	Regulation of non-utility microgrid owners.....	9-7

Table of Contents

10. Recommendations	10-1
10.1 The intersection of Commonwealth interests and microgrid development	10-1
10.1.1 Emergency preparedness	10-1
10.1.2 Smart grid planning and deployment	10-3
10.1.3 Massachusetts GHG goals and microgrids	10-3
10.2 Policy and regulatory recommendations	10-4
10.2.1 Issue a Microgrid Challenge	10-4
10.2.2 Build a foundation for microgrids with low carbon DER	10-6
10.2.3 Target clean energy and energy efficiency incentives to include microgrids	10-6
10.3 Recommendations for the longer term	10-7
10.3.1 Energy Reliability Districts	10-7
10.3.2 Commercial Property Assessed Clean Energy Financing for Microgrids	10-8
11. Conclusion	11-1
12. Bibliography	12-1
A. Appendices	A-1
A.1 Microgrid Activity in the U.S. and Europe	A-1
A.2 Microgrid Report Stakeholder Discussion Participants	A-9

List of Exhibits

Table 4-1: Distributed Energy Resource Benefits versus Microgrid Benefits	4-2
Table 7-1: Range of Costs for Microgrid Components	7-3
Table 10-1: Categories for Critical for Emergency Preparedness	10-2
Table A-1: First Phase Microgrid Projects Funded in Connecticut	A-4
Figure 3-1: Sample Graphic of Transmission and Distribution Grid	3-1
Figure 8-1: Massachusetts Grid Modernization Taxonomy	8-1

Table of Contents

Table of Acronyms

AMI- Advanced Metering Infrastructure
BMS - Building Management System
CHP – Combined Heat and Power
DER – Distributed Energy Resources
DG – Distributed Generation
DMG – Dynamic Microgrid
DR – Demand Response
EMS – Energy Management System
GHG – Greenhouse Gases
MA DOER – Massachusetts Department of Energy Resources
MA DPU – Massachusetts Department of Public Utilities
PCC- Point of Common Coupling
PPA – Power Purchase Agreement
SCADA – Supervisory Control and Data Acquisition
TOU – Time of Use

1. Executive Summary

The Massachusetts Clean Energy Center (MassCEC) sponsored this study to better understand the opportunities to promote and support the development of microgrids. A secondary goal was to coordinate with the Massachusetts' Department of Public Utilities Grid Modernization Proceedings in order to synchronize any potential technological, financial, and regulatory changes to the existing distribution grid with strategies that would enable the deployment of microgrids. Because of the cross-cutting nature of the topic, recommendations on microgrids will be of interest to and are directed at many state agencies.

The study team, consisting of DNV KEMA Energy & Sustainability and the Peregrine Energy Group, began the effort by establishing a clear definition of what a microgrid is and isn't. Because microgrids are a popular topic, it was important to have a clear understanding of what a microgrid is, versus some popular misconceptions. For the purposes of this report, a microgrid is defined as:

A power distribution network comprising multiple electric loads and distributed energy resources, characterized by all of the following: a) The ability to operate independently or in conjunction with a macrogrid; b) One or more points of common coupling (PCC's) to the macrogrid; c) The ability to operate all distributed energy resources (DER), including load and energy storage components, in a controlled and coordinated fashion, either while connected to the macrogrid or operating independently. d) The ability to interact with the macrogrid in real time, and thereby optimize system performance and operational savings.

The report focuses on the benefits of microgrids and articulates the value of microgrids, as opposed to stand-alone distributed energy resources, whose operations are not necessarily coordinated. We identified the primary benefits as: *the ability to economically provide electricity to critical loads within the microgrid, and to improve power quality, flexibility and reliability by integrating and optimizing various sources of energy.* Therefore, microgrids represent coordinated control of DERs to maximize economics, reliability and clean energy (if feasible), and to stabilize electric loads and generation while operating independently of the macrogrid.

As an emerging field that has coincided with the development of distributed generation and advances in controls and communication systems, this report provides information on the wide variety of activities occurring in the United States and European countries, including activities to pilot microgrids in developing markets, while evaluating their various advantages. To address potential conflicts with traditional distribution utility business models, this report examined four microgrid ownership/business model concepts, some of which are currently in use or are being piloted.

Massachusetts, which is now in the midst of updating its distribution grid network, preparing for climate change and advancing the deployment of clean and renewable energy systems, is well-positioned to take advantage of what microgrids offer.

To that end, this report recommends the following for the Commonwealth:

1. Emergency Preparedness: To maximize the energy reliability benefits of microgrids, this report recommends that Massachusetts coordinate state emergency and climate adaptation planning with microgrid policy and planning.
2. Smart Grid Planning and Deployment: Distribution circuit and control system planning should be executed with microgrids in mind to facilitate future interconnections, as well as cost-effective and reliable operation.
3. Massachusetts Greenhouse Gas Emissions and Microgrids: Microgrids often include fossil fuel resources and are frequently anchored by natural gas-fired combined heat and power (CHP) systems. The Commonwealth must be diligent in supporting microgrids that ultimately reduce greenhouse gas emissions.
4. The Microgrid Challenge: To foster the development of microgrids and to explore the business models and benefits through actual projects, this report recommends the Commonwealth implement a “Microgrid Challenge” pilot program. This program would engage a broad group of stakeholders, evaluate results and identify specific policy initiatives that would accelerate development.
5. Islanding Capabilities: In order to promote the deployment of DERs, which can provide energy security benefits, this report recommends that incentives from MassCEC and the System Benefit Charge be supplemented with:
 - Additional grant or other financial incentives to add microgrid functionality (including islanding and storage), and/or
 - Requirements for microgrid functionality in order to be eligible for some portion of existing incentives.
6. Energy Reliability Districts: After generation and grid vulnerabilities are identified, we suggest that the MA DPU commission a study of microgrid potential. With background work completed by the study, we further suggest that the MA DPU, MassCEC, MA DOER, MA Legislature, distribution utilities, industry leaders and municipalities consider a legal framework for Energy Reliability Districts to promote energy safe havens at the municipal level.
7. Implement C-PACE Program: The Commercial Property Assessed Clean Energy law needs to be re-written to get C-PACE funding off of the ground. This report recommends that the Massachusetts Legislature specify in any revision of the law that community and microgrid and/or district heating and cooling systems are eligible for C-PACE financing for Energy Reliability Districts, multi-user microgrids and microgrid controls and islanding equipment.

2. Introduction

The study team, DNV KEMA and Peregrine Energy Group, initiated a thorough literature review on microgrid deployment and known challenges and organized four focus groups comprising microgrid developers, microgrid owners, industry experts, distribution company representatives, combined heat and power (CHP) system operators, fuel cell system installers, and state and local officials. Attendance at the groups exceeded 40 participants. The team also conducted interviews with distribution companies: Unitil, NSTAR and National Grid specific to the topic of microgrids. The objective of each interview was to capture data, concerns, positions and supporting arguments regarding the use of electric and thermal / electric microgrids to achieve the Commonwealth's clean energy and greenhouse gas (GHG) goals. GHG goals, public safety, and emergency preparedness were used as organizing themes to frame discussions with the distribution companies and focus groups in win-win terms.

The report also considers the Department of Public Utilities Grid Modernization Working Group's proceedings on regulatory frameworks for a smarter grid, grid integration of distributed energy resources, and examines how other states and countries are currently handling the issue of microgrids. The report's recommendations are consistent with the history of market transformation in the Massachusetts' energy industry, which has been guided by clear statutes, stakeholder input, and incentives to bring cleaner energy to consumers.

This report investigates the value of microgrids to Massachusetts, examines the business case for their deployment and explores impediments to their implementation. During the course of our research, we noted a lack of understanding among some policy papers and technical reports between the benefits of distributed energy resources (DERs) and the benefits of microgrids. This confusion may result in policy decisions that do not fully support desired outcomes for the state. Microgrids encompass DERs but DERs also exist independently of microgrids. We have therefore focused our attention on the relationship of DERs to microgrid operation to help foster a better understanding of these systems and good policy decisions.

Because there are relatively few local examples of microgrids (there are more if you consider district thermal energy systems as microgrids), we examined activities in other states and countries which are also grappling with the legal, business, and regulatory issues around microgrids. We provide short synopses of these activities in the report. More detailed findings regarding Connecticut, New York, and California and three European countries are included in an appendix. Finally, we conclude with recommendations that best align microgrids to Massachusetts' goals for energy system resiliency, greenhouse gas reductions, public safety, emergency preparedness, and smart grid implementation.

3. Microgrids

3.1 What is a macrogrid, a microgrid and how do they work together?

The dominant paradigm for the generation and sale of electricity over the last 130 plus years has been the construction of large central power stations (generation) connected to transmission lines that move power from the power station to lower voltage distribution systems and eventually to the consumer. The current power grid was designed for the one-way flow of electricity. This paper will use the term **macrogrid** to describe the electricity delivery system from the point of generation to the point of use by consumers.

Figure 3-1: Sample Graphic of Transmission and Distribution Grid

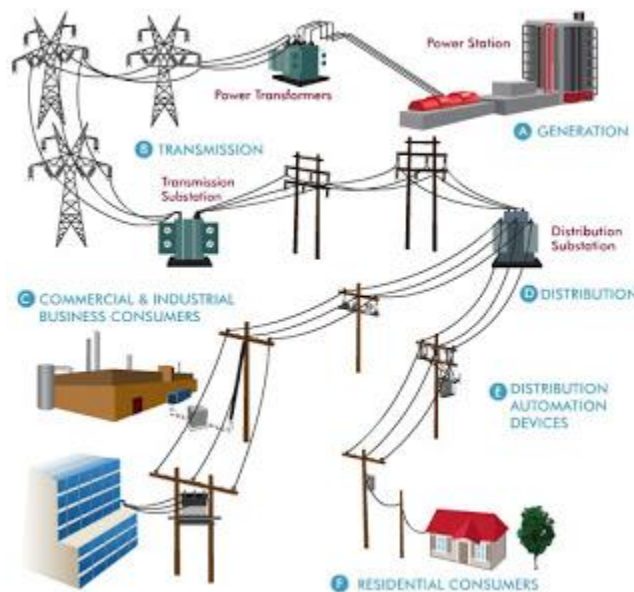


Figure 3-1 represents what is considered the traditional transmission and distribution grid with one-way power flow from a large power plant through high voltage transmission lines to lower voltage distribution lines to the commercial, industrial, and residential end users.

A **microgrid**, at its minimal level of functionality, enables local electricity generation, energy storage and load (power consuming devices) to operate independently of the macrogrid. When the power flow on the macrogrid is interrupted, a microgrid can utilize locally generated sources of energy to keep the local

lights on or maintain essential services. Typically, the greater the energy capacity of the microgrid, the greater the complexity, since multiple sources of electricity generation may be involved, along with electric and / or thermal storage, and perhaps even fuel storage. Microgrids have been gaining increasing attention lately because the impact of severe storms has driven a desire to make power delivery systems more resilient.

At this time, there is no universal agreement on the definition of a microgrid, or on how small or how large one may be with respect to geographic area or energy use. There is, however, one common theme: A microgrid has the capability to isolate from the macrogrid and independently manage generation assets and balance the critical electric loads within the microgrid. The key components that enable a microgrid to function independently of the macrogrid are: the switch gear that isolates the microgrid at the point of common coupling (PCC), the microgrid controls that maintain stability (equilibrium between supply and use), DERs, and controllable loads. A microgrid may also include electric or thermal storage. The optimal microgrid solution will be distinct to the energy requirements and goals. As in any system solution, it is not a solution without the integration of all components.

For the purposes of this study, we use the following definition of a microgrid:

A power distribution network comprising multiple electric loads and distributed energy resources, characterized by all of the following:

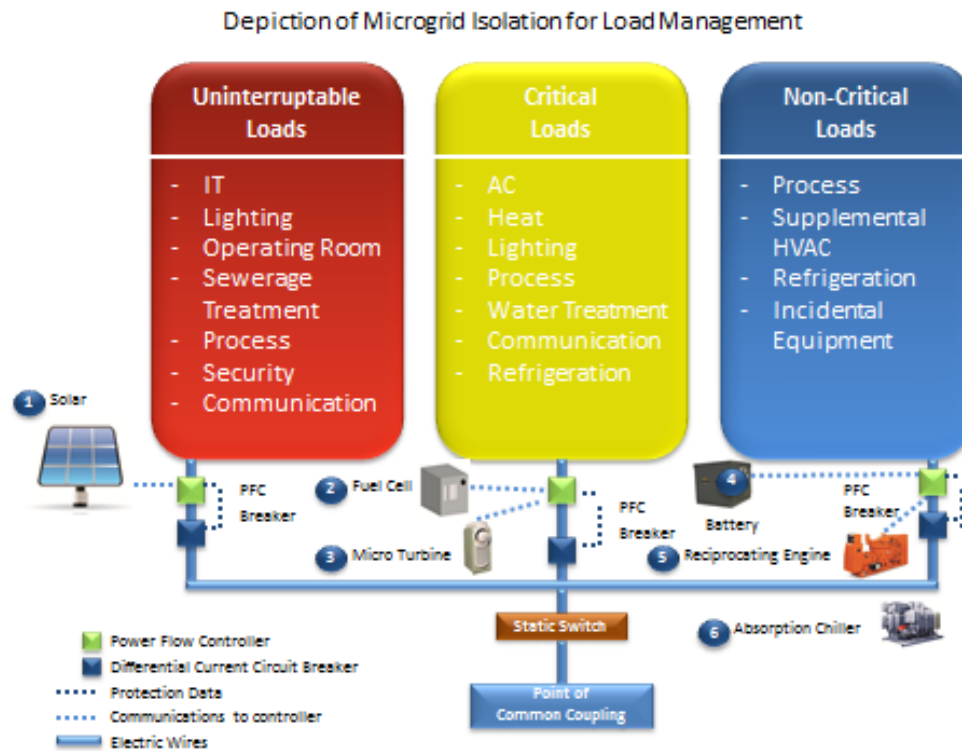
- a) The ability to operate independently or in conjunction with a macrogrid;*
- b) One or more points of common coupling (PCC) to the macrogrid;*
- c) The ability to operate all DER, including load and energy storage components, in a controlled and coordinated fashion, either while connected to the macrogrid or operating independently.*
- d) The ability to interact with the macrogrid in real time, and thereby optimize system performance and operational savings.*

3.2 Electricity generation and storage

It is vital to a microgrid that, at a minimum, adequate generation is available to support all non-interruptible and critical electric loads within the microgrid in the event the macrogrid is not available. Some microgrids will have sufficient generation capacity to meet all load requirements, and perhaps as the electric load within the microgrid changes during the day, produce excess energy for delivery to the macrogrid. Generation from sources such as wind and solar is intermittent and variable in power output. Intermittency and variability of power create instability which is compensated for by the macrogrid (when

the microgrid is operated in parallel to the macrogrid). When the microgrid is operated in isolation from the macrogrid, power variability can only be compensated for within the microgrid. A mix of controllable resources must be combined with base load sources of generation such as CHP, fuel cells, bio-mass, diesel back-up generation and thermal and battery storage, which provides a greater degree of flexibility to the system while assisting with the integration of renewables components as well.

