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Multi-User Microgrids: Obstacles to Development and Recommendations for Advancement

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Acknowledgements

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The research team is solely responsible for the final version of this report, including any remaining errors.

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Executive Summary

Multi-user microgrids (MUMs) are an emerging approach to electricity service that allows neighboring customers to obtain greater resilience in electricity service, from a set of locally-installed distributed energy resources (DERs) of their own choice (sometimes including solar energy and energy storage), through joint participation in a power production and delivery system that can operate independently from the host electric utility.

To date, there are relatively few MUMs in operation. This is primarily because regulated utility service from the electricity grid has historically been adequate and cost-effective for most customers – and it is highly likely that this will remain largely true, so that MUMs will not become widespread anytime soon. However, with improving microgrid economics and increasing customer needs for resilience, there will be a growing number of situations in which MUMs will become viable. Even today, certain sets of customers find the benefits offered by MUMs to outweigh the additional costs.

Despite this, MUM activity has been extremely limited because of a number of significant barriers associated with implementing this novel business model. Exacerbating this, there is a dearth of comprehensive study on these barriers. Consequently, the goal of this research is to provide a first investigation into the barriers to MUM development and some early hypotheses on potential remedies that would facilitate MUM development when and where they might be a good solution – with a particular focus on the Northeastern U.S.

Based on review of publicly-available information augmented by targeted interviews with individuals who have been active in the MUM arena, the research uncovered seven primary barriers to MUM development:

- Inability to Monetize Resilience (and Other Value Streams)
- Conflicts with Pre-Existing Rights Associated with Electricity Delivery
- Preferential Rights for Utilities to Cross Public Rights-of-Way
- Ambiguity About Viable MUM Ownership Models
- Utility Assertion of Rights Via Legal Action
- Lack of Suitable Risk-Mitigation Structures
- Insufficient Leadership to Coalesce Solutions

Our research further surfaced the following actions that have generally been helpful to date in addressing these barriers and facilitating development of MUMs:

- Utility Ownership or Strong Utility Participation in MUMs
- Creatively Leveraging Opportunities to Reduce MUM Costs
- Tailoring Business Models to Situation-Specific Needs
- Phased Development to Spread Costs Over Time
- Robust Execution Capability and Stakeholder Collaboration

Based on our findings, the research team recommends the following activities by stakeholders committed to advancing MUM viability:

- Increasing Awareness and Understanding of MUM-Specific Issues
- Strengthening Regulations and Policies to Improve MUM Playing Field
- Standardizing MUM Design and Implementation
- Creating Viable Mechanisms Valuing and Monetizing MUM Services
- Learning from MUM Innovations Elsewhere
- Organizing for Greater Impact

The report concludes with some suggestions on topical areas that merit additional research to improve the ability to successfully develop MUMs where they can create significant value for customers.

Introduction and Context

What is a Multi-User Microgrid?

Multi-user microgrids, or MUMs for short, are an emerging approach in the energy sector that provides multiple energy consumers the ability to self-supply electricity during grid outages while continuing to leverage the existing power grid during the majority of time when the grid is operating normally.

For most customers and in most locations where the electricity grid is robust, electricity service offered through traditional distribution utilities operating as regulated natural monopolies is fully satisfactory – and this is likely to remain the case for the most part. However, for certain customers and locations, the benefits of adopting a MUM to augment conventional electricity service may outweigh the additional costs. Moreover, this trend is likely to increase due to:

- Recent advances in the performance and economics of distributed energy resource (DER) technologies such as solar energy and energy storage

- Increasing desire for electricity customers to make their own choices about electricity supply, particularly from cleaner sources (e.g., solar) than available from the grid

- Growing necessity for continuous electricity supply in a digitized world in the face of a growing array of natural and human forces that threaten interruptions in grid-based electricity service

Referring to the last point, nonstop 24/7/365 access to electricity under any and all circumstances is sometimes referred to as "resilient power". The following four examples illustrate acute customer needs for resilient power:

- A data center providing web and cloud-based services may be required to pay compensatory damages or may otherwise lose business from dissatisfied customers if operations are disrupted by a loss of power supply.

- A fertility clinic that maintains patient eggs at a constant chilled temperature via an industrial refrigeration unit may face significant legal risk from losing power for even a short period of time.

- Certain healthcare and senior citizen resident communities.

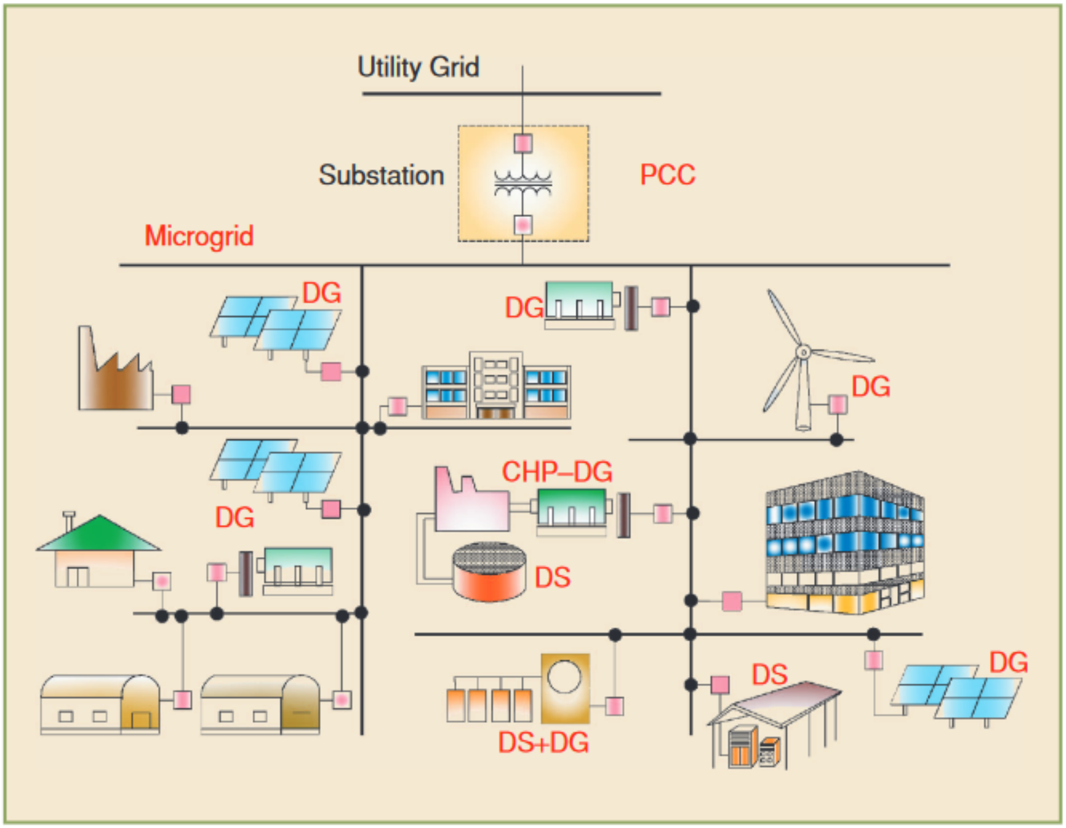
- A municipality in a region prone to extreme weather events (such as hurricanes) becomes subjected to financial and social costs when power is interrupted to critical community facilities (such as emergency response services).

For customers like these, an increasingly commonplace method to obtain resilient power is to implement a **microgrid**.

Although several alternative definitions for a microgrid have been put forward, the definition established by the U.S. Department of Energy (DOE) is one of the most frequently cited, and is suitable for the purposes of this report:

> *"A group of interconnected loads and distributed energy resources within clearly defined electrical boundaries that acts as a single controllable entity with respect to the grid. A microgrid can connect and disconnect from the grid to enable it to operate in both grid-connected or island-mode".*[i]

An illustration of a generic microgrid fitting DOE's definition is presented below.