Figure 3-2: Conceptualization of a Microgrid based on load requirements



CHP, fueled with natural gas, is a preferred technology for powering microgrids and accompanying thermal loads. Load management systems, while not a source of generation, are important energy assets in a microgrid because the ability to control load assists with stability management.

3.3 Isolation from the macrogrid

The motivation to isolate or “island” and the speed with which to do it varies widely depending on the end users’ flexibility to cover critical loads, the duration of outages, and tolerances for power quality. Depending on the occurrence of severe weather or planned maintenance of the local distribution grid,

microgrid operators may decide to island in anticipation of grid outages to avoid a disruption of their facilities and operations.

A microgrid operator may isolate from the larger grid either through manual or automatic controls. A central circuit breaker is the least-cost approach to isolation. For the safety of utility workers, a failsafe is required to maintain isolation and avoid inadvertent reconnection with the macrogrid. Microgrids are connected to the macrogrid at one or more points of common coupling (PCC)¹. To the distribution grid operators, the microgrid appears as one entity, even though it may comprise multiple-users and multiple sources of generation. A non-automated switch (at the PCC) with failsafe controls addresses utility worker safety but results in a time delay to manually throw the switch prior to the start or re-start^[2] of electricity generation within the microgrid.

Automated disconnection and reconnection switches are classified by their speed of operation (in cycles) and the amount of load which can be isolated from or re-connected to the macrogrid. The automated equipment performs more than just the function of isolating and re-connecting; it also ensures that the generation in the microgrid is synchronized the voltage and frequency of the macrogrid before re-connecting. The synchronization routine requires coordination with the distribution company, to ensure compliance with the interconnection requirements established by the distribution company.

The interconnection standards to island distributed resources and loads are contained in IEEE Standard 1547.4TM 2011, “IEEE Guide for Design, Operation, and Integration of Distributed Resource Island Systems with Electric Power Systems” published in July 2011. As with all IEEE standards, they are reviewed and revised as necessary based on unfolding events. The topic of microgrids is and will remain active in the near future. The Department is advised to monitor IEEE 1547 standard proceedings to understand the national issues. Furthermore, the Department should interact with Massachusetts utilities to observe and understand issues of safety, complexity and cost that arise from microgrid planning and installations.

While isolation is critical for safety and reliability of service, most microgrids often operate in a grid-connected mode. The PCC and interconnection requirements permit this “parallel operation” with the macrogrid and isolation (“islanding”) is only necessary when the macrogrid is down.

¹ The Medical Area Total Energy Plant (MATEP) which serves the Longwood Medical Area in Boston is an example of a microgrid which has more than one point of common coupling with the local distribution grid. MATEP supplies steam, chilled water, and electricity to five hospitals and numerous biomedical and pharmaceutical research centers located nearby.

^[2] The starting or re-starting of generation is referred to as “black start” capability. In a microgrid, black start capability can be provided by battery storage that starts up a generator or by a manually started generator. Once started, a small generator can provide sufficient power to start up larger generators which can produce sufficient power to support the critical and other load requirements within the microgrid.

3.4 How is a district energy system different from a microgrid?

A key difference of a district energy system is that it delivers thermal energy to a number of interconnected facilities, in the form of hot water, steam or chilled water. District energy systems may be limited to thermal distribution only or may be designed to co-generate electricity with the waste heat from combustion. Co-gen plants are anchored by boiler plants, engines or steam turbines that can be fueled by natural gas, biomass (particularly in the pulp and paper industry), diesel fuel, and municipal solid waste. Both district energy co-gen systems and microgrids have a macrogrid interconnection for supplemental or emergency power and two-way interaction with the macrogrid. In contrast, a microgrid is designed to distribute electrical energy over a defined network, incorporate various energy sources, interact with the macrogrid on a real-time basis, or isolate itself and operate in an islanded mode, when required.

4. Benefits of DER and microgrid systems

4.1 What are the separable benefits of DERs and microgrids?

In this section, the benefits of microgrids are compared to that of single distributed energy resource. This comparison is helpful in allowing policymakers to understand the benefits DERs can provide, as well as their limits. It is also helpful in understanding why DERs are built up to more robust microgrids, and why microgrids are developed into optimized, flexible systems that can extend reliability benefits from a single facility to an outlying community.

A device or group of devices is typically defined as a microgrid once there is the ability to island the device(s) and to operate them when the macrogrid is unavailable. However, it is too simplistic to say that the sole purpose of a microgrid is to operate independently of the macrogrid. A more complete statement of the purposes for a microgrid is: *to economically provide electricity to critical loads within the microgrid, and to improve power quality, flexibility, and reliability by integrating and optimizing various sources of energy.*

In the popular press^{2,3} and even among professionals in the energy industry, the term “microgrid” is often used interchangeably with “distributed generation” or when including controllable loads, are described as distributed energy resources. While many of the benefits of DERs can be achieved by simply being grid-tied and feeding clean electricity into the grid, there are additional benefits that can be extracted from DERs when they are planned, installed and operated in an integrated fashion.

To clarify the differences between DERs and microgrids, we have included a chart that lists some of the benefits that are often attributed to distributed energy resources. For this comparison, our study team separated the benefits of distributed resources into three categories: 1) benefits derived from grid-tied DERs on a stand-alone basis (“DER Alone”), 2) benefits of DERs that can be islanded as a microgrid (“MG”), and 3) benefits of adding advanced microgrid controls (“MG+”).

The three categories above are meant to draw distinctions between the benefits of standalone generation sources such as a commercially-sized PV and additional benefits that are captured as the devices are

² Creyts, John, Eric Maurer: “Microgrids and Municipalization: Can You ‘Micro-Municipalize’ a Utility?”. Published on 10/18/2013 at: <http://www.greentechmedia.com/articles/read/microgrids-and-municipalization-can-you-micro-municipalize-a-utility>

³ Well, Ken, Mark Chediak: EBay, Ellison Embrace Microgrids to Peril of Utilities. Published 10/20/2013 at: <http://www.bloomberg.com/news/2013-10-17/ebay-to-ellison-embrace-microgrids-in-threat-to-utilities.html>

linked into a system and then operated through sophisticated controls. The chart shows that if one focuses on a single benefit, it is clear that in some cases a simple DER device may be able to provide that benefit.

Table 4-1: Distributed Energy Resource Benefits versus Microgrid Benefits

Benefit Description	DER Alone	†MG	*MG+
Economic			
Direct			
Facility Energy cost reductions	✓	✓	✓
Participation in Ancillary Services markets	✓	✓	✓
Sales of excess electricity to the macro-grid	✓	✓	✓
Participation in demand response programs	✓	✓	✓
Optimization of Assets based on pricing signals and real time energy markets			✓
Indirect			
Reduced electric T&D losses	✓	✓	✓
Deferred electric T&D capacity investments	✓	✓	✓
Support for deployment of renewable generation	✓	✓	✓
Reliability & Power Quality			
Ability to operate absent macrogrid	✓‡	✓	✓
Reduced facility power interruptions		✓‡	✓
Enhanced facility power quality		✓‡	✓
Increase power facility electricity reliability		✓‡	✓
Ability to operate absent electricity and gas infrastructure		✓‡	✓
Environmental			
Reduced emissions of greenhouse gases	✓‡	✓‡	✓‡
Reduced emissions of criteria pollutants	✓‡	✓‡	✓‡
Security & Safety			
Safe havens during power outages			✓
Ability to support community during long term outages			✓

Table adapted from NYSERDA Report: *Microgrids: An Assessment of the Value, Opportunities and Barriers to Deployment in New York State, Final Report*. (2010)

†Considering only the islanding capabilities of microgrids

*Considering islanding capabilities and the benefits of coordinated (microgrid) controls

‡The response here is truly “it depends”. E.g., if clean/green electricity is stored in a battery, then the loss of energy to convert and reconvert back into electricity means that more energy has to be consumed. Conversely, if battery storage helps stabilize intermittent renewables feeding the distribution grid, then the grid requires fewer non-renewable fuel-fired central plants to generate power / VAR etc. for grid stabilization.

However, that device has limitations and as more benefits are added to the requirements of a system, the device capability is expanded by building the system into something more – first a simple microgrid and then a more sophisticated, optimized system.

While the chart illustrates the incremental benefits that can be obtained by creating a microgrid, the chart doesn't "weight" the importance of each of these additional benefits. For example, the last benefit listed - the ability to support a community during long term outages - may have a much, much higher value than the indirect benefit of "reduced electric T&D losses."

To work from the example in the chart, consider the case of a commercially-sized PV plant. The direct economic benefits are straightforward: free energy from the sun supplements grid electricity. Even if the discussion shifts to natural gas-fired CHP plants, energy costs savings arise from significantly reduced transmission losses, energy efficiency savings from co-generation (making use of the normally wasted exhaust heat to meet heating or cooling loads) and avoided utility costs such as transmission, distribution, and demand charges for electricity.

But these systems are limited. In the case of the PV system, even if the system is has the ability to "island" to allow independent power production during outages, its capabilities are limited because the PV system most likely will not provide "full facility" needs and obviously, will not be able to provide power when the sun goes down. As the system expands, perhaps by adding storage and a generation device, the benefits of 24 hour support are captured, but the system may still be limited in its ability to optimize its operation. If the system expands further, with advanced microgrid controls, an additional benefit of improved reliability will then be obtained. The improvement in reliability may then lead to perhaps the most significant benefit of security and safety.

The "MG+" microgrid has the ability to not only serve its targeted loads, but in times of emergencies or long term outages, but also serve the surrounding community, thereby acting as an island of refuge while the macrogrid is restored. Such scenarios are the reason why some states, in their quest to build more resiliencies into their grids, have dedicated funds to the development of community microgrids, rather than the development of simple DER devices.

This reliability and resiliency are discussed in greater detail below, but it is not difficult to envision that the ability to island provides a difficult-to-quantify benefit of securing power for critical facilities and/or public safety operations during storm conditions or other emergency events.

As DER devices are essentially a subset of microgrids, the benefits that are attributed to a DER device should also be attributed to microgrids as well. The argument for reduced greenhouse gases for standalone DERs and microgrids is complicated by the way intermittent renewable technologies - such as wind and solar PV farms - are absorbed by the grid, and also by the variety of devices that make up the category of distributed energy resources. Each of the categories is given an "*It Depends*" designation in the chart because examining whether there are reductions in greenhouse gases or enhanced power quality depend on the application itself and on the technologies that make up the DER devices.

Even if the DER devices are clean energy sources, the intermittency of some renewable resources can pose challenges to grid operators. The ability of the electricity grid to absorb the output of small renewable systems is similar to adding drops of water to the ocean. There is no discernible effect on such a large system. However, when many megawatts of renewables are added to the grid, the intermittency of these sources can cause grid instability problems, as has occurred in Germany, Spain, Hawaii, California, Colorado, and elsewhere. The impacts are seen in two areas. The first impact is on the feeder itself. The intermittency can lead to system protection issues for the distribution network and add to electrical stress imposed on certain devices. The second impact area is on the grid itself. The intermittency caused by renewable devices adds variability to both the supply and the load of the system, creating difficulties in maintaining stable operations for the entire system. Hence, because even the addition of clean DER devices may lead to downstream impacts that could limit their use, or require the use of balancing resources from fossil sources, there could be net increase emissions. Consequently, the “Reduced Emissions” benefit is modified with an “*It Depends*” designation.

4.2 Improved reliability

When energy generation and storage (thermal and electric) are widely distributed on the macrogrid, reliability is generally improved, because the more sources of electricity generation that are available across a wide geographic area, the less likely a weather event (or other emergency condition) will knock out all generation. However, when a DER can only be used when connected to the grid, it may not result in improved reliability, since a grid outage may curtail its ability to operate. In addition, the DER device is often not designed to supply an entire facility load, further limiting the reliability benefits for the full facility. The deployment of microgrids ensures that power distribution continues within the microgrid, thereby maintaining the reliability of service. In fact, microgrids are often deployed at the types of industrial facilities that require high levels of reliability.

Microgrids not only improve reliability, but may help to restore power more quickly when the macrogrid is down. As an example, on September 6, 2013 a weather related outage demonstrated the value of the Borrego Springs microgrid⁴ in San Diego Gas & Electric’s service territory. Power to Borrego Springs was interrupted, but “As soon as the storm passed and utility patrols were able to determine the damage, the microgrid began to restore power to customers. In total, 1,060 customers (out of 2,780 in the town) had their power restored automatically within hours by the microgrid, using on-site power.”⁵

⁴ U-T San Diego, November 10, 2013. <http://www.utsandiego.com/sponsored/2013/nov/10/sgde-repair-crews-storm/>

⁵ Ibid

The storm that affected power delivery in Borrego Springs was modest compared to “Hurricane Sandy which knocked out power to more than 8 million people.”⁶ Microgrids at South Windsor High School in Connecticut, New York University and Princeton University were “islands” in the aftermath of Sandy. The microgrid at South Windsor High served as an emergency shelter during the storm.⁷ When the two microgrids at Princeton University went into island mode, the campus load requirement was 16 MW though only 15MW of power was available. Load was shed via automated and manual switches, and the two microgrids were interconnected and remained so for two and a half days without utility supplied power. While isolated, the dining halls at Princeton provided hot meals and power to charge cell phones to first responders, students and staff.