Source: "Microgrids Management" by Katiraei, Iravani, Hatziargyriou and Dimeas, IEEE, 2008

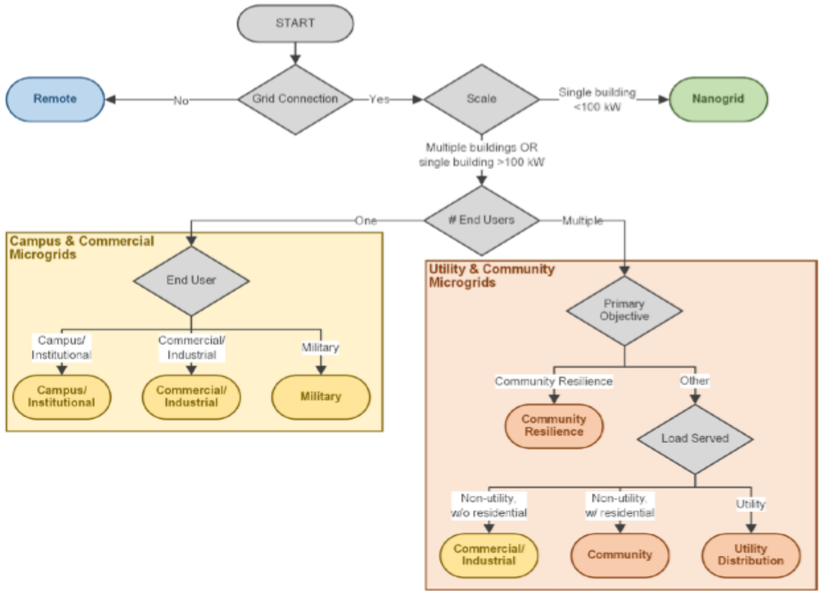
A critical concept within DOE's definition, the term "island-mode" means that the microgrid can sustain electricity service for its customers when the larger grid (sometimes referred to in this report as the "macrogrid") is experiencing an outage. The microgrid is able to preserve electricity service by disconnecting as necessary from the macrogrid, at the point of common coupling (PCC) where the microgrid normally interfaces with the macrogrid at one of its substations, and becoming an independent network under its own control. For a microgrid to have the capability of islanded-operation, its network must have a controllable set of distributed energy resources (DERs) – including a portfolio of distributed generation (DG) devices, probably of multiple types (e.g., solar, wind, CHP), and most likely also distributed storage (DS) equipment – to continue supplying electricity to its customers without accessing the macrogrid.

While microgrid activity has been increasing in recent years, most microgrids to date have been implemented for a single customer. However, many situations exist in which multiple electricity customers could benefit from jointly participating in a common **multi-user microgrid** (MUM), provided that they are in reasonable proximity to each other and generally share needs/preferences in regards to resilient power and preferred sources of electricity generation.

For the purposes of this research, a MUM must fit the DOE's description of a microgrid – specifically in regards to the ability to island – while also serving multiple decision-making entities, with each customer paying separately for the microgrid services. Because they do not provide islanding capability, "virtual microgrids" were not considered MUMs.

To be considered a MUM for this report, the microgrid does not need to serve multiple buildings or facilities, as long as different tenants within a single building/facility purchase the microgrid's services separately. In contrast, microgrids which serve multiple facilities owned by a common party (such as a municipality or university) were not considered as MUMs in this research.

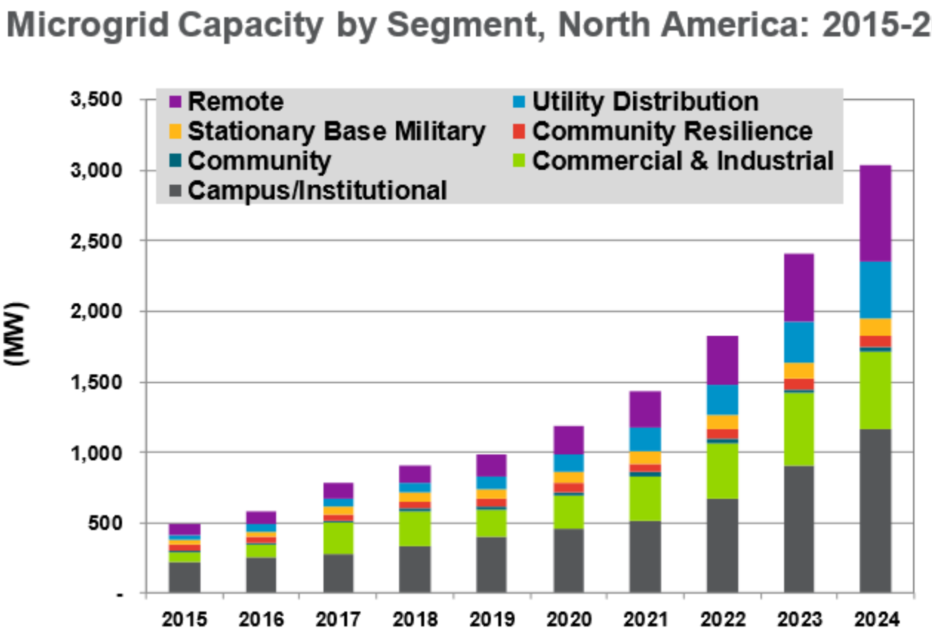
The schematic below provides an illustration of different types of microgrids. The pink-shaded box in the lower right corner labelled "Utility and Community Microgrids" characterizes the MUMs that are discussed in this report.



Source: Navigant Consulting

Why Study MUMs?

While the microgrid market is still nascent, it has been and is expected to continue growing at a healthy rate, as indicated in the chart below. However, as the chart also illustrates – in gray, green and orange – single-user microgrids dominate the current microgrid universe.



(Source: Navigant Research)

Single-user microgrids represent the majority of current microgrid activity because it is relatively easy for electricity customers, electric utilities, and vendors to commercially structure a single-user microgrid. A single customer can implement an “islandable” microgrid on their own, requiring no coordination with other stakeholders nor any changes to any pre-existing regulatory structures governing electric utility service. The economics of single-user microgrids are straightforward to evaluate and monetarily structure, because the single entity incurs all the costs of microgrid development, operations and maintenance – and gains all of the benefits that the microgrid affords.

Since the majority of real-world microgrid experience has been with single-user microgrids, nearly all of the growing body of literature on the general topic of microgrids focuses primarily (if not exclusively) on single-user microgrids.

Meanwhile, relatively little exploration has been undertaken into the issues inhibiting the development of MUMs. This deficit is concerning, because the future direction of the electricity industry – towards greater utilization of customer-sited DER assets, often based on intermittently-available renewable energy augmented with energy storage – suggests that a growing number of MUM opportunities will become of interest to businesses, institutions and other facilities within a geographically-compact area. This is especially true as DER costs – and thus the cost of MUMs – continue to decline as the industry further matures.

To begin filling this gap in knowledge, this study is an effort to examine the particular issues facing MUMs to better understand the barriers and obstacles to their development – and to make recommendations to alleviate these challenges to facilitate future development of otherwise attractive MUM opportunities.

This report does not consider the potential for cost reductions in equipment and services that could improve the ability to develop MUMs. Obviously, MUMs will become more economically viable and easier to implement in a broader range of circumstances if and as they can be developed and operated at lower cost. Likewise, certain technical issues, such as maintaining power quality at sufficiently high levels through the transition to islanded operation, may inhibit MUM development. Vendors and other parties supporting the microgrid industry – particularly those engaged in DER-related technologies – are already intensively active in pursuing cost reductions and technical improvements, and this report is not positioned to contribute any incremental value to such efforts.

Since the opportunity for MUMs to create value for a growing number of customers should only increase as DER economics continue to improve, research should be conducted to alleviate other obstacles to successful MUM implementation beyond costs that are currently too high.

Such non-cost obstacles to successful MUM development are numerous and significant.

Because multiple parties with differing objectives are stakeholders to MUM development, all aspects of planning, managing, and monetizing these systems involve reaching agreement on various complex and nuanced matters. Multi-user microgrids open questions of:

- What services that companies developing and/or owning microgrids -- companies that are not regulated utilities -- are allowed to sell to other parties, and
- How the microgrid interfaces both operationally and commercially with respect to the utility owning the distribution grid in the area

This report investigates these issues in greater detail, by assessing commonalities across a set of case studies of microgrids developed in the United States, with a particular focus on the Northeastern U.S.

Project Description

Research Objectives

In order to address the substantial gap in research focused on multi-user microgrids, the Northeast Clean Energy Council (NECEC) and the Institute of Sustainable Energy (ISE) at Boston University (BU) collaborated on this research project, with two primary objectives:

- Identify barriers to the development of otherwise economically-attractive MUMs
- Make specific, actionable recommendations to reduce/eliminate these barriers

As noted previously, this research specifically considers MUMs (rather than single-user microgrids) because many serious impediments to microgrid adoption arise once more than one electricity customer is served by a microgrid. If the barriers that prevent the development of MUMs can be reduced or eliminated, a wide range of stakeholders (private individuals, utilities, businesses, etc.) stand to benefit from the internalization of various social surpluses that MUMs can produce. To varying degrees for different MUMs, these surpluses may include (but are not limited to) resilience benefits, lower overall costs of electricity service provision, and reduced environmental (primarily greenhouse gas emissions) footprint.

This research was sponsored so that stakeholders interested in the advancement of MUMs can take actions that improve the ability to develop commercially successful MUMs. This report aims to accomplish this goal by:

- Identifying common barriers to the successful development of MUMs
- Exploring the characteristics of successful MUMs and the situational attributes that lend themselves to successful MUM development, and articulating strategies that key stakeholders have pursued or could pursue to reduce or eliminate barriers
- Providing insights that will improve regulation and policy surrounding multi-user microgrids

Study Methodology

The initial phase of research in this project involved compiling information on microgrids in the Northeastern United States. This was conducted by performing a literature review, augmented by interviews with parties highly knowledgeable about regional microgrid activity.