As is evident in these stories, microgrids improve reliability. Second, a microgrid doesn’t need to supply all the power requirements to have an impact; shedding load is as important as providing generation. Lastly, these experiences demonstrate the value of an island of refuge and provide anecdotal support for the creation of Energy Reliability Districts or Municipal Emergency Service Districts powered by microgrids.

Community Microgrids:

The reliability benefits of microgrids need to be considered in the context of the facility it serves and the surrounding community. For a facility, a microgrid can provide the “5-9’s” (operate 99.999% of the time) reliability that may be necessary for operations and to cover short term outages. However, the system may also be able to provide critical support to the surrounding community.

Many state planners are examining how to increase resiliency of their grids. The outages that resulted from recent severe storms such as Super Storm Sandy and during Hurricane Katrina lasted multiple days and in some cases, more than a week. Hence, the benefits of microgrids are being expanded to areas beyond a single facility, to also encompass the community as well. During a crisis, a microgrid may be able to reduce the power supplied to a certain facility, and redirect that power to support certain critical care or public safety requirements of the community. This capability is not something that can be achieved with a single DER device or a simple microgrid, but rather the “MG+” system with advanced microgrid controls. As state planners consider a modernized grid, this feature and capability is beginning to take on greater and greater significance when weighing the benefits of microgrid applications.

⁶ The Christian Science Monitor, Clayton, M., November 15, 2012, <http://www.csmonitor.com/USA/2012/1115/Lessons-from-Sandy-how-one-community-in-storm-s-path-kept-lights-on>

⁷ Ibid

5. What are other states and countries doing about microgrids?

Several U.S. states and European countries have designed and launched various initiatives to promote the development of smart grid technologies. With the exception of a few states, very few programs are explicitly focused on microgrids. European countries are cooperating through the EU to understand the full costs and capabilities of smart grids, and to pilot real-time market transactions that can be enabled by these systems, since real-time, bi-directional power exchange capabilities can improve the economics of smart grid and microgrid systems. In the U.S., there are similar efforts to incorporate smart grid technologies, incentivize grid-tied DERs, and pilot microgrids for economic and reliability purposes.

A brief overview of microgrid-related projects and programs outside of Massachusetts is provided in the appendix. Highlights of programs currently operated in the various states include:

1. Connecticut has launched a microgrid grant and loan pilot program that was initially funded at \$15M and later increased to \$18 M. The state has also established a “Commercial Property Assessed Clean Energy” (C-PACE) program to assist with the financing of district energy projects with plans to alter legislation to include microgrid projects. The program provides security for funding through a property tax assessment. The return of benefits is allocated to the C- PACE participants in proportion to the funding provided.
2. New York and California provide incentives to establish islandable DERs. In New York, CHP systems must be capable of “grid-independent” operation during outages and an incentive bonus is available for CHP systems that support critical infrastructure.
3. Net metering rates, generally set at levels that are closer to retail pricing than wholesale pricing, provide an incentive for solar power development. In Massachusetts and 42 other states⁸ such net metering rules that have provided the primary incentive for development. However, the fairness of the net metering rates is under review in several states.
4. A feed-in tariff is another mechanism used to encourage renewable generation⁹. A microgrid may integrate various types generation, including carbon-based generation. The use of net metering rates for carbon based electricity exported to the grid may not be appropriate, unless other efficiency and reliability benefits are considered.

Highlights of relevant European programs include:

⁸ http://www.seia.org/sites/default/files/resources/Net-Metering-by-State_0.pdf

⁹ <http://www.eia.gov/todayinenergy/detail.cfm?id=11471>

1. Northern Europe has an excess supply of renewable energy. EU policy is therefore driving toward a “pan-European competitive electricity market”¹⁰ to maintain an incentive for continued renewable development across the continent.
2. UK tax law allows Exempt Supply Services, the equivalent of DG projects in the U.S., to use the electric distribution system to wheel power to other sites. The distribution utility is allowed to charge for the use of its system for power distribution, thereby offsetting any additional costs that may be incurred.
3. On the Danish island of Bornholm, nearly 2,000 electric customers participate in a smart grid project. The purposes of the project are to successfully balance the island grid with as much as 50% renewable energy, and to gauge customer responses to real-time pricing, such as adoption of DR.
4. In The Netherlands, 25 interconnected households participate in a demonstration using real-time energy prices as a balancing mechanism between grid-purchased vs. self-generated power during periods of peak demand.

The appendix provides additional details on all of these examples. While only one of the examples above (the Connecticut Microgrid Grant and Loan Pilot Program) is specific to microgrids, they illustrate that a number of jurisdictions have launched programs to promote objectives or test specific policy ideas. This concept of testing policy ideas re-appears in the recommendations section, where we suggest Massachusetts pilot specific policy concepts, monitor the results, and then implement policies that incorporate lessons learned through actual experience.

¹⁰ Ibid

6. Business models that will enable microgrids

What business models will allow microgrids to succeed? To answer this question, we examined four models of microgrid ownership and operation:

- A distribution company microgrid
- A single user microgrid
- A hybrid microgrid
- A multi-user microgrid

6.1 Distribution company microgrid

6.1.1 Distribution company microgrid – ownership and participants

Examples of distribution company microgrids are the Consortium for Electric Reliability Technology Solutions (CERTS) demonstration project in Ohio, owned by American Electric Power¹¹ and the Borrego Springs microgrid owned by San Diego Gas & Electric. This model obviously requires that distribution companies be allowed to own generation assets, which is the case in a number of states. In Massachusetts, however, utilities are prohibited from owning generation assets with one exception - they can own up to 50 MW of solar generation. As discussed in Section 4, using solar generation by itself would not enable the development of an effective microgrid. One alternative would be for Massachusetts to relax the prohibition of utility ownership of generation assets for the purposes of conducting a pilot program.

Another alternative is to consider the use of energy storage as a means of providing an energy source for a microgrid. The California Public Utilities Commission on October 21, 2013 issued its Decision 13-10-040 adopting energy storage procurement targets for the three investor-owned utilities in the state. The MassCEC and Department of Public Utilities are advised to monitor utility procurement of energy storage prior to drawing conclusions about the viability of utility ownership and use of energy storage. A third alternative would be for the distribution company to obtain generation produced within a microgrid via a Power Purchase Agreement (PPA) with the microgrid owner, and then acquire responsibility for operating the microgrid.

The active control of the macrogrid for stability has been a responsibility of the distribution company since its inception. Microgrid owners report that maintaining stability of operations, when isolated from the macrogrid, is challenging. There are many more generation and load resources available within a large utility distribution network than within a microgrid. Consequently, the distribution network has a far

¹¹ <http://certs.lbl.gov/certs-derkey-mgtb.html>

greater diversity of sources and loads, which directly contributes to maintaining system stability. As mentioned previously, most DERs and microgrids are operated in parallel to the larger grid, which demonstrates the value of the distribution company participation in the control of a microgrid. This issue is highlighted here because integration with the distribution company is essential to maximizing the benefits of microgrids, and a certain expertise is required to do so.

The rules associated with the wholesale electric market also need to be evaluated to determine whether utility ownership of or participation in generation would alter the fair-play of the wholesale electricity markets.

6.1.2 Distribution company microgrid – benefits

The benefit of a distribution company owning a microgrid lies in the coordination and control of the microgrid within the larger grid operated by the distribution company. The Borrego Springs microgrid is an example of the distribution company locating the microgrid to improve reliability and integrate DER.¹² The pilot project will hopefully demonstrate that a microgrid was a better economic choice for improving the reliability of the distribution system that provides power to Borrego Springs. Like the Hybrid model discussed in 6.3.1 below, this model does not create the uncertainties with respect to franchise issues discussed in Section 9.3 of this report.

6.1.3 Distribution company microgrid – complexity, challenges, regulatory suggestions

This model reduces complexity because it reduces the number of parties coordinating the design and operation of the microgrid to one, the distribution company. The model presents a challenge for Massachusetts, since distribution companies cannot own generation. We do not suggest that ownership restrictions on generation be removed at this time. Rather we suggest that ownership exemptions be granted to enable the development of pilot programs that would be designed to evaluate potential benefits.

¹² http://www.smartgrid.gov/sites/default/files/pdfs/project_desc/NT02870%20RDSI%20Fact%20Sheet%20SDG%26E%20Borrego_3.0.pdf

6.1.4 Distribution company ownership example - SDG&E Borrego Springs, CA

SDG&E Borrego Springs Microgrid Demonstration Project –Distribution Company Microgrid	
Objective	Reduce outages and grid downtime for the community of Borrego Springs, CA, which is at the end of a long feeder line. The goals are to achieve a 15% reduction in feeder peak load, explore microgrid islanding, and improve distribution system reliability. In Sept. 2013, lightening shattered a transmission pole on the only transmission line into town. Within hours, 1,060 customers had power restored (one circuit in Borrego Springs) via the microgrid’s generation and storage assets, and by the next day, SDG&E had restored all 2,780 customers to full power.
Project Cost: Funding Source	\$15.2 M: U.S. DOE - \$2.8M, SDG&E - \$7.5M, Public-Private Sources - \$4.9M
Microgrid Assets	<p>Generation:</p> <ul style="list-style-type: none"> Two (2) 1.8 MW Caterpillar Diesel Generators Residential PV up to 125 households <p>Battery Storage:</p> <ul style="list-style-type: none"> One (1) 500 kW/1500 kWh battery at Borrego Substation Three (3) 25 kW/50kWh units for Community Energy Storage <p>Controls:</p> <ul style="list-style-type: none"> Six (6) 4 kW/8kWh units for Home Energy Storage (HES) Switch - Feeder Automation System Technology (FAST)

6.2 Single-user microgrid

6.2.1 Single-user microgrid – ownership and participants

In this model we specify only a single owner and participant.

6.2.2 Single-user microgrid – benefits

CHP systems can provide dual fuel use benefits that support the achievement of GHG reduction goals. Massachusetts (similar to the state of New York) encourages GHG reduction with incentives for the qualified purchase of CHP systems. Lower energy costs are the economic incentive for DER. The value of business continuity, and the isolation capability to maintain service to non-interruptible and critical

loads, is very specific to the individual user. The single user is in control of its own expectations and performance with respect to microgrid stability and critical load support capability.

6.2.3 Single-user microgrid – complexity, challenges and regulatory suggestions

The complexity of the CHP system and its controls are guided by the owner's requirements. Simple generation and load requirements result in a relatively simple microgrid configuration. A more complex situation will result in a more complex microgrid. However, even a simple system requires a certain level of expertise to maintain stability. One focus group participant, who owns a small CHP system, offered that his firm lacked expertise to operate CHP as a microgrid. When presented with the costs and complexities to isolate from the grid, the firm decided it was not only financially unattractive but presented an operating risk.

On the other hand, the GHG reduction benefits of CHP systems are easily understood by owners. Having system performance monitored and managed by the distribution company resolves a complexity for the owner while ensuring Massachusetts incentives are being properly administered. The process works for increasing CHP penetration and reducing GHG emissions, but falls short in creating an incentive for building a microgrid. Massachusetts should consider additional incentives for providing isolation capability when installing a CHP system.

6.2.4 Single-user example – The Santa Rita Jail Microgrid, Dublin, CA

Santa Rita Jail – Single - User Microgrid	
Objective	The goals are to achieve 15% reduction in feeder peak load and to ensure there is enough energy to maintain full service between a blackout and back-up diesel generators reaching full power. Overall reliability and energy cost savings are also goals.
Project Cost: Funding Source	\$12 M: U.S. DOE - \$7M, CEC - \$2M, Other Public Sources - \$1M
Microgrid Assets	Generation: <ul style="list-style-type: none"> ▪ Two (2) 1.0 MW Diesel generators ▪ One (1) MW molten carbonate fuel cell with heat recovery ▪ 1.2 MW PV Rooftop Mounted System ▪ Five (5) 2.3 kW Wind Turbines Battery Storage: <ul style="list-style-type: none"> ▪ One (1) 2 MW/4 MWh Li-ion battery Controls: <ul style="list-style-type: none"> ▪ 12kV sub cycle static disconnect switch

6.3 Hybrid microgrid

6.3.1 Hybrid microgrid – ownership and participants

In the hybrid model, the generation is owned or contracted for by the microgrid participant(s) whose load is controlled within the microgrid. (Examples might include campuses, office complexes or industrial facilities.) The distribution system and the individual service meters are owned and maintained by the distribution company. The hybrid model thus combines the best aspects of Distribution Company and private ownership. By involving both parties, the operational expertise of distribution companies is applied, while the private ownership provides a separate source of investment capital which is being used to enhance the overall distribution system.

Control of the microgrid would remain the responsibility of the distribution company, as in the previous case. The distribution company manages the points of interconnection. When the microgrid is isolated from the larger grid, the distribution company maintains control on both sides of the point of interconnection.

During isolation from the macrogrid, load management would be required to ensure the adequacy of supply for the participants within the microgrid. Using smart grid technology, the distribution company could selectively and automatically disconnect certain customers or loads to balance the available supply with the demand. The quality of service during a grid event could be less than under normal conditions, but at least microgrid participants would have access to electricity during the event. The cost to manage the microgrid in isolation would be the responsibility of the microgrid participants.

6.3.2 Hybrid Microgrid – benefits

The benefit of a hybrid microgrid is that it can provide additional sources of investment capital for improving the overall performance of the distribution grid. In addition, multiple owners of DER can participate and can aggregate their thermal and electrical loads (and their demand reduction resources) to optimize project economics. The greater diversity of loads with multiple users also promotes stability within the microgrid.

6.3.3 Hybrid microgrid – complexity, challenges and regulatory suggestions

The inclusion of multiple DERs makes this model more complex for the distribution company than the PPA or utility ownership approach described in the distribution company microgrid model. However, the identification and inclusion of many points of DER is a challenge faced today by distribution companies and should not be considered an impediment to microgrid development. Whether these DER assets are within a microgrid or not, the impact on the stability of the macrogrid must be considered¹³ by the distribution companies.