Resulting from this initial information-gathering phase of effort, a total of 161 microgrids were catalogued into a dataset. The dataset was structured to include notable characteristics about the microgrid, including such elements as:

- Location

- Size
- Customer profile
- Host utility

From both the dataset and the perspectives gained from the interviewed experts, the researchers further investigated a smaller set of microgrids that had the potential of being truly multi-user in nature, and upon confirming that they were MUMs of interest to the research team, sought to identify individuals that were both (1) deeply knowledgeable about the microgrid and (2) willing to share their perspectives with the researchers.

Based on this screening process, five microgrids were chosen to study in-depth as case studies:

1) BG&E Microgrids (Baltimore and Columbia, MD) - Failed proposal
2) Bronzeville Microgrid (Chicago, IL) – Under Development
3) Burrstone Energy Center (Utica, NY) – Operational
4) Philadelphia Navy Yard (Philadelphia, PA) - Operational
5) Potsdam Community Microgrid (Potsdam, NY) - Planning phase

The team strived to select more MUMs from the states of New England, but suitable examples did not reveal themselves.

Even so, the resulting set of five MUMs reflects a considerable degree of diversity among various segmentation factors (state, utility territory, project type, status, as well as customer base, density, and motivation). This breadth was deliberately sought so that any common findings from across the case studies would more likely indicate insights widely applicable to the possible universe of future MUMs.

Once the five MUM case studies were selected, a thorough literature review was completed on each microgrid in order to bolster our understanding of the project characteristics and the history of its development before conducting follow-up interviews with individuals involved in these microgrids in some important capacity – either as project developer, engineer, or host utility. Interviews provided insight into the challenges that arose during the development of these particular MUMs, and how they were addressed. In certain cases, challenges could not be completely overcome and either significantly altered the final microgrid configuration (such as its generation mix or ability to connect to the macrogrid) or caused the microgrid project to be abandoned.

After completing interviews and literature review, short reports were developed for each of the five MUM case studies to summarize key takeaways. When compared to each other, these summaries surfaced hypotheses on common obstacles that arise during the development of MUMs. Finally, these hypotheses were shared with a select group of external reviewers – first in a workshop, and then in textual form – to produce the findings presented below.

Key Findings

What are the main barriers to successful MUM development?

Excluding high costs as an inhibiting factor (for reasons described above), our research suggests that the following seven factors are significant and pervasive barriers to successful MUM development:

Inability to Monetize Resilience (and Other Value Streams)

One of the most common challenges facing potential developers of MUMs is the simple inability to produce sufficient economic value for stakeholders relative to the cost of installing and operating a MUM. In this case, the net present value (NPV) for the MUM will be negative, and the developer will not be able to attract the financing needed to move forward.

There are a variety of reasons that a prospective MUM fails to generate a positive NPV. MUM costs are non-trivial, and while they are falling with technological advancement, increasing standardization and greater efficiencies of vendors/suppliers, the costs of MUMs will never be negligible. Even when the cost structure for MUMs is much lower than it is today, there will be many cases in which the economic benefits to prospective customers of a MUM simply don't outweigh the costs.

However, even with today's economics, MUMs in certain circumstances might be able to theoretically generate economic value in excess of costs – but the developer, investor and/or owner of the microgrid is unable to capture that economic surplus through a pricing mechanism or revenue stream.

The inability to capture these potential revenue streams usually derives from a lack of market structures to create price signals, or from the failure of at least one of the key stakeholders (the developer, the investor/owner, and/or the involved utility) to fully recognize the value some of the benefits offered by the MUM.

The most vivid illustration of this phenomenon is resilience.

Although it is commonly accepted that "everyone values resilience", there is no widespread agreement on how to actually measure resilience, how much customers value resilience beyond levels generally offered by the macrogrid (i.e., current service quality is "taken for granted"), whether to require more resilience, and finally (and crucially) how to value and price resilience.

Without an ability to transact on resilience, one of the major sources of value of a microgrid cannot be captured in a revenue stream that can help finance its installation. (Please see box "How is Resilience Valued?" for a more detailed discussion of this important topic.)

While resilience is the most obvious and important value stream that is currently difficult or impossible for MUMs to capture and monetize, others may include:

- Capacity and energy value and ancillary services in regional wholesale markets
- Alleviation of local network constraints and/or deferment of need for distribution upgrades
- Thermal energy opportunities associated with combined heat and power (e.g., heat, cooling or steam)
- Improved economics associated with other non-energy infrastructure changes caused by MUM implementation (e.g., building improvements, water system efficiency gains)

How is Resilience Valued?

Microgrids usually cost millions of dollars to design, develop and construct. Justifying such a substantial capital investment has become a common hurdle to microgrid implementation. Enhanced electrical service reliability and resilience is one of the most significant value propositions for a microgrid, as they can maintain electrical service in the event of larger grid disruptions. Alas, this value has been difficult to quantify.

Historic estimates of the value of resilience have ranged from roughly $30 billion to upwards of $150 billion for the total cost of lost service nationwide.[ii] Estimating the monetary value of microgrid reliability and resilience can be challenging. For instance, how does one apply a value to keeping a patient on life support? Or, how does one apply value to maintaining years of cancer research? In these situations, the value of electricity service is essentially priceless.

This is why entities like municipal emergency services (police, fire, emergency medical services), hospitals, universities, military facilities, and data centers are more frequently electing to adopt microgrids to better guarantee resilience. Institutions like these recognize the high value of sustaining electricity service (or more precisely, the high cost of interrupted service).

While impact of service interruptions may not be as dire for private sector customers as it is for institutional customers, appropriately estimating the value of electric reliability and resilience for industrial, commercial or residential consumers remains difficult – and there is no consensus on the appropriate methodology to do so.

Entities like National Renewable Energy Laboratory (NREL), Lawrence Berkeley National Lab (LBNL), and Electric Power Research Institute (EPRI) have accumulated extensive research investigating methods and approaches for valuing the loss of electrical service.[iii]

For commercial and industrial consumers, a common approach to estimating the value of lost service involves a benefit-cost analysis (BCA). In a simple manufacturing example, a BCA would quantify the expected value of interrupted production due to interruption of electric service, resulting in a dollar per hour value specific to that industrial customer.

Aggregated to the national level, an analysis presented by LBNL in 2017 estimated that power interruptions annually cost U.S. commercial customers $41 billion (about $2300 per customer) and U.S. industrial customers at $16 billion (over $19,000 per customer).

When planning a microgrid, the estimated cost of lost service corresponds directly with the value of added resilience and reliability. Electric utilities maintain several reliability metrics, most prominently SAIDI (System Average Interruption Duration Index) and SAIFI (System Average Interruption Frequency Index). SAIDI and SAIFI are based on the power outages experienced by the average customer annually in a utility service territory, and provide an approximate forecast of anticipated outages aggregated to the utility level.

By estimating the cost of lost service for a customer using BCA (say $1M per hour) and knowing the anticipated duration and frequency of outages for a given utility (say 4.5 hours annually), one can roughly determine the added value of resilience and reliability for that system. For this example, if a microgrid could maintain service during those expected periods of outages, on average the consumer would save $4.5 million annually – though the savings in any one particular year could be much less or greater, depending upon the frequency and duration of outages that actually were avoided.

However, this basic BCA approach has several downfalls.

First, it is better suited for industrial and commercial consumers: it is straightforward to estimate economic consequences to a for-profit enterprise, whereas it is harder to assess the cost of lost service to residential consumers, for whom it is commonly assumed that the cost of lost service is relatively minimal. For instance, the 2017 LBNL report indicated the approximate annual cost of lost service to residential customers was as low as $11 per customer.[iv] However, these estimates do not consider the possibility of home-based businesses or the true out-of-pocket losses associated with an outage (e.g., food spoilage).

Secondly, utility reliability and resilience metrics can be biased toward shorter term outages, particularly if there were no previous extended blackouts in an area. The implementation of a microgrid hedges against unexpected, low-frequency events that may be spread periodically over many years.

Lastly, and perhaps most importantly, the cost benefit analysis method does not incorporate market connectivity. Upstream suppliers and downstream vendors are affected by an outage, even if they didn't lose service themselves. These upstream and downstream costs are typically ignored in BCA.

With growing digitization of society, the increasing need to effectively value economic and societal costs associated with lost electricity service has spurred additional studies in this arena. EPRI and the New York State Energy and Research and Development Authority (NYSERDA) completed research on the subject in 2017 and 2018, respectively.[v] These studies evaluated the merits of a more comprehensive regional economic analysis, taking into consideration overall economic activity in a given region. Such economic studies considered "industry-to-industry" transactions, where changes in productivity (due to loss of service) result in economic trends within a sector such as changes in demand, employment, income, etc. In its study, NYSERDA concluded that, in a single day, a microgrid could mitigate millions lost in the regional economy while providing millions in societal benefits.