The coordination and controls required of a distribution company are a challenge due to multiple sources of generation and participant load requirements. That challenge is magnified during isolation from the macrogrid as a result of a major outage event. One result could be that each generator is required to isolate and meet its own load requirements resulting in smaller pockets of reliability during a macrogrid event. This could result in less than full service capability for participants of the microgrid, but maintains the reliability of service to certain critical loads.

In this model, the physical structure of the distribution grid becomes more expansive in terms of geography and users. The interconnection points, reclosers, and communications systems are managed

¹³ There are too many load-related variables specific to a feeder or grid to define the level of penetration at which intermittent generation will create instability. The specific location of the generation also plays a role. Instability is not likely to be a problem when intermittent generation is below 10% of the total load or even at possible 30%. Predicting the ranges and circumstances is beyond the scope of this study, but it does support the need for the distribution company to be aware of the DER, loads and load management capabilities within the grid.

outside the control of the generator of the energy. During reliability events, individual users competing for energy can introduce instability, unless the distribution company managing the microgrid has full authority to manage both generation and load for all participants.

The prime purpose of the microgrid is to always provide enough energy for non-interruptible and critical loads. The control of load during an event preventing a participant from using electricity for non-critical purposes may result in participant dissatisfaction, but the level of satisfaction with respect to available power is a potential issue regardless of the ownership model.

There will be times when generation exceeds the requirements of the participants in the hybrid microgrid. A means of selling this energy (preferably at higher than wholesale prices) into the grid must be defined for the purposes of a pilot program. A pilot program may also want to establish common practices for interconnection/isolation, load control and communications costs that may be charged to microgrid participants, to maintain fairness for all parties.

6.4 Multi-user (non-utility) microgrid

6.4.1 Multi-user microgrid – ownership and participants

The Multi-user microgrid model expands the pool of microgrid participants to enable business entities to own or operate a microgrid that serves multiple customers, multiple customer meters, and multiple facilities. A business proficient in the processes to safely and efficiently generate and distribute energy to recipients would own or operate the microgrid facilities. Several participants in the focus groups commented that this model would create a more diverse and larger group of microgrid providers and users.

6.4.2 Multi-user microgrid – benefits

Similar to the hybrid model, the benefits of a multi-user model may be shared capital costs and access to private capital, resulting in a more rapid expansion of microgrids and DER. Where load requirements and capability to generate exist in geographic proximity and are complementary to each other, this model could achieve a higher ROI than that of a single user microgrid. Federal and state tax credits may accrue to commercial owners, or be assigned to developers in the case of municipal/non-profit ownership.

6.4.3 Multi-user – complexity and challenges

There are several complexities, challenges and obstacles to this business model. The key challenge is that the Multi-user microgrid appears to require the utility to grant an exception to the utility franchise rules. Those rules are discussed in Section 9.3. Beyond the franchise rules, the transaction cost to attract

additional participants and bill them for their energy use adds a unique complexity to this model and may inhibit microgrid development. In other models, the utility already has the billing and customer support infrastructure in place. In discussion with retailers¹⁴ there is a possibility others can provide the necessary customer support, but it seems improbable in the short term. Perhaps even with the relaxation of franchise rules there will be limited opportunities in the near term for this business model due to the complexity and challenges cited above.

These challenges can be compared with a hybrid model, which avoids the issue of franchise rights¹⁵ and will likely promote a more rapid development of microgrids. We suggest the franchise issue be further investigated while simpler microgrid business models are being piloted and evaluated. However, the MassCEC and the DPU will want to ensure that its policies providing incentives don't exclude the multi-user model.

¹⁴ DNV KEMA has an annual Retail Energy Executive Forum. The topic of microgrids was informally discussed with retail executives. They see a possibility to provide both the customer interface and a multi-user microgrid but it is several to many years out.

¹⁵ The franchise right issue and the potential to classify an owner of this model as a utility to be regulated by the DPU and the limited benefits beyond what might be accomplished with the other models support an initial focus on the other models rather than a dilution of effort to implement the most complex model at this time.

6.4.4 Example of a Multi-user Microgrid – Burrstone Energy Center, Utica, NY

Burrstone Energy Center – Multi-User Microgrid	
Objective	The project comprises three separate entities, St. Luke’s Hospital, St. Luke’s Nursing Home and Utica College. Each entity has critical, uninterruptable loads that have been adversely affected by local power disruptions. Therefore, reliability was a major driver. Energy cost savings were also another reason for investing in a CHP-based microgrid. Since starting up in 2009, the system has exported over 5 M kWh of electricity, although the campus has also imported 33 M kWh since that time.
Project Cost: Funding Source	\$15M: NYSERDA - \$1M, Oneida County - \$150k
Microgrid Assets	<p>Generation:</p> <ul style="list-style-type: none"> ▪ Three (3) 1.1 MWe Natural gas CHP units ▪ One (1) 334-kWe Natural gas CHP unit ▪ Peak thermal capacity of the four (4) units combined: ~7,000 lbs/hour (100 psig steam) and 700 gpm (200 deg F) hot water. <p>Battery Storage: None.</p> <p>Controls:</p> <ul style="list-style-type: none"> ▪ Automated- Microprocessors at the PCC that energize the microgrid within 2 minutes.

6.5 Section conclusion

There are several observations to note in the comparison of microgrid business models. First, the expertise of the distribution company in maintaining grid stability is an important consideration in the development of microgrids. And while the ability to sell excess electricity at rates closer to retail than wholesale will improve financial returns, it is an issue that is also associated with DER. The GHG reduction incentives associated with CHP development could be enhanced to promote the inclusion of isolation capabilities, which would improve reliability. There are two ways to measure the value of the reliability improvement - the value of business continuity, and the societal value of providing power to critical populations and resources. The first measure is specific to the participant(s) in a microgrid. The second is the potential benefit to the adjacent community. We believe the “Energy Reliability District” concept, where a microgrid is established to improve reliability for users and emergency power for adjacent communities is a concept that should be piloted and evaluated.

The ownership models represent a wide range of feasibility from single-user systems that already exist to hybrid or multi-user systems that conceptually should work but have many more technical, regulatory, and financial hurdles to overcome. The discussion of ownership models demonstrates a diversity of possibilities; however, no particular model will drive microgrid development. Identified, critical needs for power, power quality, control over utility costs, and integration of renewables drive microgrid development and business models are adopted and adapted to operationalize microgrid systems and capitalize on the benefits. As a result, we do not advocate any particular business model, as we anticipate they will emerge organically once microgrid drivers are identified and microgrids are contemplated at different locations across the state.

It is also important to note that while DERs are rapidly expanding, the control mechanisms and operating systems required for microgrids are far from plug and play technology. Significant learning is still required and can be accelerated through a planned program of multiple microgrid pilots that engage distribution companies, municipalities, potential owners and other stakeholders in the development and testing of microgrid systems and energy reliability districts.

7. Development costs and operational challenges of microgrids

We begin with the operational challenges of microgrids and work backward to their development costs. The key operational challenge is stability – i.e., maintaining the equilibrium of generation and load. In a microgrid, responsive generation such as CHP and storage can accommodate variations in load. Other forms of DER are less able or unable to alter electricity output to provide stability. Technologies such as smart inverters¹⁶ are in development to make variable supply more possible at a reasonable cost. Load management systems are also becoming more responsive and capable of modulating load. Battery and other storage technologies that can absorb or discharge energy are growing in importance both at a macrogrid level and at a microgrid level.

Because there are fewer resources in a microgrid, the challenge to maintain stability is greater when the microgrid is isolated from the macrogrid. When a microgrid is operating in a connected mode, variations in equilibrium are resolved through the support of the macrogrid. When the macrogrid is down, the isolated microgrid must maintain stability solely with the resources within the microgrid. If the sources of DER produce an oversupply of electricity, a generator may trip-off, resulting in a loss of power to the microgrid. Restarting generation and gradually adding load to regain equilibrium can be time consuming. Likewise, an undersupply of power can subject the equipment to malfunction or damage, and can also cause a loss of stability, which in turn will cause a shutdown of generation. It is for this reason that advanced control systems are essential for the operation of a microgrid.

As an example of the challenges involved, one participant in the workshops stressed that his company had recently installed a small natural gas-fired CHP system. While they had enough expertise to run the CHP, they did not feel they had the expertise to run a microgrid (i.e. the isolated CHP system) in the event of a grid outage. Continuing technology developments will make it easier to maintain stability within a microgrid, but until then, experienced distribution system engineers will be required to design and operate microgrids. Larger sites, such as university campuses, have the engineering staff and expertise to operate microgrids, and some are currently doing so. But for smaller installations, it may be too costly to keep an experienced engineer on staff, especially when operating independently from the grid is not a frequent occurrence.

¹⁶ Smart inverters allow solar PV systems to stay connected to the grid during minor grid disturbances and to change their output to assist in grid stability. In addition, smart inverters will have functions which are ‘randomized’ so that inverters don’t all disconnect from the grid at the exact same time when grid voltage or frequency are out of tolerance.

A second challenge is for the microgrid to determine when it must take over for the macrogrid. A short duration outage or dip in generation from the macrogrid might be almost immediately restored, even as the local generation ramps up. Yet if the generation is not rapidly responsive, the loss of energy within the microgrid can result in power outages and require a more time consuming “black start” operation to restore power. The cost of relays and monitoring systems to make these determinations, and the cost of switches to execute various transitions, can vary significantly. Thus, a comprehensive understanding of the requirements for managing operational transitions between the microgrid and macrogrid is important in the specification of equipment. Depending on the complexity of the loads, and the number and types of sources of generation within the microgrid, the engineering and modeling cost to develop the required specifications can range from \$10,000 to \$1,000,000 or more for a large, complex system.

Costs and benefits are difficult to generalize because each microgrid depends on the requirements and configuration of the user. The table below summarizes the equipment required for a typical installation, and provides a range of costs for a microgrid supporting 5 MW of load. Sophisticated controls are required to operate the assets and optimize reliability, revenue production or GHG reduction. In this table the cost of islanding, control and communications equipment represents about 15% of the total cost. All of these costs would be balanced against the frequency of local power interruption, the expected duration of outages, and the value of the benefits achieved.

Table 7-1: Range of Costs for Microgrid Components

Qty	Microgrid Equipment	Description 5 MW Multi-DER Installation	Range	
			Low	High
Microgrid Isolation and Stability Controls				
1	Main transfer switch	Disconnect when out of tolerance. Required for islanding.	\$50,000	\$100,000
1	Master controller	Microgrid stability controller ¹	\$150,000	\$500,000
1	Switchgear	Generation switchgear and controls (basic) ²	\$100,000	\$400,000
Distribution Automation (2 circuits: non-interruptible + critical load and, non-critical load)				
2	Sectionalizing switchgear	Sectionalize non-interruptible and critical load from total load	\$100,000	\$200,000
1	Remote switchgear control	Master station for remote load shedding and distribution switchgear operation	\$70,000	\$110,000
1	Automatic fault protection	Relaying, protection and control equipment to enable switchgear to automatically detect and isolate fault.	\$60,000	\$125,000
5	Smart meters ¹⁷	Includes data warehousing	\$50,000	\$100,000
Communication infrastructure				
1	Costs from smart-grid enabled substation communication infrastructure up to the point of common coupling, i.e. the utility transformer.		\$500,000	\$1,000,000
Total			\$1,080,000	\$2,535,000
¹ SCADA/EMS (forecasting, load-shedding, scheduling, optimization, market participation, resynchronization, islanding transitions, automated protection settings etc.) to monitor and manage power system from PCC to building circuit panels.				

Developing a compelling business case for a microgrid can be a significant challenge. Obviously, without DER, there would be no opportunity for a microgrid, and DER may be supported with incentives to achieve carbon reduction, rather than grid isolation or reliability benefits. Connecticut has approved the use of diesel generators in its microgrid awards, choosing reliability as the primary objective rather than carbon reduction. New York is providing incentives for the use of carbon reduction technologies while also requiring islanding capability as a means of achieving both objectives. Thus, where microgrids are being installed, there is either an incentive for building the system, a very high value for continuity of service, or a significant revenue opportunity.

¹⁷ Smart meters enable load measurement at points of interest. At least every building should be measured on an hourly basis. Metering and consumption evaluation should be the first step in the planning process. Costs of smart meters are usually \$5K – \$10 K. Additional meters for gas / steam may be added if required. Data is collected, stored, visualized and analysis performed.

A simple example is that combined heat and power resources are generally controlled to follow thermal load. However, simple changes in the controller can enable the generator to modulate its output based on electrical load or energy prices, thus providing an additional source of revenue to the microgrid owner. From evaluating use cases in NY and CA, this additional revenue can result in a 10% – 40% reduction of the total energy costs for the facility.

Given the discussion above, it may prove useful to the state to develop use cases for sample customer facilities in Massachusetts. These use cases will help crystallize the regulatory, cost, revenue and environment factors that pertain to Massachusetts. The development of such use cases is suggested as a prerequisite to launching a microgrid pilot program.

8. Smart grid technologies that enhance microgrid operation

The Department of Public Utilities has initiated a process to modernize the electric grid, and stakeholders have created a taxonomy that can be used to identify which new technologies are needed for microgrids. The following chart from the July 2013 report of the Grid Modernization Stakeholder Working Group includes “intentional islanding”, which the report also refers to as “microgrid controls”.

Figure from “Massachusetts Electric Grid Modernization Stakeholder Working Group Process: Report to the Department of Public Utilities from the Steering Committee,” 2 July 2013.