Regardless of the approach, estimating the cost of lost electricity service (or the value of resilience/ reliability) is highly variable and lacks a standard methodology. Inevitably, this is further complicated when there are multiple users who receive the reliability/ resilience benefits, but who value those benefits differently. This factor represents an additional complexity facing MUM development.

Conflicts with Pre-Existing Rights Associated with Electricity Delivery

The reason that most currently operational microgrids have been implemented for single customers is simple: today's regulatory and legal structures easily suit single-user microgrids, but don't accommodate MUMs.

A single user microgrid is a natural extension of the commercial relationship in which a single customer is served by a regulated utility via the macrogrid. A typical single-user microgrid involves a conventional tariffed service agreement between the utility and the customer.

In contrast, a MUM is a commercial construct that is not contemplated by most regulatory and legal structures, which were established a century ago under the historic social compact that provides electric utilities natural monopolies on delivering electricity within defined territories.

In a single-user microgrid, all electricity generated on the microgrid not consumed by the customer is sold back to the grid – either to the distribution utility or to wholesale markets. The customer continues to buy electricity from the grid as usual to meet whatever remaining needs they have: there is no purchasing electricity of the grid in bulk, to resell to multiple customers.

Now, consider the circumstances associated with a MUM. Unless owned by the monopoly utility itself, the owner of the MUM is effectively prohibited from delivering and/or selling electricity to the various customers because, within a utility's service territory, an independent third-party generally cannot deliver electricity.

While it may be possible for the MUM owner to become the sole buyer of electricity – and then sell services defined in some other way to the MUM customers – the non-electricity service introduces considerable complexity and/or risk to the commercial arrangement that may be unattractive to the MUM and/or the customer.

The 2016 rejection by the Maryland Public Service Commission (MPSC) of MUMs proposed by the utility Baltimore Gas & Electric (BG&E) provides another illustration of how regulatory interpretation of electricity delivery rights can hinder the advancement of MUMs.[vi] While there were several other reasons underlying its rejection, the MPSC found that users do not have a choice of electricity supplier when a microgrid is operating in "island mode", therefore violating Maryland's Electric Customer Choice and Competitive Act that provides end users the right to choose their electricity supplier.[vii] Thus, the MPSC's 2016 ruling effectively prevents any form of "islandable" microgrids.

The additional complexity and/or risk in ensuring legal compliance of a commercially attractive and workable MUM is an additional burden that MUM development must bear if it is to succeed.

Preferential Rights for Utilities to Cross Public Rights-of-Way

In many jurisdictions, only regulated electric utilities are allowed to distribute and deliver electricity with wires that cross a public right-of-way (ROW). Even where this right is neither absolute nor exclusive, exceptions to this generally accepted practice must be affirmatively obtained.

Clearly, this issue generally restricts MUMs not owned by utilities to only serve customers on contiguous parcels of private property, and inhibits including other nearby customers in a MUM that would otherwise find the value proposition compelling. Indeed, as more users of a MUM are contemplated in order to expand the pool of economic value that can be created, the likelihood of needing to cross a public ROW increases.

The example of the Burrstone Energy Center, a multi-user microgrid in Utica NY, is highly instructive on this issue.

In planning the Burrstone microgrid, Cogen Power Technologies (CPT), confronted the need to cross a public ROW to reach a prospective customer, Utica College. For this project, CPT should *theoretically* have faced no issues in crossing the public ROW – but in fact it did.

Independent legal analysis[viii] suggests that, in the state of New York, "municipalities are prohibited by statute and case law from granting their own exclusive franchise by contract" – although municipalities might be able to grant an exclusive franchise if given special permission from a city council. Further research failed to reveal any evidence indicating that the Utica city council had provided any exclusive franchise within city limits to National Grid, the utility that provides electricity service in the Utica area. Thus, at least on paper, CPT should have been able to cross the public ROW in its Burrstone microgrid without needing to secure any special approvals.

Despite these facts, CPT was nevertheless required to obtain a special waiver from the New York Public Service Commission to cross the public ROW in order to serve Utica College at its Burrstone microgrid. This process of obtaining a waiver was time-consuming and expensive, requiring CPT to hire an attorney with experience in handling cases involving utilities and public service law.

Ambiguity About Viable MUM Ownership Models

Projected MUM economics and financial viability can depend significantly upon the optimal ownership structure for the microgrid – which in turn may not be compatible with current regulatory and legal precedents.

To illustrate how this might occur, note that certain parties may be able to monetize selected value streams associated with a microgrid that other stakeholders – including the utility developer, customers or investors – cannot. Two examples of this phenomenon:

- Tax credits associated with ownership of solar assets in a microgrid may have value to only those stakeholders with a tax obligation that can take advantage of these tax credits – in which case, it might be essential that ownership of these assets be allocated exclusively to those stakeholders.

- Some stakeholders in a MUM may be prohibited from participating (or may simply not want to participate) in wholesale power markets offering potential revenue streams that may be necessary to ensure MUM economic viability.

Consequently, hybrid ownership structures may be of interest or possibly even necessary for some MUMs. However, it may be the case that the best (or perhaps the only viable) ownership structure for a MUM is precluded by state regulations.

As arguably the most prominent example of this possibility, certain states (including New York) do not allow for utility ownership of generation assets. Yet, for some MUMs (such as those with few or no for-profit stakeholders), an attractive solution may entail utility ownership of the microgrid's generation assets. To the extent that this is the case, opportunities for viable MUM development may be thwarted.

Utility Assertion of Rights Via Legal Action

Relating to the prior three issues – rights associated with electricity delivery, preferences for utilities to cross ROWs, and ambiguity about potential MUM ownership structures – multiple leaders and experts in the microgrid industry expressed the concern that utilities have demonstrated the ability to effectively assert their rights via legal action, thereby causing delays and increasing costs and risks in MUM development.

According to a 2010 NYSERDA report[ix], “the mere threat of tying up a potentially small enterprise such as a microgrid, in litigation over franchise rights could stop a project”. Moreover, the report also states that it is “likely that regulatory authorities will be inclined to protect the incumbent distribution utility” and that “the utility itself is likely to defend its franchise rights in court.”

One interviewee described the case of a private developer working on a microgrid that had to abandon the project because the local utility wore them down with legal litigation.

Even the threat of potential legal action by utilities deters MUM market advancement, as it increases risks that third-party project developers may be unwilling to accept.

Lack of Suitable Risk-Mitigation Structures

The MUM market likely will struggle to approach its full potential until there is a greater availability of standardized financial instruments – specifically, insurance products at fair prices – that mitigate the risk of an investor’s involvement in a multi-user microgrid.

One difficulty in developing a replicable financing structure is that it is costly to perform due diligence on customer credit risk for a MUM, because unfortunately there are few if any economies of scale to credit risk assessment as more users participate in a MUM.

In addition, a MUM is subject to substantial financial risk if and as customers decide to discontinue participation, since the overall economic viability of the MUM is likely to require all parties (and especially the largest customers) to remain being served by the microgrid. While “exit penalties” may be considered to mitigate this risk, such an approach is likely to discourage certain customers from joining the microgrid in the first place.

Although increasing the number of users in the customer base of a MUM might dilute some risks through diversification, it also increases the likelihood of at least one customer defaulting or exiting.

Unless and until financial structures are created to better mitigate these risks – particularly when combined with the ambiguity about the ability to capture certain value streams, especially resilience – obtaining third-party investment in MUMs is likely to remain a major challenge.

Insuffiecient Leadership to Coalesce Solutions

Before a multi-user microgrid starts taking shape, a well-positioned and knowledgeable individual must become a champion – identifying the opportunity to create value via a MUM, becoming convinced that it's worth pursuing, and convincing the potential MUM owner of these values, notwithstanding the various barriers – to initiate action towards MUM creation. To effectively lead a MUM development initiative with impact, this individual will almost certainly need to be associated with a well-respected organization within the energy sector.

One obvious possible organizational home for an individual who can perform this leadership function is the local electric utility, which clearly has the requisite technical and engineering capabilities, and also – because every user of electricity knows the identity of the local electric utility – possesses pre-existing relationships with the customers of any prospective MUM.

While some utilities have demonstrated the willingness to pursue a MUM with the aim of creating value for a set of customers – as evidenced by National Grid at Potsdam and Commonwealth Edison at Bronzeville – not all utilities have reached this degree of commitment. Moreover, even those utilities that have participated in MUM initiatives have yet to scale these activities into sizable initiatives, due either to insufficient strategic desire to achieve a commercial growth ambition or inadequate tactical capacity to focus on MUM possibilities in lieu of traditional utility projects. As a result, many MUM opportunities that could be attractive to utilities are almost certainly not being led by utilities (or passionate individuals within utilities) at present.