Figure 8-1: Massachusetts Grid Modernization Taxonomy

Outcomes	Capabilities/Activities*	Network Systems Enablers
Reduce Impact of Outages	Fault Detection, Isolation and Restoration	• Communications
	Automated Feeder Reconfiguration	• SCADA/Distribution Management System
	Intentional Islanding	• Outage Management System • Geospatial Information System
Optimize Demand	Volt/VAR Control, Conservation	• Communications
	Voltage Reduction	• SCADA/Distribution Management System
	Load Control	• Metering System
	Home Area Network Capability	• Meter Data Management System
	Advanced Load Forecasting	• Billing System
	Time Varying Rates	
Integrate Distributed Resources	Voltage Regulation	• Communications
	Load Leveling and Shifting	• SCADA/Distribution Management System
	Remote Connect/Disconnect	
Workforce and Asset Management	Mobile Workforce Management	• Communications
	Mobile Geospatial Information System	• Outage Management System
	Remote Monitoring and Diagnostics	• Geospatial Information System
Prevent Outages	System Hardening	
	Aging Infrastructure Replacement	
	Vegetation Management	

Annotations in the diagram:

- Microgrid Controls:** Points to the 'Intentional Islanding' capability.
- Microgrid Generation:** Points to the 'Integrate Distributed Resources' outcome.
- SCADA & DMS or EMS:** Points to the 'SCADA/Distribution Management System' enabler for 'Intentional Islanding' and 'Optimize Demand'.
- Advanced Metering:** Points to the 'Meter Data Management System' enabler for 'Optimize Demand'.

*Note: Capabilities/Activities are connected here to their primary outcomes. Some Capabilities can also help facilitate other outcomes (see definitions).

As illustrated in this taxonomy, there are several “capabilities” that support the integration of distributed resources, and which are also needed to make microgrids possible, including voltage regulation and load leveling and shifting.¹⁸

The Working Group’s report further identifies the distribution company’s SCADA and Distribution Management Systems as “network systems enablers” for microgrid control and generation.

We provide a brief overview of measurement and control technologies important to microgrids:

1. Supervisory Control and Data Acquisition (SCADA) – these systems provide communication and control of and to distribution automation technology such as reclosers.
2. Energy Management Systems (EMS) Controls for Utility Distribution Networks¹⁹ - A microgrid, could relieve distribution system congestion if it is identified as a potential source of generation or load reduction by the utility’s EMS. It could then be controlled to provide either additional generation or load reduction, as required to alleviate the congestion.
3. Advanced Metering Infrastructure (AMI) – provides extensive meter data, including historic usage, load profiles, voltage variations and outages. This information is useful in developing the business case for a microgrid installation. As an example, time-of-use (TOU) meter data, when combined with time-sensitive pricing, can determine the benefit of participating in the utility’s demand response or demand management programs.

¹⁸ This load shifting capability will need to include “voltage ride-through capabilities that enable distributed generators to operate uninterrupted though grid disturbances”, and in the case of substantial penetration of microgrids with generation, will have to include intentional two-way power flow.

¹⁹ Our use of the term “Energy Management System” is not equivalent to the use of the term “Distribution Management System” in this report.

9. Policy and regulatory issues

There are a number of policy and regulatory issues that affect microgrid development, including:

- Climate policy: mitigation and adaptation
- Regulatory issues that in general affect distributed energy resources
- Utility franchise rights
- Regulation of non-utility multi-user microgrid owners

9.1 Climate policy: adaptation and mitigation

There are two components of climate policy: adaptation and mitigation. Adaptation strategies are designed to reduce our vulnerability to the impacts of climate change, including improving the resiliency of the electric grid. Mitigation strategies are designed to reduce the magnitude of climate change, including reducing emissions of greenhouse gases.

Adaptation

The primary role of microgrids in climate policy is as an adaptation strategy. As discussed earlier, microgrids can provide islands of refuge during grid outages. Microgrids can be designed to ensure that critical facilities remain operational, and that critical populations are served, even if the macrogrid is down for an extended period.

Mitigation

Massachusetts has adopted an aggressive climate mitigation goal of a 25% reduction in greenhouse gas (GHG) emissions from 1990 levels by 2020, and an 80% reduction of GHG emissions by 2050. While energy efficiency and conservation play important roles, the Commonwealth's plan to achieve those goals includes a significant increase in renewable energy generation. Low carbon DERs, whether deployed within a microgrid or not are important to achieving the GHG goals.

As described in Section 4, microgrids *may* contribute to the Commonwealth's GHG mitigation efforts. However, most of the GHG reduction benefits do not result from the microgrid itself but from operating a renewable energy source, which can be done without a building a microgrid. A policy of promoting microgrids may produce GHG reductions, if it leads to an increase in deployment of clean DER. However, there is an additional cost for microgrid development (above and beyond the cost of DER) that may inhibit its development. There are also less visible impacts of microgrids, such as the requirements for balancing power as described previously, which may be produced by fossil fueled energy sources. Thus the net GHG reduction benefit, if any, is difficult to quantify, but it is unlikely that a microgrid

policy will produce much more clean generation in the short-term as compared to other clean energy strategies that the Commonwealth could employ.²⁰

On the other hand, there are several offsetting factors that could lead to an increase in clean energy development as a result of microgrids. These include:

- Customers interested in CHP who have high thermal loads relative to their electric loads may be able to increase the size of their CHP systems - if they are able to export electricity to the grid during times of high thermal use. This may provide a total energy efficiency benefit.
- Customers who are planning a microgrid to meet resiliency objectives may decide to increase the capacity of clean energy they install (above what they would have installed in the absence of the microgrid) in order to extend the period during which they can operate in islanded mode.

9.2 Regulatory issues affecting distributed energy resources

Distributed energy resources are essential to microgrids. As a result, the regulatory issues that affect DER in general also affect microgrids. These issues include:

- Interconnection processes and requirements;
- Distribution company rates for customers with DER;
- Natural gas rates for customers using gas-fired CHP systems.

The resolution of these issues will have a direct impact on the viability of microgrids in Massachusetts. If the interconnection process is too slow and expensive, or if distribution company rates discourage DER development, microgrids will not flourish. However, because these issues have been fully addressed in other reports,²¹ and because they are not unique to microgrids, they are not addressed in detail in this report.

9.3 The utility franchise

The utility franchise is a threshold issue for microgrids; it determines what ownership and operational models are possible. The applicability of the franchise rules to multi-user microgrids is not entirely clear.

²⁰ For example, extending virtual net metering (now available to wind and solar) to CHP could potentially provide a more direct and quicker boost to CHP development. Virtual net metering could improve the economics of CHP systems by enabling them to receive a higher price for exported power without the need to challenge the utility franchise.

²¹ See, e.g., KEMA, Inc., "Massachusetts Distributed Generation Interconnection Report," July 25, 2011, for Massachusetts Department of Energy Resources and Massachusetts Clean Energy Center.

Because the DPU has not yet been asked to review and rule on a multi-user microgrid proposal, it is unclear whether the DPU would consider the multi-user microgrid to be a utility and therefore subject to the rules governing utilities. A ruling that subjects a multi-user microgrid to such rules may discourage that ownership model. (See further discussion in Section 9.4 below.) However, subject to an actual review and decision by the DPU, an examination of the Massachusetts utility franchise law and of related DPU precedent suggests that the following microgrid models are currently permissible:

- **Single-user microgrid**, for example a university that owns and operates a distribution system serving multiple buildings on its campus;
- **Hybrid microgrid**, where the utility owns and operates the distribution systems within the microgrid and a customer or third party owns the DER;
- **Multi-user, non-utility microgrid**, where an entity other than the utility owns and operates the distribution system as well as the DER. *This is allowed only with the permission of the utility.*

Background on the utility franchise

Prior to the Electric Restructuring Act of 1997, it was not clear whether Massachusetts utilities enjoyed exclusive franchises.²² The state's "patchwork quilt" of utility franchise areas was created piece by piece over a period of more than 100 years and through a variety of authorizing documents including legislative acts, Department orders, municipal permits, and corporate charters.²³ As the Department observed, it became very difficult to verify those rights "given the passage of time and the attendant hazards of recordkeeping by the companies and their predecessors."²⁴ In one notable case, where a utility was unable to produce "documentary evidence which clearly delineated [its] franchise rights," the Department ruled that a customer was free to take distribution service from another company.²⁵ However, the Electric Restructuring Act of 1997 clarified the picture. It directed the Department to define the service territories as actually served at that time (without the need to comb through the ancient records). It established an obligation to serve, and provided that the franchises were exclusive, that no one other than the distribution utility can provide distribution service within a territory unless the utility provides its written consent. The exclusivity of the franchise is codified in Section 1B (a) of Chapter 164 of the General Laws. The statute provides that:

The department shall define service territories for each distribution company by March 1, 1998, based on the service territories actually served on July 1, 1997, and following to the extent possible municipal boundaries. After March 1, 1998, until terminated by effect of

²² Department of Telecommunications and Energy, Report to the General Court Pursuant to Section 312 of the Electric Restructuring Act, December 29, 2000 ("MBIS Report").

²³ Boston Edison Company, D.T.E. 06-40, p. 32 (2006)

²⁴ Id.

²⁵ Ecological Fibers, Inc., D.P.U. 85-71 (1985)

law or otherwise, the distribution company shall have the exclusive obligation to provide distribution service to all retail customers within its service territory, and no other person shall provide distribution service within such service territory without the written consent of such distribution company which shall be filed with the department and the clerk of the municipality so affected.

Section 1 of Chapter 164 defines the key terms used in that paragraph:

“Distribution”, the delivery of electricity over lines which operate at a voltage level typically equal to or greater than 110 volts and less than 69,000 volts to an end-use customer within the commonwealth. The distribution of electricity shall be subject to the jurisdiction of the department of public utilities.

“Distribution service”, the delivery of electricity to the customer by the electric distribution company from points on the transmission system or from a generating plant at distribution voltage.

“Distribution company”, a company engaging in the distribution of electricity or owning, operating or controlling distribution facilities.²⁶

“Retail customer”, a customer who purchases electricity for its own consumption.

“Service territory”, the geographic area in which a distribution company provided distribution service on July 1, 1997.

The Department addressed franchise exclusivity in 2002 in a proceeding involving the Olin College of Engineering (“Olin”).²⁷ Although located in Needham, which is in the NSTAR service territory, Olin requested permission to take distribution service from the Wellesley Municipal Light Department (“WMLD”). The Department denied the request, ruling that NSTAR’s service territory is exclusive and that Chapter 164, section 1B (a) “prohibits encroachment on a defined distribution service territory, absent the deliberate consent of the incumbent distribution company.”²⁸ Significantly, the Department refused to even consider Olin’s arguments that it should be able to choose to take distribution service from WMLD because WMLD could provide service more quickly, more reliably, and at lower cost.²⁹ In affirming the Department’s order, the Massachusetts Supreme Judicial Court observed that while the

²⁶ The text goes on to exclude the Medical Area Total Energy Plant (MATEP) from the definition of distribution company: “provided, however, that a distribution company shall not include any entity which owns or operates plant or equipment used to produce electricity, steam and chilled water, or an affiliate engaged solely in the provision of such electricity, steam and chilled water, where the electricity produced by such entity or its affiliate is primarily for the benefit of hospitals and non-profit educational institutions, and where such plant or equipment was in operation before January 1, 1986.”

²⁷ Franklin W. Olin College of Engineering, D.T.E. 01-95 (2002).

²⁸ Id at pp. 10 – 11.

²⁹ Id at p. 18.

Department has some discretion in resolving franchise disputes, it was reasonable to conclude that “such discretion does not extend to customers such as Olin, who seek principally to get a better deal on their electric rate from a provider across the border.” The Court noted that the “pressure on the department from customers anxious to get relief on that basis would threaten to recreate the very ‘patchwork quilt’ of electric service providers that G. L. c. 164, § 1B, was intended to prevent.”³⁰

This guidance is applicable to any potential microgrid where the primary benefit for customers is lower cost distribution service than is available from the franchise utility. Such a benefit is not sufficient to justify an exception to the exclusivity of the franchise.

The Department also addressed franchise issues in two other orders issued since the passage of the Electric Restructuring Act in 1997. In a report to the legislature in 2000, the Department reviewed arguments for and against franchise exclusivity and concluded that no amendments to the statute were warranted at that time.³¹ In 2002, the Department concluded that a supermarket could choose whether to take distribution service from Massachusetts Electric or Peabody Municipal Light Department where the parcel on which the supermarket was located straddled the two service territories.³²

In its discussions of franchise rights, the Department has articulated several principles that are relevant to microgrids:

- Customers are free to distribute purchased electricity for their own use within their own premises.³³ There are examples of this in Massachusetts today. For example, Harvard University distributes electricity within its campus.
- Franchise rights are triggered even if the entity distributing the electricity does not charge for the distribution service.³⁴ Accordingly, a microgrid developer cannot get around the franchise by providing “free” distribution service.
- A distribution company’s exclusive franchise in a municipality covers the entire municipality, including as yet undeveloped parcels.³⁵
- The Department will look askance on “creative conveyancing” designed to circumvent franchise rights. The Department listed as examples of creative conveyancing: “consolidation of fee

³⁰ Franklin W. Olin College of Engineering v. Department of Telecommunications and Energy, 439 Mass. 857, 864 (2003).

³¹ MBIS Report.

³² Stop and Shop, D.T.E. 98-122 (2002).

³³ Stop and Shop, D.T.E. 98-122, p. 9.

³⁴ Olin College at 24, n. 15

³⁵ MBIS Report.

interests in adjacent parcels on the franchise borderline, or extinguishment of public easements, so as to give rise to colorable claims of mere internal-distribution of purchased electricity.”³⁶

Crossing public ways

There is a common perception that permission from the utility is required to run a distribution line across a public way. While commonly believed, this is not correct. Section 87 of Chapter 164 provides that the consent only of the town “alderman or selectmen” is required to cross a public way. The consent of the utility is not required. Section 87 reads as follows:

In a town³⁷ where a person is engaged in the manufacture, sale or distribution of electricity, no other person shall lay, erect, maintain or use, over or under the streets, lanes and highways of such town, any wires for the transmission of electricity except wires used by street railway companies for heat or power, without the consent of the aldermen or selectmen granted after notice to all parties interested and a public hearing.

It is true that a utility would be free to contest another entity’s request to run a distribution wire across a public way. Section 87 provides that the municipality must hold a public hearing on any such request. In addition, section 88 of Chapter 164 provides that any person aggrieved by the municipality’s decision may appeal it to the Department of Public Utilities. However, the utility does not have veto power.