Absent decisive action by the utility, the individual and organizational leadership needed to make progress on new MUM development is often lacking. In addition to likely capability and information deficits, any one customer on a prospective MUM is poorly positioned to serve as a project leader because this would create perceived inequality with the other potential customers. A consortium of customers can be created to become a MUM developer, but bringing a new entity into existence – not to mention capitalizing it and recruiting key talent – is a major endeavor that often calls for expertise and relationships outside of the core capabilities of the customers.

This gap can be filled by alternative service providers: organizations other than utilities that take the lead in MUM development. A number of such companies are already positioning for this opportunity, including:

- Large multinational corporations, such as Engie, Schneider Electric, Shell, Enel, and Veolia
- Power project developers and energy efficiency service providers, such as Anbaric and Ameresco

Based on activities they have already taken to accumulate expertise, capabilities, and credibility in developing single-user microgrids, companies such as these have a head-start in positioning to become significant players in MUM development. In addition to providing competitive choices to potential MUM customers, alternative service providers are more likely than the local utility in becoming distinctive specialists in particular types of MUMs, because they can gain their particular expertise and market it anywhere as opposed to (at least primarily) in their own service territory.

Although only a few exist today, developer-led MUMs are beginning to appear. One of the most significant examples of a multi-faceted MUM is the Philadelphia Navy Yard (PNY) microgrid, owned by the Philadelphia Authority for Industrial Development (PAID) and managed by the Philadelphia Industrial Development Corporation (PIDC). At PNY, a multi-year master energy planning and implementation project to redevelop a large urban parcel of land led to the creation of a MUM community. The resulting microgrid is one of the most diverse MUMs in North America, with approximately 80 electric customers, and PIDC virtually serves as the community's electric utility. Only minimal public subsidies were necessary for the viability of the PNY MUM, because PIDC was able to earn superior returns on its investments relative to the capital and operating costs of "business as usual" that would have been incurred if generation supply were instead purchased from the local utility.

What actions have successfully addressed barriers to MUM development?

While not all MUMs encounter all of the above obstacles, some of them are likely to pertain in any given MUM project development.

And while there are no "silver bullet" solutions to these obstacles, certain MUM developers have been able to partially if not fully overcome these obstacles in MUM development activities to date through tangible actions.

Utility Ownership or Strong Utility Participation in MUMs

In many cases, the obstacles listed above can be minimized if not completely eliminated if the MUM is developed, owned and operated by the local monopoly utility:

- The issues associated with crossing public ROWs and authority to deliver electricity will be mooted if a MUM is owned by a utility.

- To the extent that assets from a utility-owned MUM can be rate-based, and the resulting MUM service is delivered via a regulated tariff that satisfies all parties, financing challenges will essentially be eliminated, and customer acquisition will be significantly eased – although such approaches will confer the utility a competitive advantage over any other potential alternative service provider that might otherwise consider developing a MUM for these customers.

Not only does utility MUM ownership minimize some of the aforementioned challenges to MUM development, other advantages may arise as well. For instance, utilities may be more inclined to increase the reliability and resilience of their own macrogrids if they are able or encouraged to participate in MUM development in particularly vulnerable locations. Utilities may also be able to take advantage of economies of scale (e.g., in equipment procurement, engineering, and legal/permitting) to reduce MUM costs relative to what a smaller MUM developer could achieve.

For these reasons, utility-ownership is a promising enabler of MUM advancement. The highly-visible progress being made at the Bronzeville multi-user microgrid under development in Chicago by the utility Commonwealth Edison is indicative of this promise.

None of the above is to suggest that utilities must or even should develop and own MUMs. Rather, it is merely an acknowledgement that utility-ownership greatly simplifies the MUM implementation process.

Even if the utility doesn’t develop or own the MUM, deep involvement of the utility in some manner (i.e. operation, billing, customer management, financing, engineering, etc.) is often an important facilitator of successful MUM implementation. This is because utilities usually have great credibility and influence both with customers and regulators, who will play significant roles in whether or not a proposed MUM will be completed:

- Supportive participation of utilities in MUM planning will not only minimize any opposition that they might otherwise raise, but should streamline discussions with regulators and other governing bodies (e.g., local permitting), thereby accelerating receipt of necessary approvals and reducing development costs.

- Utility support will also be helpful in securing the customers to a multi-user microgrid, who might otherwise harbor concerns about project viability or reliability of the resulting service.

- Utilities can also play a useful role in MUM engineering activities – especially in navigating the interconnection process at minimum cost – not only to ensure continued reliability of the macrogrid, but also to validate or even improve reliability of the MUM service.

Creatively Leveraging Opportunities to Reduce MUM Costs

Microgrids are a relatively new approach for electricity service that encompass many still-advancing technologies. As a result, while costs should decline over time with continued improvements, microgrids remain somewhat expensive to develop today.

Acknowledging this challenge, successful developers are creative in finding ways to reduce the net costs of implementing a microgrid. For instance, many of the microgrids we identified that have completed the arduous development process and became operational, whether single or multi-user, received more than $1 million from various state or federal funding programs.

Another common aspect of a successful MUM is the presence of pre-existing infrastructure that could be incorporated into the MUM. Similar to the availability of grant programs, the presence of existing infrastructure helps to alleviate capital costs of microgrids. Both the proposed Baltimore Gas & Electric (BG&E) MUMs and the operational Burrstone MUM represent examples in which the developers took advantage of preexisting infrastructure.

Tailoring Business Models to Situation-Specific Needs

Conventional electricity service via the macrogrid exemplifies the concept of a “one-size-fits-all” offering. Prices, terms and conditions, and other service attributes (e.g., reliability, quality) are standardized and available in a non-discriminatory manner to any and all customers within the defined customer class in a regulated monopoly utility service territory.

Microgrids inherently represent a break from that underlying philosophy. Microgrids intrinsically offer much greater customization of electricity service delivery to customers. As such, microgrid developers fundamentally must design and engineer a system of equipment and infrastructure to meet the specific needs of the customers to be served.

If the physical design of the microgrid is configured to meet the specific needs of its customers, then it follows that the commercial design of the microgrid should also be tailored to meet the situational circumstances.

The commercial arrangements intrinsic to the Burrstone microgrid provide an example of a developer offering a creative approach that reduces energy costs for participating users while ensuring the resilience and reliability of electricity service that the MUM’s customers require.

The Burrstone microgrid owner Cogen Power Technologies (CPT) sells electricity from the microgrid to National Grid on the macrogrid via a Power Purchase Agreement (PPA) under which CPT is reimbursed at the wholesale electricity price during the hour of the sale. CPT monitors the price to be received for exported power, total power consumption on the microgrid, and the cost of running the microgrid’s generators for an hour. It then considers this data and simulates 50 scenarios in order to optimize microgrid operations at an hourly level.

To take this optimization to the next step, CPT is currently developing a pilot program with National Grid that works almost like a supply-side version of demand response, in which National Grid will pay a premium on electricity exported by CPT during peak periods when pricing is high. National Grid will temporarily increase the price they pay for CPT exported electricity in order to incentivize microgrid customers (including a hospital and nursing home) to temporarily curtail electricity consumption to enable increased sales of electricity to the grid.

Phased Development to Spread Costs Over Time

Because MUMs are capital-intensive, it may be preferable for both the developer and the customer base to implement the microgrid in phases, so as to spread the economic and financial impacts over time.

The example of the Potsdam Community Microgrid is illustrative in this regard.

Potsdam is a remotely located town in upstate New York subject to intense storms during the winter that make it difficult for the utility (National Grid) to send a service truck to fix infrastructure. To make matters worse, Potsdam receives power via long transmission lines of aging vintage that are highly susceptible to damage from extreme weather. In 1998, Potsdam faced major consequences of these vulnerabilities, when a winter storm led to a three-week power outage.

Since Potsdam community leaders do not want to face such a circumstance again, National Grid is developing plans for a community microgrid to support a range of critical facilities – including a hospital, local police and fire departments, water treatment plants, and Clarkson University – as well as a number of commercial buildings.

National Grid recognized that a MUM for Potsdam merits serious consideration as a solution, because the aging electricity infrastructure to supply Potsdam requires significant ongoing repair and maintenance expenditures, and the cost of full replacement was deemed prohibitive.

Alas, for other reasons, the Potsdam community is fiscally stressed and finds it difficult to afford the costs of the community microgrid, even though the payback on investment is likely to be attractive.

An original plan prepared by National Grid for the Potsdam microgrid, involving complete build-out upon commissioning, was determined to be economically infeasible because it would lead to an increase in electricity prices too substantial for the economically-challenged community to absorb. Consequently, National Grid split the project into several stages, resulting in more modest price increases at the completion of each stage. (Further detail on the staged development of the Potsdam microgrid is provided in Appendix 1.)

It could be argued that, by lengthening the MUM development process, overall projects costs for the Potsdam microgrid may have increased somewhat. Likewise, by not immediately implementing the MUM in its full vision, certain customers in Potsdam will not immediately gain access to resilient energy infrastructure, and will thus be delayed in gaining benefits that only will materialize when the MUM is complete.

Nevertheless, it appears that these disadvantages are outweighed by the fact that large one-time economic consequences of implementing the MUM are instead spread over time.

Robust Execution Capability and Stakeholder Collaboration

Developing a MUM is inherently a significant business initiative. As such, successful MUM development requires the same suite of strong resources critical for any business success: especially good talent, a good plan, and a cooperative, collaborative team of stakeholders.

Reflecting the discussion above, a project champion possessing both the passion and the requisite set of technical, commercial and interpersonal capabilities is vital to navigate MUM development through the numerous and substantial barriers. The project leader will also need to play a significant leadership role, including both:

- Relying upon a deep cadre of supporting staff, including outside experts in engineering and legal disciplines to advance the project.
- Nurturing collaboration among representatives spanning the multitude and diversity of stakeholders affected by a MUM project.

A skilled project leader will develop and coalese support among the diverse stakeholder team, such that all members are collectively engaged and advancing the project together. It is also very important that all team members – both from the developer and from the various stakeholders – maintain a positive and constructive attitude seeking to overcome challenges rather than exacerbate them with the goal of thwarting progress.

In turn, to ensure that a MUM development team is aligned in its actions, a solid business plan is also valuable. Multiple interviewees emphasized the importance of creating a solid business plan, because it serves as both a focusing mechanism and communication device to:

- Target the right mix of customers to maximize the aggregate economic benefit
- Coordinate among stakeholders – many of whom with divergent perspectives – to reach agreements
- Clarify how the benefits of a microgrid will be monetized in order to recover development and operating costs, and
- Ensure that customers would utilize the microgrid over a sufficiently long period of time

As with any venture, important components of a strong business plan for a MUM include:

- The value proposition for identified users, especially related to loss avoidance through greater resilience of energy supply, relative to the *status quo* and other alternatives
- Mechanisms for capturing some of this added value for the MUM developer
- Realistic estimates of capital investments, operating expenses, and revenue projections
- Identification and assessment of key relationships (e.g. with local utilities, potential customers)
- Governance in decision-making and operational/financial roles/responsibilities
- How growth and contingencies (such as departures of key customers) will be handled
- Assessment of primary risks

Recommendations

Stakeholder Actions

The advancement of multi-user microgrids will happen only hesitantly – and correspondingly the benefits they could offer to customers and society will remain largely unrealized – without targeted and sustaining actions by stakeholders who have crucial roles to play in MUM development.

Our research suggests the following thematic initiatives have the potential of creating the most positive impact to advance MUM activity:

Increasing Awareness and Understanding of MUM-Specific Issues:

A critical first step to facilitating the development of MUMs is to increase the level of understanding across the full spectrum of parties involved in microgrids, including utilities, regulators, developers, investors, and customers.

Because the entire topic of microgrids is new and consequently evolving rapidly, and because many of its aspects differ quite significantly from the conventional ways of thinking about electricity service, considerable education remains necessary to ensure that stakeholders even have a common language to use in considering issues that require solutions. This is especially the case for the subset of microgrids that are truly multi-user, since they have only rarely been developed to date and raise a number of unique issues highlighted in this report.

Developing a common understanding of the potential value of MUMs relative to other energy services, and the circumstances under which MUMs are especially beneficial, will help to galvanize support for MUM development and assuage fear and uncertainty about what such development means for incumbent interests. All stakeholders need to understand the issues presented in this research, and discuss how these obstacles can best be overcome in ways that benefit all.

Targeting an audience of state regulators, utilities, private developers, and experts on utility/franchise law, workshops that gather stakeholders involved in MUM activities should be convened to discuss best practices and establishing common terminology and frameworks for considering issues related to MUM development.

Because of the importance of introducing new financial structures – many of which are akin to insurance products – to facilitate greater activity in the MUM marketplace, special attention should be paid to attracting and involving experts on pricing and design of services and solutions that provide customers power resilience under contingent circumstances.

Strengthening Regulations and Policies to Improve MUM Playing Field:

As this report strives to emphasize, improving clarity on state laws surrounding the franchise rights of utilities and several other regulatory issues will be essential in eliminating or at least reducing barriers to successful MUM development. In some cases and ways, greater clarity will not be enough: regulations and policies may need to change.

In particular, greater effort should be made to eliminate ambiguities stemming from the absence of microgrid law by pushing for codified standards pertaining to microgrids. As described in the sidebar box “Policy Initiatives to Advance MUMs”, Massachusetts House Bill 4324 and New Hampshire House Bill 1338 are strong examples of this. While the bill from New Hampshire didn’t pass and the (pending) bill from Massachusetts has been criticized as unambitious and watered down, they both represent the type of policy efforts that are needed to establish a clearer legal framework for microgrids.

Ideally, changes to these laws can create the assurances necessary for private developers (and their investors) to implement multi-user microgrids while still protecting utilities from loss of revenue and customers from unfair shifts in cost allocation. Once states create legal definitions for MUMs and clarify the ownership models that are allowed, stakeholders can structure a feasible MUM with much less uncertainty, avoid costly and time consuming legal battles, and assure investors that their planned business model meets regulatory requirements.

Even better, if the development of definitions and regulation for MUMs comes from a larger community agreement, many of the rules and standards may become commonplace industry-wide. Such clarity of rules and standards would allow for the development of more standardized models for MUMs that can be applied across multiple microgrids – and also in microgrids in different states. This would not only reduce development risks about what will be accepted, but would also lower the soft costs of MUM design and development.

For the most part, under current regulatory approaches, utilities are able to earn profits only on capital expenditures that are approved to be included in rate base. To the extent that utilities might be interested in a MUM opportunity, this framework creates a strong incentive for the utility in favor of asset deployment, effectively ensuring that the utility would seek to be the owner of the MUM – and indeed might oppose the MUM if utility ownership were not an option. Therefore, regulatory innovations to allow utilities to be able to earn profits on services provided (i.e., engineering services to support MUM implementation), rather than solely on capital investments, would incentivize utility MUM participation even if utility ownership is for some reason not the best option.

Policy Initiatives to Advance MUMs

As described in this report, there are many aspects of state law and regulations that affect whether and how MUM development activity can occur. In turn, there is a great deal of variability between states on how these laws and regulations are written. And, in most cases, the relevant laws and regulations were written long before MUMs were considered plausible.

Reflecting upon this often confusing and/or ambiguous situation, and the interest of many parties to advance MUMs, early initiatives are underway to reform or otherwise clarify laws and regulations in ways so as to improve the ability for MUM development to proceed efficiently.

In the Northeast United States, the following pieces of legislation involving MUMs have recently advanced:

- Drafted in March 2018, New Hampshire House Bill 1338 “establishes a committee to study the changes in law necessary to allow for microgrids in electricity supply”.[x] While the bill did not come to fruition, it demonstrates the type of state-level initiative that provides greater regulatory clarity regarding microgrids.

- Earlier in 2018, the Maine legislature (both the House and the Senate) passed a bill (H.P. 190/L.D. 257) allowing for petitions to construct microgrids that serve the public interest. However, the bill was vetoed by Governor LePage in April 2018.

- In Massachusetts, House Bill 4324 was drafted to enable the Economic & Development Corporation of Boston to choose a “a single energy service company for the design, construction, operation, maintenance, and financing of a district energy/microgrid project and related energy savings performance contract to serve the public and private property owners and tenants in the Raymond L. Flynn Marine Park.”

The contrast between these bills is particularly noteworthy: Maine HP190/LD257 and Massachusetts HB 4324 work towards the legalization of either a specific microgrid or microgrids on a case-by-case basis, whereas the New Hampshire bill is more generalized, providing a legal framework for microgrid development in the state.

Another powerful policy approach to promote MUMs has been implemented by the Boston Planning and Development Agency[xi] (BDPA), which now requires all new real estate developments in the Boston area over 1.5 million square feet to conduct a feasibility study of a microgrid.

Standardizing MUM Design and Implementation:

While microgrids inherently represent a departure from “one-size-fits-all” electricity service from the regulated monopoly utility, an excessive degree of microgrid customization to perform optimally in a given set of circumstances can introduce substantial additional complexity and cost. MUM development thus far has no doubt been highly susceptible to this pitfall, as most

MUM plans have required significant adaption to account for existing infrastructure, customer needs, utility requirements, tariff restrictions, and so on.

Rather than offering bespoke solutions, parties seeking to advance MUM development must adopt a "modular and scalable" approach, similar to how vendors of power and cooling solutions view their infrastructure offerings to data centers. While a microgrid may inevitably consist of a large number of potential components, the components must be sufficiently standardized so that they can easily be combined with minimal alteration. By combining standardized modular components together, any given project can be customized for the needs to the specific MUM, and developers will be able to create a manageable number of standardized solutions across the multiple dimensions of MUM design.