Stakeholder Positions

During focus groups held in July 2013, one stakeholder argued that owners of combined heat and power systems should be able to distribute electricity to nearby customers. He explained that the owner of a CHP system receives, in effect, the full retail value of the electricity when it offsets the host customer’s use. However, for any generation that exceeds the host’s needs, it receives only a much lower price – the wholesale power rate with no credit for distribution charges. If the CHP system owner could distribute power to nearby users, it could receive a higher price (closer to the full retail value), improving the economics of the project and leading to the deployment of more and larger CHP systems.

The franchise law appears to prohibit the arrangement that the stakeholder suggested, absent the agreement of the utility. However, if the Commonwealth wanted to incentivize CHP through a higher rate for excess power, there is an easier approach than allowing non-utility distribution. The

³⁶ Boston Edison Company, D.T.E. 06-40, p. 33, n.28, citing Stop and Shop and Olin College.

³⁷ Although the statute refers to a “town” rather than a “city”, the Supreme Judicial Court has interpreted the statute as applying to cities. See Boston Edison Company v. Boston Redevelopment Authority, 374 Mass. 37, 54-55 (1977).

Commonwealth could extend virtual net metering (now available to wind and solar) to CHP systems. This virtual approach could provide the same financial benefit, without the need to run additional wires or to tinker with the utility franchise. Alternatively, the exported energy could be metered and compensated for at a rate above wholesale and below retail that compensates the distribution company for the dissemination of the energy in the macrogrid.

9.4 Regulation of non-utility microgrid owners

The prospect of a multi-user, non-utility microgrid raises interesting questions about what elements of utility distribution company regulation would be applied to such an entity, including:

- Would the microgrid be classified as a “customer,” given that it would take distribution service from the utility at the PCC?
- Or, would the microgrid operator be classified as a “distribution company” and subject to regulation as such? If so, what would be the extent of that regulation?
 - Would the microgrid operator be able to set its own prices or would it be subject to MA DPU rate regulation?
 - Would the microgrid operator be subject to other MA DPU requirements for distribution companies, such as Terms and Conditions for Distribution Service, Standards of Conduct, Service Quality Standards, and Billing and Termination Procedures?
- Would the microgrid operator have an obligation to serve customers within the microgrid? Would the utility serving the surrounding franchise have an obligation to serve those customers?³⁸
- How would the rules regarding the competitive electricity market be applied to sales of electricity to customers within the microgrid?
- To what extent or limitations would restrictions on ownership of generation apply?

Our research did not uncover any Massachusetts precedent that sheds light on these questions. Massachusetts does have one multi-user, non-utility microgrid: the Medical Area Total Energy Plant (MATEP), which produces and distributes steam, chilled water, and electricity for five hospitals in Boston. However, MATEP was granted a specific legislative exemption from regulation as a distribution company.³⁹ The MATEP example does not reveal how a microgrid without such a legislative exemption would be regulated.

³⁸ Depending on the existence of wires and other factors, it might not be possible for a distribution company to immediately serve a customer seeking to separate from a microgrid, without going through a process similar to the connection of a new customer.

³⁹ The statutory definition of “distribution company” excludes “any entity which owns or operates plant or equipment used to produce electricity, steam and chilled water . . . where the electricity produced by such entity or

As discussed more fully in the Recommendations Section, we do not recommend that the DPU attempt to answer these and other microgrid regulatory questions in the abstract. Instead, we recommend that the Commonwealth launch a microgrid pilot program, and that it address the regulatory issues raised by the actual pilot projects in the context of those specific projects.

its affiliate is primarily for the benefit of hospitals and non-profit educational institutions, and where such plant or equipment was in operation before January 1, 1986,” i.e. MATEP. G.L. c. 164, § 1.

10. Recommendations

In this section, we present our recommendations which we have crafted to closely align with Massachusetts' goals for emergency preparedness, smart grid planning and deployment, renewable and clean energy installations, GHG reductions, and grid modernization and resiliency. In a state which is a leader in energy policy development, green energy technology, and prone to damaging winter storms and coastal flooding, there is a role for microgrids to enhance public safety and energy reliability to consumers. While a variety of opportunities exist to create islandable microgrid systems, we focused our recommendations on those that would provide the greatest benefit to the Commonwealth.

10.1 The intersection of Commonwealth interests and microgrid development

10.1.1 Emergency preparedness

One of the paramount benefits of microgrids is their contribution to emergency preparedness. As reported in the September 2013 microgrids report to the Minnesota Department of Commerce entitled, *Minnesota Microgrids: Barriers, Opportunities, and Pathways Toward Energy Assurance*, the authors identify three primary areas where microgrids can support emergency services: *Crisis Response and Management*, *Public Health and Safety*, and *Basic Needs and Services*. The final category addresses the need to provide access to electricity, heat, and cooling to populations who do not have the means to shelter in place.

Table 10-1: Categories for Critical for Emergency Preparedness

Asset Category	Examples	Priorities and Microgrid Factors
Crisis Response and Management	<ul style="list-style-type: none"> ■ Utility and transportation crew dispatch, supply, and staging centers ■ Government command and control centers ■ Telecom infrastructure 	<ul style="list-style-type: none"> ■ Critical to facilitate repair and Recovery, minimizing the damage from a crisis and avoiding cascading effects on interdependent systems. ■ Microgrids can be more effective when crisis management facilities are clustered together, allowing asset sharing and load diversity.
Public Health and Safety	<ul style="list-style-type: none"> ■ Hospitals and other health care facilities ■ Police and fire departments ■ Public water systems 	<ul style="list-style-type: none"> ■ Vital to support first response, medical care, and law and order. ■ Many such facilities already have backup power systems that can be upgraded with microgrid technologies to increase their effectiveness.
Basic Needs and Services	<ul style="list-style-type: none"> ■ Storm shelters and temporary housing ■ Grocery stores ■ Fuel infrastructure, including gas stations ■ Public transportation and transit systems 	<ul style="list-style-type: none"> ■ Vital products and services to support basic needs of residents, and provide shelter and vital mobility for displaced and at-risk populations. ■ Load-management systems and protocols can help conserve fuel and extend effectiveness of basic backup power supplies.

Source of table: *Minnesota Microgrids: Barriers, Opportunities, and Pathways Toward Energy Assurance*, by Michael T. Burr, Michael J. Zimmer, Brian Meloy, James Bertrand, Walter Levesque, Guy Warner, John D. McDonald. (2013) Minnesota.

To maximize the energy reliability benefits of microgrids, Massachusetts should coordinate state emergency and climate adaptation planning with microgrid policy and planning. Key questions to address include: In which of the above categories do emergency planners see the greatest need for enhanced energy reliability? How can microgrids augment emergency energy plans? What should be the key design principles for microgrids relative to incorporation of renewables, energy storage and interactions with the utility grid? Close coordination between energy planners and regulators will help to assess and quantify the benefits of microgrids and to target their development to locations where they would provide the greatest public impact. We recommend that the Department work with the state's distribution companies, including municipal utilities, the Massachusetts Emergency Management Agency, the Massachusetts Clean Energy Center, and MA DOER, to analyze the intersection between emergency services and the provision of reliable, clean energy particular when the macrogrid may not be available. We offer further guidance in the "Microgrid Challenge" section of the recommendations.

We also believe there is a role for MEMA in assisting municipalities in planning, not only for emergency shelter, food, water, and health services, but in provision of emergency power (and heat and cooling, if practical). California, in its overall resilience planning⁴⁰, advises municipalities on a variety of resiliency topics including microgrids. Likewise, municipalities are at the heart of Connecticut's electricity resiliency programs, empowering municipalities to form Energy Improvement Districts and giving municipal microgrids special dispensation to include commercial customers and cross public rights-of-way for systems 5 MW or under.

10.1.2 Smart grid planning and deployment

Tying into the idea of state advisory support for municipalities that may want to develop microgrids for emergency operations support, the ongoing design and upgrade of local distribution networks presents an opportunity to build islanding capabilities at strategic points in grid systems. Distribution utilities can and will play an important role in supporting municipalities that may wish to install additional sources of generation, and microgrid system islanding capabilities, to improve emergency response. For example, Consolidated Edison started to explore the capacities of reliably dispatchable DERs on its system and began to include these numbers in their 10 and 20 year load forecasts.⁴¹ The dispatchable DERs, which could be sited at municipal facilities, could also help utilities like Con Ed defer infrastructure investments – e.g. of substations and sub-transmission assets. However, as noted in the Massachusetts Electric Grid Modernization Stakeholder report, most current utility business models do not “recognize a future that is about connections and capability, not simply delivery.” Distribution circuit and control system planning should be done with microgrids in mind, to facilitate future interconnections, as well as cost-effective and reliable operation.

10.1.3 Massachusetts GHG goals and microgrids

This report provides a definition of a microgrid which includes the following characteristics:

- One or more points of common coupling with the local utility grid
- The ability to operate in a connected mode, or islanded from the local utility grid, and
- The ability to control DERs in a coordinated fashion.

There is no reference in the definition to the types of DERs that may power a microgrid. Every single Phase I microgrid project selected for funding in Connecticut uses natural gas and/or diesel-powered

⁴⁰ CaLEAP (California Local Energy Assurance Planning) is a California Energy Commission (CEC) sponsored project to assist local governments throughout the State in preparing plans to ensure that key assets are resilient to disaster events that impact energy. <http://www.caleap.org/>

⁴¹ Burr, M, et al, Minnesota Microgrids: Barriers, Opportunities, and Pathways Toward Energy Assurance. (2013) P 24.

technologies, with solar PV making up a small portion of the total generation capability. (See a table of Connecticut Phase I projects in the appendix). The reason for fossil-fueled based systems as the primary energy source is to improve reliability and grid stability, rather than advance GHG goals. Thus, without careful consideration, Massachusetts could fund microgrids that increase GHG's, when compared with other generation sources that may be available or developable.

10.2 Policy and regulatory recommendations

In previous sections of this report, we covered four different potential ownership models for microgrid deployment, provided examples of three different microgrids currently operating in the United States, and reported on how a handful of states and European countries are investigating microgrid-enabling markets and regulations. As the team prepared recommendations for this report, a lengthy initial list of policy and regulatory recommendations and considerations emerged. In our attempt to cover every potentiality that could occur with different end-user configurations, tariffs, rate treatment, ownership models, energy services contracts etc., it became clear that regulators and policymakers could waste significant amounts of time regulating situations that might never come to pass in Massachusetts.

Therefore, our overarching policy and regulatory recommendation is to initiate a Microgrid Challenge, similar to the program (with perhaps a higher emphasis on GHG goals) established in Connecticut, and, in doing so, "pilot and learn". The Microgrid Challenge, as laid out below, will allow the MA DPU, MA DOER, MassCEC, and the distribution utilities to focus on the actual issues that arise, rather than forecasted regulatory and policy issues that have to be addressed to move microgrids forward.

10.2.1 Issue a Microgrid Challenge

To foster the development of microgrids, and to explore the business models and benefits through actual projects, the Commonwealth should implement a "Microgrid Challenge" pilot program.

The Microgrid Challenge should have the following elements:

- The MassCEC would run the Challenge and would provide incentive funding to the winning pilot projects ("projects")
- The MA DPU would encourage each utility to participate actively in the development of one or more projects, and provide for cost recovery.
- The Challenge would fund at least one project in each of the following categories:⁴²

⁴² A project could consist of more than one of these three elements. The MassCEC could attempt to select projects with a diversity of sizes, loads, generation mixes, etc.

- **Municipal Security:** a microgrid serving critical facilities in a municipality such as police and fire, town offices, and a building that could serve as a shelter, e.g. a high school or YMCA
 - **New Development District:** an area of a municipality that is targeted for significant new development with the potential for CHP and other clean energy generation
 - **Energy Reliability District:** an existing portion of the macrogrid would be converted to an energy reliability district through the addition of islanding, controls and DER within the district
- The Challenge would seek competitive proposals, and would strongly encourage proposals from teams including developers, utilities, municipal light plants, municipalities, and customers
 - Proposals would be required to use carbon reducing generating technology such as dual fuel use CHP and renewables and the project would produce a net decrease in GHG emissions
 - Proposals would be developed in coordination with the local utility, and would be required to identify any exemptions from existing DPU regulations or special tariffs needed to implement the project
 - MassCEC would select winners in consultation with the DPU
 - The DPU would review and approve tariff / regulatory exemptions as necessary and appropriate
 - Open communication is vital to extracting value from each microgrid project. The developers/utilities must regularly report to the MassCEC and the staff at the MA DPU any barrier encountered. Ongoing reports of project performance and lessons learned would be issued and made public by the MassCEC.

Regarding possible regulatory exemptions, because the specific configuration of microgrids, participants, and sources of generation that may be proposed for a Microgrid Challenge are, as yet, unknown, we cannot be specific as to which exemptions might apply. It's possible to anticipate that the Department would need to consider the following exemptions:

1. Permit the use of distribution company wires within the designated microgrid for a set monthly fee to the distribution company.
2. Waive requirements for a competitive supplier when the power is shared only within a designated microgrid.
3. Permit microgrid participants to allocate energy purchased from the macrogrid to participants based on an administrative agreement with the participants
4. Consolidate demand charges at the PCC for participants and permit the allocation of charges based on an administrative agreement of the participants.

For instances in which the distribution company does not own the wires in the microgrid:

5. Hold the distribution company responsible for power quality only up to the PCC (unless fees or distribution charges are billed by the distribution company individually to the participants).
6. Waive the obligation to serve by the distribution company beyond the PCC. Participants later opting out of the microgrid would request reconnection as a new customer load.

We recommend the pilot program approach because it is impossible to anticipate all of the issues and adopt a comprehensive framework at this time. While there is a good deal of discussion about microgrids, and much promise, the number of actual microgrid projects that could be developed in the short term is likely to be limited. The Commonwealth can advance these projects more quickly by implementing a pilot program that identifies and resolves issues rather than attempting to promulgate a comprehensive set of rules, which might end up being used by only a handful of projects. Also, much of the technology and the business models for microgrids are at an early stage of development and are evolving rapidly. Given this dynamic situation, we believe the Commonwealth should support a limited number of pilot projects as the best way to advance the development of microgrids and assess the need for changes in regulatory framework. It is critical that lessons learned be shared with the state and the public.

10.2.2 Build a foundation for microgrids with low carbon DER

One of the most important things that the Commonwealth can do to support microgrids is to continue to create a favorable environment for DER development. The framework needed to support DER is not microgrid-specific; however, it is an essential enabling condition for microgrid development.

A favorable framework for DER includes several regulatory and program initiatives already in-place or underway in Massachusetts. These include streamlined interconnection standards, an alternative energy portfolio standard, incentives for combined heat and power projects, and virtual net metering. Additional topics for review include cost allocation when cost is incurred for the distribution system to accommodate DER, rate design for the export of excess DER electricity to the grid at a higher than wholesale rates, the availability of time-varying rates, appropriateness of standby charges and the obligation to serve, as it applies to customers with DER. Additional progress in these areas will enable additional development of DER systems, on both a stand-alone basis, as well as within a microgrid environment when appropriate.

10.2.3 Target clean energy and energy efficiency incentives to include microgrids

Massachusetts has a remarkably successful history of using incentive funds to foster the deployment of clean energy technologies. Renewable generation technologies have received support from MassCEC and the utility energy efficiency programs now provide support for CHP. In order to promote the deployment of DER that provides energy security benefits, we recommend that these incentives be supplemented with:

- Additional grant or other financial incentives to add microgrid functionality (including islanding and storage), and/or
- Requirements for microgrid functionality in order to be eligible for some portion of existing incentives.

The existing clean energy programs also provide a valuable opportunity to offer technical assistance along with financial incentives. For example, program administrators and state agencies should arrange for provision of education and training for potential companies and employees in the “microgrid industry”, along with information exchange with the electric utilities operating within the state. This information should include the application to microgrids of new technical protocols and design standards as they are developed, as well as existing codes⁴³. This could be done through an expansion of the information exchange functions related to the existing interconnection process for distributed generation.

10.3 Recommendations for the longer term

The Microgrid Challenge will help the MA DPU, microgrid developers, the distribution utilities and microgrid participants to flesh out the near-term regulatory and financial hurdles to creating and operating the several types of microgrids suggested for the Microgrid Challenge. There are issues that can and should be explored whose resolution will support energy efficiency and distributed generation deployment in addition to supporting microgrid development where practicable.

10.3.1 Energy Reliability Districts

The idea of an Energy Reliability District (ERD), introduced as a close facsimile of energy improvement districts, builds upon the concept of energy improvement by creating districts that can island from the macrogrid. The critical loads within the ERD may include municipal infrastructure, but other issues such as local grid congestion, businesses that are sensitive to power outages and power quality, may motivate development. As the Commonwealth recently announced funding for comprehensive climate change preparedness initiatives, with directives for Executive Office of Environmental Affairs to inventory generation facility vulnerabilities, the state will soon have an overview and maps where generation facilities need to be protected and potentially supplemented by power from microgrids.

After initial generation and grid vulnerabilities are identified, we suggest that the MA DPU commission a study of ERD potential. With background work completed by the study, we further suggest that the MA DPU, MassCEC, MA DOER, MA Legislature, distribution utilities, industry leaders and municipalities

⁴³ This would include for example IEEE 1547, the National Electric Safety Code (“NESC”), the National Electric Code (“NEC”) and NERC requirements.

consider a legal framework for ERD's. The logical path to implementation would be to introduce legislation. Based on establishment of ERD's within municipalities and elsewhere, encourage utilities to include the ERD's in their system planning activities. The MassCEC is well-positioned to lead this effort due to its extensive community programs and close connections to all agencies listed.

10.3.2 Commercial Property Assessed Clean Energy Financing for Microgrids

The Massachusetts Legislature passed PACE legislation in 2010, and there have been subsequent efforts to augment the law to address the structure of project financing. Commercial Property Assessed Clean Energy (C-PACE) allows financing of energy efficiency and renewable energy projects that have a long payout and therefore are not attractive to lenders (or borrowers) through traditional debt-financing mechanisms. Rather, PACE is paid for by an assessment via local property taxes and becomes the senior lien, meaning first lien to be paid off, when a property transfers hands. The assessment does not appear as a debt on a business's books, and more importantly, the unpaid portion of the debt stays with the property where the benefits (i.e. energy improvements) also remain.

To date, no Massachusetts municipality has implemented a PACE program under the 2010 statute, which, according to a DOER commissioned study, is because the law created obstacles to financing by adopting a "top down" or "fund based" approach. It is our understanding that revising PACE legislation is currently under consideration by the Massachusetts Legislature.

Connecticut recently established its own C-PACE program as administered by its Clean Energy Finance and Investment Authority (CEFIA). As of this writing, at least 68 municipalities⁴⁴ had adopted the state's C-PACE program. CEFIA has taken steps to alter the enabling C-PACE legislation to address development of microgrids and their associated financing. The Investment Authority is taking advantage of a recently amended Connecticut law that allows CEFIA to finance district heating and cooling systems, and will seek the approval to fund microgrids as well.

To help developers finance district heating and cooling systems, CEFIA is considering district participant payments using two invoicing approaches: 1) fixed costs that would pay for infrastructure (similar to the rate-based costs that utilities levy to recoup their capital investments). The fixed costs could be correlated to the system capacity built for each participant's building; 2) varying costs; not only monthly utility bills but a roll up of any CHP –related electricity savings such as demand response program participation.

When commercial buildings such as a supermarket or convenience store plan to participate in a microgrid that includes public entities – perhaps city hall, a library, or a recreation center – then C-PACE property assessments can only be made to hosts that are non-municipal entities (including non-profits). However,

⁴⁴ See Connecticut's C-PACE program website: <http://www.c-pace.com/site/page/view/resources>

CT law does allow municipal entities that are in a long-term contract with a microgrid host to benefit from virtual net metering. The municipal building(s) is not required to contain the microgrid's generation equipment but can still assign the full retail price of electricity exported to the grid by the microgrid to other municipal electricity accounts.

The Massachusetts Legislature should consider in any revision of the PACE law specifying that community and microgrid and/or district heating and cooling systems are eligible for commercial PACE financing including Energy Reliability Districts and/or simply multi-user microgrids. Specifically, it will be necessary to address public/private combinations of properties to ensure that the appropriate lower cost long-term financing is available. The Commonwealth should also consider whether microgrid enabling controls and islanding equipment qualify for C-PACE financing.

Because PACE legislation has passed in so many states, it will be useful to review progress in states with active programs and adopt best practices in Massachusetts.

11. Conclusion

The intent of this research report is to provide a clear policy direction for the Commonwealth of Massachusetts on the subject of microgrids. At present, designing the DERs, controls, communications, and isolation technologies to operate as a coordinated, stable, and islandable microgrid is a rapidly emerging technical field. Furthermore, while the benefits of installing DERs on the grid and the benefits of microgrids are often mistakenly interchanged, a microgrid may provide incremental clean energy benefits. Microgrid control technologies can also provide additional (monetary) value by managing power exchanges with the macrogrid, and thereby generating additional revenue for the microgrid facility.

We have offered a set of recommendations that align with Massachusetts' goals for greenhouse gas reductions, public safety, emergency preparedness, and smart grid implementation, and rather than setting forth all of the legal, policy and regulatory changes the Commonwealth could possibly anticipate, we have suggested a focused pilot program that will guide the Commonwealth, distribution utilities, and future microgrid developers and other stakeholders, while identifying the most pressing legal and regulatory issues that must be addressed. We have also suggested Energy Reliability Districts and the augmentation of Massachusetts PACE legislation for long term focus by the Commonwealth.

12. Bibliography

- An Act Relative to Green Communities in the Commonwealth of Massachusetts, Senate No. 2768. 2008.
- Berry, T., *Ownership & Operation Options for a Neighbourhood Energy Utility*, prepared for the City of Seattle, Compass Resource Management, Ltd., 4 April 2011.
- Blik, Frits, Albert van den Noort, Bart Roossien, R. Kamphuis, J. de Wit, J. van Der Velde, and M. Eijelaar. "PowerMatching City, a living lab smart grid demonstration." In Innovative Smart Grid Technologies Conference Europe (ISGT Europe), 2010 IEEE PES, pp. 1-8. IEEE, 2010.
- Bowles, I. 2010. *Massachusetts Clean Energy and Climate Plan for 2020*.
- Burr, Michael T., Michael J. Zimmer, Brian Meloy, James Bertrand, Walter Levesque, Guy Warner, and John D. McDonald. "Minnesota Microgrids." (2013).
- California Public Utilities Commission Energy Division, "Introduction to the California Net Energy Metering Ratepayer Impacts Evaluation," October 28, 2013.
- Compass Resource Management Ltd. "Towards a Long-Term District Energy Vision & Strategy for the City of Vancouver: Background, Issues and Opportunities," prepared for the City of Vancouver, Vancouver, BC, Canada, December 2012.
- Connecticut Public Act 13-298, An Act Concerning Implementation of Connecticut's Comprehensive Energy Strategy and Various Revisions to the Energy Statutes, July 2013.
- Danforth District Heating, *Hamburg is the District Heating Capital of Germany, Case Story – Hamburg HafenCity, Germany*.
- DeBlasio, D. 2013. "Distributed Generation and Microgrids, Cycle of Innovation". *Fortnightly Magazine*, <http://www.fortnightly.com/article-categories/distributed-generation>.
- Department of Energy, United States of America, Office of Electricity Delivery and Energy Reliability Smart Grid R&D Program. "Summary Report: 2012 DOE Microgrid Workshop," Chicago, IL 2012.
- e-Lab Electricity Innovation Lab, Rocky Mountain Institute, "A Review of Solar PV Benefit & Cost Studies," April 2013.
- Electricity Innovation Lab, Rocky Mountain Institute, "New Business Models for the Distribution Edge, the Transition from Value Chain to Value Constellation," April 2013.
- Energy Future Coalition, a Project of the United Nations Foundation, *Utility 2.0, Piloting the Future for Maryland's Electric Utilities and Their Customers*, submitted to Governor Martin O'Malley, 15 March 2013.

Eto, J. "The CERTS Microgrid Test Bed." 2012 Smart Grid R&D Program Peer Review Meeting, Lawrence Berkeley National Laboratory, 7 June 2012.

Executive Office of Energy and Environmental Affairs – Department of Energy Resources, Massachusetts Clean Energy Center, Meister Consultants Group, "Heating and Cooling in the Massachusetts Alternative Portfolio Standard, Report to the Legislature," December 2012.

Hyams, M.A., 2010. *Microgrids: An Assessment of the Value, Opportunities and Barriers to Deployment in New York State, Final Report*. Prepared by Center for Energy, Marine Transportation and Public Policy at Columbia University, New York, NY, with Columbia Law School's Environmental Law Clinic, New York, NY and with Pace Energy and Climate Center, White Plains, NY.

Jones, A. "OFGEM Distributed Energy Review, Review of Arrangements for Distributed (Decentralised) Energy." (2007).

KEMA Inc., Itron, and Energy & Resource Solutions. 2011. Project 1C Combined Heat & Power Market Characterization, Large Commercial & Industrial Evaluation, prepared for Massachusetts Energy Efficiency Program Administrators.

King, M. and Parks, M. "Community Energy: Planning, Development and Delivery." International District Energy Association, 2012.

McGuire Woods & McGuire Woods Consulting, *District Energy Systems: An Analysis of Virginia Law*, prepared for the Northern Virginia Regional Commission, August 2011.

Massachusetts Department of Energy Resources. "Grid Modernization and Integrating Distributed Generation." <https://sites.google.com/site/massdgc/home/interconnection/grid-modernization>.

Massachusetts Distributed Generation Collaborative, "2005 Annual Report," submitted to The Massachusetts Department of Telecommunications and Energy in Response to D.T.E. Order 02-38-B, May 31, 2005.

Massachusetts Technology Collaborative, "Massachusetts Distributed Generation Collaborative 2006 Report," June 30, 2006.

Microgrids at LBNL. <http://der.lbl.gov/>. Berkeley, Calif.: Lawrence Berkeley National Lab.

Morris, Greg Young. (2012). A Framework for the Evaluation of the Cost and Benefits of Microgrids Lawrence Berkeley National Laboratory: Lawrence Berkeley National Laboratory. LBNL Paper LBNL-5025E.

NYS 2100 Commission. "Recommendations to Improve the Strength and Resilience of the Empire State's Infrastructure." (2013).

- Petrill, E., Thimsen, D, Price, S., Nimmons, J., Torpey, J., and Weston, R. 2007. *Creating Incentives for Electricity Providers to Integrate Distributed Energy Resources*. EPRI, Palo Alto, CA, California Energy Commission, Sacramento, CA; Massachusetts Division of Energy Resources, Boston, MA; Massachusetts Technology Collaborative, Westborough, MA, and National Association of State Energy Officials, Alexandria, VA. 1014899. CEC-500-02-014.
- Raab Associates, Ltd. & Synapse Energy Economics, Inc., “Massachusetts Electric Grid Modernization Stakeholder Working Group Process: Report to the Department of Public Utilities from the Steering Committee,” 2 July 2013.
- The City of New York Mayor’s Office of Long Term Planning and Sustainability. 2013. “New York City Distributed Generation Collaborative – Summary of Proceedings.” New York, NY.

A. Appendices

A.1 Microgrid Activity in the U.S. and Europe

California

California is home to arguably the three best known microgrid demonstration projects in the U.S.: SDG&E's Borrego Springs project, the Santa Rita Jail, and the University of California-San Diego microgrid. The state has successfully leveraged funding from the federal government, primarily the U.S. DOE, and invested its own funds through the California Energy Commission and other state-sponsored programs to support microgrid development. The latest CEC microgrid awards include a mix of military and university projects:

- \$1.7 million award to develop a set of intelligent microgrids that use community scale renewable resources within an existing utility grid - Marine Corps Base, Camp Pendleton.
- \$2 million award to share costs in a U.S. DoD vehicle-to-grid demonstration project - Naval Air Weapons Station, China Lake.
- \$1.6 million award on top of previous funding of \$1.4 million for the UC San Diego's electric microgrid. Additional \$200,000 funded to expand campus charging network for plug-in electric vehicles.