Greater commonality of rules and regulations, as well as standards for interoperability and communication, will improve economic viability of a greater number of MUM opportunities, by:

- Streamlining review and approval by regulators and other permitting authorities
- Systematizing understanding and facilitating learning across projects
- Reducing engineering, installation, commissioning, interconnection, and other soft costs of development
- Allowing cost reductions in equipment via economies of scale and in shipping via standardized logistics
- Making projects easier for financiers to value and invest in, thereby opening up new sources of capital

Creating Viable Mechanisms Valuing and Monetizing MUM Services:

There is a significant need for agreed-upon mechanisms to both calculate the value of resilience and other benefits offered by MUMs, and allow at least some of this value to be captured by the MUM provider – otherwise one of the main economic benefits associated with MUM development cannot be used to support financing of usually-significant capital costs.

The approach for calculating the value of resilience must first and foremost reflect the fact that the value of resilience varies substantially between users. This need for user-specific calculation must be balanced with the need for a calculation methodology to be both rigorous and acceptable to all parties.

In addition to standardizing a methodology for benefit-cost analysis (BCA) calculations of the expected value of resilience, reliability, and grid flexibility offered by MUMs, valuation methods could benefit from leveraging more advanced valuation practices.

For example, if one conceptualizes participation in a MUM as providing flexibility (for both connected customers and the associated distribution utility) in the event of uncertain future events, it is possible to use real options analysis to value the added benefit of this flexibility. In this example, the MUM may offer customers and / or the distribution utility the ability to choose between using on-site generation assets, drawing from energy storage, purchasing power from the grid, or reducing load in the event of constrained electricity availability. Because there is uncertainty about future events and about the future value of these alternatives, the flexibility to choose among them at a point in the future (when their relative values are known) has value.

Using valuation methods such as real options to supplement the expected value calculations based on the expected frequency and cost of outages will advance a robust and comprehensive methodology for valuing MUM services throughout the connected system.

With an agreed-upon methodology for valuing resilience and other services, the next requirement is an acceptable means through which the MUM operator is able to capture some of this value for the purposes of economic and financial viability. This is a rate design question, but the rules for what and how the MUM operator is allowed to price and collect payments from users are not yet well developed – and in fact relate to the question of whether the MUM is considered a regulated utility.

Many alternative pricing structures could be considered, including such possibilities as flat monthly fees for resilience service and premium pricing per kWh, to reflect the value of resilience provided by the MUM. While no one rate structure might be best for all scenarios, MUM developers need clarity on what collection mechanisms are allowed and accepted, to support the revenue projections in their business plans and discussions with prospective investors.

An example of progress in this area can be seen in the proposed Potsdam community microgrid, in which National Grid is proposing a tiered tariff cost recovery plan. In this approach, customers that receive the greatest benefit from resilience provided by the microgrid (i.e., those with the greatest potential cost of lost service) contribute the most to the tiered tariff. Thus, in the event of a macrogrid outage, it is planned that the microgrid will provide highest priority in its service to the hospital and municipal emergency services, as they will be paying more in the tiered tariff than other customers. (Further detail on the tiered pricing approach being implemented at the Potsdam microgrid is presented in Appendix 1.)

Learning from MUM Innovations Elsewhere:

In general, microgrid stakeholders should look to path-breaking models that are advancing innovative models for multi-user microgrids.

Arguably the most prominent example forging a path for new utility-owned MUM potential is the Bronzeville microgrid in Chicago. At Bronzeville, the utility Commonwealth Edison (ComEd) plans to construct a new microgrid that will integrate with an existing microgrid at the Illinois Institute of Technology and operate it over a ten year period to inform ComEd on how to most efficiently operate interconnected microgrid networks. Once fully completed, the microgrid will be able to serve peak demands (estimated at 7 MW) even during an islanding event of over a thousand customers from a diverse user-mix, including residential, commercial and industrial customers.

An important aspect of the Bronzeville microgrid is that its costs will be dispersed across all of ComEd's nearly 4.1 million ratepayers, even though when only a thousand customers will directly benefit from the microgrid. However, ComEd successfully argued to its state regulator (the Illinois Commerce Commission) that all of its ratepayers, the public, and other relevant stakeholders will benefit from the microgrid and that much will be learned from this pilot project for microgrid interconnections.

In addition, ComEd initially planned to own the generation assets on the Bronzeville microgrid, even though it had previously voluntarily divested all of its generation assets following the 1997 restructuring of the Illinois electricity sector. Accordingly, ComEd's intentions to own the Bronzeville generation assets drew significant pushback from certain interest groups who did not want this MUM project to set a precedent for more utility-owned generation assets. However, ComEd exhibited the willingness to cooperate and find a satisfactory solution: rather than fighting the pushback, ComEd agreed to facilitate a competitive bidding process for third-parties to own and operate the microgrid's generation assets – and if no reasonable bids were made, ComEd would lease the generation assets.

Although still under development, the Bronzeville MUM serves as a model for MUMs by highlighting many of the common attributes of other successful MUMs, including:

- Direct utility involvement
- Utilization of preexisting infrastructure
- Ambitious in its goals/scope
- Diverse user-mix
- Multiple phases of development

Two attributes of the Bronzeville MUM in particular stand in notable contrast to many other MUMs under development: the ambition of the goals/scope and the diversity of the user mix. Most importantly, Bronzeville demonstrates the importance of utilities, regulators, and relevant stakeholders keeping an open mind and acknowledging each other's respective concerns through negotiations and concessions.

The lessons learned from Bronzeville will inevitably be important for other MUMs, especially utility-owned MUMs. As Bronzeville and other pioneering MUMs are pursued and implemented, their trials and triumphs need to be fully understood, communicated and applied to future MUM development activities.

Additionally, there are early signs that privately developed and owned MUMs may also provide a channel of opportunity that takes advantage of a different set of stakeholder benefits. The example of the Philadelphia Navy Yard microgrid demonstrates how this kind of MUM becomes feasible, and many similar projects are currently being considered throughout our study geography.

Organizing for Greater Impact:

Although a growing number of conferences are being convened on the topic of microgrids, with the annual Microgrid Knowledge conference[xii] arguably being the best and most well-attended, the microgrid community generally lacks a focal point – such as a trade association – that is well-positioned to serve in convening, educational, research and advocacy capacities. No doubt, this reflects the fact that the microgrid market is still immature and consequently small, but there is a risk that the microgrid market will remain underdeveloped unless and until stakeholders organize for impact and provide necessary leadership for market participants.

Future Research

This report appears to be one of the first in the overall body of literature to address issues that specifically pertain to multi-user microgrids. As such, this report should be viewed as an initial attempt to identify and frame the issues in such a manner that they lend themselves to additional further analysis.

We believe we have accomplished this goal to a substantial degree, and offer the following suggestions for follow-on research:

1. Summarize status of state regulations and laws that impinge upon MUM development. Each state defines in its own unique manner how the topics raised in this report – exclusivity of delivery and sale of electricity, ability to cross public ROWs, viability of MUM ownership structures – shall be interpreted for legal and public policy purposes. A summary of state regulations/laws relevant to MUM activity would enable geographic priorities to be set for clarification activities, as well as offer possible templates for preferred wording in policy recommendations.

2. Design an ideal model for enabling legislation. A collaborative effort to design a model for enabling legislation in a coordinated and cohesive manner would provide a guide for state-level regulatory initiatives that facilitate MUM development. Leveraging research efforts and learning across states would both reduce the aggregate costs of policy advancement and promote policy consistency across jurisdictions so as to reduce the soft costs of MUM development going forward.

3. Evaluate lessons from insurance industry regarding pricing and product design. The provision of power resilience services to customers is in many ways akin to an insurance policy. As such, it would likely be highly illuminating to delve into how underwriters price and design policies to determine lessons learned that are relevant and can be offered to the microgrid community. In particular, insurance companies are well-versed

at valuing low probability, high-impact events such as prolonged macrogrid outages, and these methods could be informative in developing standardized methodologies for valuing MUM services.

4. Monitor progress of Bronzeville and summarize implications (and pros/cons) of utility-ownership of MUMs. As discussed above, utility-ownership alleviates many of the challenges facing potential MUM opportunities. From this, a substantial share of future MUMs will probably be owned by utilities. However, it is likely that there are negative consequences of MUMs when they are developed and owned by utilities. Moreover, most parties of interest will want to ensure that utilities have the ability, but not an exclusive ability, to develop and own MUMs. Because utility-owned MUMs are largely untested as yet, further research on this area is warranted as progress is made, including whether and how the ability for utilities to own MUMs might disadvantage alternative service providers, and if/how the ability for utilities to participate in (and profit from) MUMs other than by owning assets might alleviate any concerns.