The projects are presented to demonstrate the scale of investment required for microgrid innovations.

In addition to the CA Renewable Portfolio Standard requirement of generating 33% of the state's electrical energy requirements with renewable resources by 2020, California passed legislation in 2009 requiring net surplus compensation for customers producing renewable energy in excess of their site-loads over a 12 month period. The majority of net energy metering (NEM) customers in California generate energy with solar PV systems (99% of accounts, and 96% of capacity).⁴⁵ For solar PV, the NEM tariffs paid by California IOU's are equivalent to full retail electricity rates. Thus, the market for renewable energy production, and particularly solar PV production, has been very attractive. The NEM and microgrid awards created a financial environment in which innovation (and microgrids) can flourish.

On the resilience front, California joined the U.S. DOE in funding the California Local Energy Assurance Program (CaLEAP) in 2011. The program aims to help local governments develop strategic plans for energy assurance by offering education and technical assistance. While not solely focused on promoting

⁴⁵ Energy and Environmental Economics, Inc., *California Net Energy Metering Ratepayer Impacts Evaluation*. 2013. San Francisco, CA.

microgrids, the program has led three educational sessions for local government officials focusing on microgrids and even included a trip to see the UCSD microgrid installation. CaLEAP also encourages communities to collaborate with their local utilities to better understand their positions in regard to local energy assurance and resilience.⁴⁶

Connecticut

Of the states currently piloting microgrid projects, the state of Connecticut has proven to be a front-runner in terms of enabling legislation and state funding for microgrids. A brief review of electricity reliability and congestion problems provides insight into Connecticut's push to develop microgrids. Among the New England states, which experience the highest electricity rates in the continental U.S., Connecticut's electricity rates are consistently the highest⁴⁷. While higher New England electricity rates are due to the structure of the electric industry in New England as well as wholesale market rules, grid congestion is a considerable factor in Connecticut.⁴⁸

In 2007, the Connecticut legislature passed An Act Concerning Electricity and Energy Efficiency (PA 07-242) which among other provisions, empowers a municipality, by a vote of its legislative body, to establish energy improvement districts (EID's). The EID concept is based upon the better known Business Improvement District, and the purpose of the EID is not only to reduce energy costs, improve reliability, and promote clean energy systems, it also provides the legal framework for municipalities and non-municipal entities to work together voluntarily. An EID lays out the leadership structure, financial powers, and relationships between EID participants, governing board, and municipality itself.

More specifically, in Connecticut, an EID is governed by an appointed district board which has the power to: hire staff, operate distributed resources, charge fees for its projects and issue revenue bonds. The district is required to develop a plan, in conjunction with the CT Center for Advanced Technology, for siting, financing, and coordination with the integrated resources plans of the local electric distribution company. Municipalities themselves are empowered by the Act to guarantee district bonds, issue general obligation bonds to support the district, and fund district activities. Thus, the EID is an organizational tool and legal entity meant attract capital investment by mitigating the risk of investing in self-organized, wild cat projects.

⁴⁶ Burr, M, et al, Minnesota Microgrids: Barriers, Opportunities, and Pathways Toward Energy Assurance, report page 21

⁴⁷ U.S. Energy Information Administration. Accessed December 2013. Retail Sales and Revenue Aggregated 1990-current. See: <http://www.eia.gov/electricity/data/eia826/>

⁴⁸ McCarthy, Kevin. Factors Behind Connecticut's High Electric Rates. (2008) Office of Legislative Research, Connecticut General Assembly. Web published: <http://www.cga.ct.gov/2008/rpt/2008-R-0452.htm>

By the end of 2011, two storms had ripped through the New England region, Tropical Storm Irene and an unexpected Halloween ice storm that downed utility infrastructure across the state. In fact, the ice storm left thousands of people without power for up to three weeks, and in a few instances, even longer.

In response, Connecticut Governor Dannel Malloy acted quickly to pass Public Act No. 12-148, or An Act Enhancing Emergency Preparedness and Response, effective July 1, 2012. The law created a new CT Department of Energy and Environmental Protection (DEEP) and empowered the agency to “establish a microgrid grant and loan pilot program to support local distributed energy generation for critical facilities.” Initially funded at \$15M and later augmented to \$18 M, DEEP sought RFI’s for microgrids from municipalities, electric distribution companies, participating municipal electric utilities, energy improvement districts and private entities. Shortly thereafter, DEEP rapidly published an RFP to solicit microgrid projects that would enhance preparedness of critical facilities. DEEP’s grant funding has been targeted for the costs of islanding equipment, connections, and interconnection studies, and the first round of projects has been selected.

As municipalities, universities, hospitals and developers prepared proposals for CT’s microgrid grant program, it forced the state to begin addressing the regulatory and legal impediments that have unintentionally created barriers to microgrid systems. By July 2013, Connecticut had passed additional legislation - Public Act No. 13-298 (An Act Concerning Implementation of Connecticut’s Comprehensive Energy Strategy and Various Revisions to the Energy Statutes) - with provisions that:

- Further define critical infrastructure such that municipal microgrids may include critical commercial areas,
- Provide a pathway for commercially and publically-owned buildings to participate together in a microgrid,
- Establish virtual net metering for microgrids that host municipal, state, or agricultural customers, and
- Allow municipal, state, or federally owned microgrids to independently distribute electricity across a public highway or street that is generated from Class I renewables (solar PV, wind, fuel cells, biomass etc.) or from a generation source under 5 MW of capacity.

Table A-1: First Phase Microgrid Projects Funded in Connecticut

Host	Microgrid Project Details	Energy Sources	DEEP Grant Funding is targeted to equipment and costs related to interconnection
Bridgeport	City hall, police station, and senior center	Three 600 kW gas-fired microturbines	\$2.97 million
Fairfield	Police station, emergency operations center, cell tower, fire HQ, and homeless shelter	50 kW and 250 kW gas-fired engines, 47 kW PV array	\$1.16 million
Groton	Naval submarine base	5 MW turbine CHP, 1.5 MW diesel generator	\$3 million
Hartford - Parkville Cluster	Parkville neighborhood, including school, senior center, library, supermarket, and gas station	600 kW gas turbine	\$2.06 million
University of Hartford	University campus and St. Francis Hospital	250 kW and 150 kW diesel engines plus existing, 1.9 MW diesel engine	\$2.27 million
Middletown	Wesleyan University campus and athletic center/public shelter	2.4 MW and 676 kW, gas-fired CHP	\$694,000
Storrs	University of Connecticut Depot campus	400 kW fuel cell, 6.6 kW PV array	\$2.14 million
Windham	Two schools for public shelter	Two 130 kW gas engines, 250 kW PV array, 200 kWh battery, and 2 kW diesel	\$639,950
Woodbridge	Police station, fire station, Department of Public Works, town hall, and high school	1.6 MW gas turbine, 400 kW fuel cell	\$3 million

To address the financing of microgrids, Connecticut is considering altering the language authorizing Commercial Property Assessed Clean Energy program (C-PACE) to fund microgrids. The law currently applies only to buildings and district heating and cooling systems.

Connecticut's focus on microgrids for emergency preparedness helps limit current regulatory and legal legwork. Even so, there is more work to be done. For example, the Public Utilities Regulatory Authority (PURA) must conduct a proceeding to develop program specifications for virtual net metering, and new

configurations of microgrids will cause new questions to surface. Connecticut's leadership on microgrids is helping to address microgrid issues now being raised across the U.S.

Europe

A number of European countries have developed and tested microgrids. Generally, EU countries have tackled the study of microgrids under the larger conceptual umbrella of smart grids. Europe is itself an interesting landscape in which to consider "smart grids" in that historically, each nation has planned and developed its own grid system, with limited interconnections between countries. Flipping this traditional model on its head is the aggressive pursuit of renewable energy generation by the European Union. The European Council has set a target of a 20% share of renewable energy in the European Union (EU) by 2020 (European Commission 2008b.)

Because renewable energy systems, particular wind power, are located in northern Europe, and cannot be wholly absorbed by local energy storage or consumption, European countries are undergoing multiple transmission system upgrades including installation of new transmission lines (which are naturally running into local opposition from those who would be neighboring the new installations).⁴⁹ The point of reviewing the overall state of the European grid is to note that EU policy is driving EU countries toward a "pan-European competitive electricity market".⁵⁰ Therefore local experiments real-time market pricing - a.k.a. transactive energy - will be subject to significant change once a pan-European competitive electricity market is functional. Following are descriptions of two European countries with microgrid experiments.

Denmark - EcoGrid EU

Denmark's state-owned gas and electricity transmission utility launched the "Cell Controller" project in 2005 to demonstrate use of grid-connected DERs to support grid reliability and power-flow applications. The state transmission utility, Energinet.dk, worked with DERs such as wind turbines, demand response measures, and CHP plants to provide and augment ancillary services on the local grid network. The seven year project developed Danish expertise with grid control technologies and the output of DERs that are required to control power quality and synchronization with the larger grid, and that lead to design of successful microgrids. The project, in part, was intended to island the low voltage distribution networks and provide power through local DERs. Live field tests including a demonstration of the Cell Controller were implemented in 2008 and continued through 2011.

⁴⁹ Lewin, P. L., J. Altus, G. Amaratunga, R. Belmans, J. Blom, H. Frank, L. Haarla et al. "Transforming Europe's Electricity Supply—An Infrastructure Strategy for a Reliable, Renewable and Secure Power System." EASAC policy report 11, 2009.

⁵⁰ Ibid

After this successful demonstration, a Cell Controller project was launched on the Danish island of Bornholm as part of the four-year EcoGrid EU smart grid project. The purposes of the project are manifold: 1) to successfully balance the island grid with as much as 50% renewable energy sources (wind, biomass and photovoltaics), 2) to engage electricity consumers in response to real time market prices, 3) to gauge consumer response to real-time prices such as adoption of DR, and 4) to solicit customer feedback on the perceived successes and failures of the demonstration.

The project involves 1,900 electricity customers and up to 100 industry/commercial buildings who are provided real-time market prices in five minute increments. For commercial customers, the EcoGrid EU project will test direct control options advanced building control software developed by Siemens. The software integrates with the local building management system (BMS) and automates the decision process of shedding loads (or not) based on minimizing costs and occupant discomfort.

Households, on the other hand, are divided into four groups:

1. Statistical control group: 200 households with smart meters but no access to specific information or smart equipment.
2. Manual control group: 400-500 households with smart meters receiving simple market price information. These users must manually change their energy consumption pattern themselves.
3. Automatic control group 1: 700 automated households with IBM Green Wave Reality equipment and smart meters. All houses have heat pumps or electric heating all respond autonomously to price signals.
4. Automatic control group 2: 500 automated households with Siemens equipment and smart meters. All houses have heat pumps, or electric heating; all respond to aggregator control.

The EcoGrid EU project on Bornholm began in May of 2013 with system installations extending through August 2013. The project continues with early field testing and will carry on the demonstration for the next 2 to 3 years.

The Netherlands – PowerMatching City

Started in 2007 as part of the EU-funded INTEGRAL program, the PowerMatching City developed, built and demonstrated an integrated smart grid solution in Hoogkerk, (near the city of Groningen) The Netherlands. The initial phase consisted of 25 interconnected households, and the purpose of the demonstration was to optimize each stakeholder's goals simultaneously using real-time energy market information. The parameters were cost and comfort, both of which were optimized among the 25 households while managing market information from the local distribution grid.

The demonstration was facilitated by agent-based PowerMatcher technology which computes simultaneous optimizations. Each household had a variety of “smart” technologies including micro-CHPs, hybrid heat pumps, hot water storage, electric cars, smart appliances such as freezers, washing machines etc. which communicated via a single ICT solution. Project proponents explain concisely how PowerMatching City worked in terms of the consumer/producer or “prosumer”:

The economic benefits for a prosumer can be maximized by continuously seeking the highest profits for energy export towards the grid and minimizing the costs for import from the grid. This provides the flexible reactive power for a smart grid. The real time price is used as a balancing mechanism to express the scarcity or surplus of energy in the grid. With the introduction of a transport tariff or energy tax, effectively the in-home market is partly decoupled from the local electricity market. This introduces a preference to consume the in-home produced energy and results in less flexibility to be provided to the grid.⁵¹

In 2011, Phase I results showed that the combination of technologies and control software deployed for the demonstration allowed households to reduce peaks and flatten consumption curves, making it easier for the grid operator to balance supply and demand. A 15 minute video of the project including assessments by the household participants is available at:

<http://www.youtube.com/watch?v=jBYPXF84f4s>

Phase II, now under way, will focus on the development and demonstration of business models for new electricity and heating services. Participation will be increased from 25 to 50 - 75 households and the number of electric vehicles and charging stations will be increased. Different control schemes will be offered to the end-users, based on real-time pricing. There are also plans to integrate results of

⁵¹ Blik, Fritz W. A. van den Noort, B. Roossien, I.G. Kamphuis, J. de Wit, J. van der Velde, M. Eijelaar, PowerMatching City, a living lab smart grid demonstration. IEEE. Jan 01, 2010.

PowerMatching City into normal energy market processes like allocation, reconciliation, and customer billing.⁵²

⁵² Ibid.

A.2 Microgrid Report Stakeholder Discussion Participants

The Massachusetts Clean Energy Center would like to thank the following groups for participating in our microgrid stakeholder discussions:

Anbaric	MA Division of Capital Asset Management
Boston Redevelopment Authority	MA Department of Energy Resources
Celtic Energy	Massachusetts Port Authority
City of Boston	Metropolitan Area Planning Council
Clean Energy State Alliance	Millennium Partners
ClearEdge Power	MIT Lincoln Laboratory
Constellation	National Grid
COWI	New England Clean Energy Council
DNV KEMA	NSTAR
EDF Climate Corps	NYU Law
Edison Electric Institute	Pareto Energy
Environment Northeast	Peregrine Energy Group
Greenwood Energy	PowerOptions
Harpoon Brewery	U.S. Department of Energy
Harvard University	UMass-Amherst
ISO-NE	Veolia Energy NA
Longwood Medical Energy Collaborative	