5. Undertake customer-focused research. This research was oriented towards identifying the barriers to MUM development – from the perspective of those who might seek to develop/implement a MUM on behalf of multiple customers. In turn, this begs many questions about customer needs and preferences for MUMs. Of note, it appears that most MUM initiatives to date have been driven by desire for enhanced power resilience, yet it would be interesting to test how important environmental considerations – as reflected by increasing quantities of corporate purchasing of renewable energy – might be among the potential customer base for MUM developers. In general, further incorporating customers into the MUM development stakeholder ecosystem will be valuable.

6. Improve and maintain microgrid database. The database of microgrids that was developed for this research is limited to the Northeastern United States (corresponding to the area of interest to the Northeast Clean Energy Council, one of the project's partners), and moreover represents a snapshot in time in early 2018. It would be useful to expand the dataset beyond the Northeastern United States, and to refresh the data on a periodic basis, providing a better information set from which to identify and follow emerging trends in MUM activity.

Appendices

Appendix 1: Summary of MUMs Selected for Case Studies

Baltimore Gas & Electric Public Purpose Microgrids	
Customer Base	Commercial entities (gas station, bank, grocery store), Academic and Hospital
Utility and Location	Baltimore Gas & Electric (Exelon subsidiary); Baltimore, MD and Columbia, MD
Status	Proposal rejected by Maryland Public Service Commission (MPSC)
Motivation for Microgrid	Public Benefit Microgrid – Reliability and resilience for critical community services
Generation / storage assets	3 MW natural gas; 2 MW natural gas
Obstacles Encountered:	1) Inequitable allocation of costs vs. benefits 2) Regulatory interpretations of service requirements 3) Overreliance on natural gas generation
Effective Actions Taken:	1) N/A, as the microgrid proposal was rejected by the MPSC. However, the reasons provided in the rejection have been used as working guidelines and expectations for subsequent microgrid proposals in the state.

In December 2015, Baltimore Gas and Electric (BG&E) submitted a proposal for two separate "public purpose" microgrids to the Maryland Public Service Commission (MPSC), to serve as pilot studies for the implementation of MUMs in the state of Maryland.[xiii]

- The first microgrid was proposed to be located in Baltimore, at the 4600 block of Edmonson Avenue. A microgrid at this location would service a major grocery store and pharmacy, local restaurants and a medical center (amongst other buildings and facilities). The given proposed microgrid was to be powered by a 3 MW natural turbine and cost approximately $9.2-million to develop and implement.

- The second microgrid was proposed to be located along Guilford Road in Columbia, Maryland (Howard County). This proposed microgrid was to service a gas station, high school, pharmacy, and local meeting house. The proposed Howard County microgrid would be serviced by 2MW of natural gas generation and cost approximately $7.4 million.

In developing these microgrid proposals, BG&E chose sites where easily adaptable infrastructure was already available, and close to critical community facilities – such as urgent care facilities (hospitals, medical offices), schools (or other places of shelter), gas stations and grocery stores – that would benefit most from improved resilience enabled by the implementation of microgrids.

Under its microgrid proposal, BG&E was to construct, own and operate all assets of the two microgrids, including generation as well as distribution. The cost of the microgrids was to be recouped through a monthly tariff applied to all BG&E customers.

In July 2016, the MPSC rejected the BG&E microgrid proposal[xiv] for several reasons, including:

1) The proposed monthly tariff to recoup microgrid costs would be applied to all BG&E customers and not just those customers benefitting from the microgrid;
2) The microgrids would solely rely on natural gas generation assets (as opposed to renewables); and
3) When operating under "island-mode", microgrid customers no longer have the option to choose the electricity supplier – as is mandatory in Maryland since the electricity market was restructured in the late 1990s.

While the BG&E microgrid proposal was rejected, the MPSC's rationale for rejecting the proposal has subsequently helped establish loose guidelines and expectations for microgrids in Maryland. Following BG&E's failed proposal, the MPSC initiated PC44 to study electric distribution systems that are sustainable, customer-centric, affordable and reliable – such as microgrids.

In October 2017, PEPCO (another subsidiary of Exelon serving other parts of Maryland) submitted their own proposal to the MPSC for "Public Purpose" microgrids.[xv] Like BG&E's proposal, the microgrid would service community health centers, grocery stores, gas stations, etc. in the event of an outage. However, there are distinct differences that address the responses BG&E received. For instance:

1) The microgrids would rely on natural gas generation plus renewable PV and storage
2) PEPCO would solicit developers to build the microgrid through a competitive bidding process and the developer or another third party would own the generation assets.
3) PEPCO proposed that the microgrid customers can retain whatever retail energy supplier they choose, meaning the supply rate the customer pays would not be affected by the microgrid development.

Bronzeville Microgrid	
Customer Base	1060 residential, commercial, and industrial customers
Utility and Location	Commonwealth Edison (Exelon subsidiary); Chicago, IL
Status	Under Development
Motivation for Microgrid	Demonstration project for interconnected microgrid network
Generation / storage assets	Planned 7 MW load across two phases: Phase 1: 2.5 MW load with solar PV and battery ESS, and diesel generators Phase 2: 4.5 additional MW load, 7 MW of natural gas and diesel generation
Obstacles Encountered:	1) Opposition to cost-sharing across entire customer base 2) Opposition to utility re-entering generation ownership business
Effective Actions Taken:	1) Constructive engagement between utility, regulators and other stakeholders to resolve issues 2) Scaling back ambitious plan for 6 microgrids, which drew concerns over fair competition from alternative energy providers 3) Allowing for private entities to purchase generation assets 4) Phased development

The Bronzeville microgrid is a planned community MUM that will interconnect a new microgrid with a pre-existing microgrid at the Illinois Institute of Technology in the Bronzeville neighborhood on the south side of Chicago. Once completed, the microgrid will serve roughly 1,060 customers from a diverse user-mix, including residential, commercial and industrial customers, and have an aggregate load of 7 MW.

The local electric utility Commonwealth Edison (ComEd) is planning the project, as a pilot for gathering data over a ten-year period to inform how to most efficiently operate interconnected microgrid networks, in two phases:

- The first phase will cost $8 million, involve 750 KW of solar PV with 500 MWh of battery storage, and serve 490 customers with 2.3 MW of load.
- The second phase will cost $17 million, largely involving diesel and natural gas turbines, and incorporate an additional 570 customers with about 5 MW of load.

Upon completion, the Bronzeville microgrid will be able to support the peak electricity demand of all its customers during an islanding event. Consequently, the microgrid operator won't need to worry about prioritizing certain users to determine a feasible load shedding protocol.

There has been a great deal of debate over the proposed Bronzeville microgrid. One major criticism is that the microgrid costs are dispersed evenly across all of ComEd's nearly 4.1 million ratepayers, while only 1,060 will directly benefit from the microgrid. However, ComEd successfully argued to the Illinois Commerce Commission (ICC) that all of its customers and other stakeholders will benefit from the microgrid based on what will be learned from this pilot project for use in subsequent microgrids – for a cost said to be "pennies per month per customer".

Another major criticism was that ComEd planned to own the generation assets of the project. Since the Illinois electricity market was restructured in 1997, ComEd had voluntarily divested itself of its generation assets, and ComEd's plans to own generation on the Bronzeville microgrid raised concerns that this would set an adverse precedent. Rather than fighting pushback from concerned parties, ComEd agreed to facilitate a competitive bidding process for third-parties to own and operate the microgrid's generation assets – unless no reasonable bids were made, in which case ComEd will step in to lease the generation assets.

Although still under development, the Bronzeville microgrid is a promising illustration of successful MUMs, and merits continued monitoring of progress.

Burrstone Energy Center	
Customer Base	Academic and medical (3,000-student college, 300-bed hospital, and 200 bed nursing home)
Utility and Location	National Grid; Utica, NY
Status	Operational
Motivation for Microgrid	Lower electricity costs; Improved resilience during extreme weather
Generation / storage assets	3x 1,100 kW natural gas turbines; 1x 334 kW natural gas turbine; Steam and heat to hospital
Obstacles Encountered:	1) Right-of-way dispute with utility
Effective Actions Taken:	1) Developing innovative economic models via PPA with NG and developing pilot program to sell back electricity to NG during critical hours for a premium price 2) Successfully overcoming right of way dispute through the award of a waiver from the Public Service Commission

In upstate Utica NY, the Burrstone Energy Center is a shining example of a multi-user microgrid that overcame significant regulatory hurdles, exhibits an innovative economic model, and is owned by a third-party developer that is neither the local utility nor affiliated with its three sizable institutional customers:

1) Faxton-St. Luke's Hospital
2) St. Luke's Nursing Home
3) Utica College

The developer and owner of the Burrstone Energy Center, Cogen Power Technologies (CPT) developed and pursued a 15-year business model that produces revenue by providing electricity to all three customers (plus steam and heat sales to the hospital) and selling electricity to National Grid via a Power Purchase Agreement (PPA) in which they are reimbursed at the wholesale electricity price during the hour of the sale.

The Burrstone Energy Center also managed to overcome one of the most prominent barriers to multi-user microgrids: exclusive franchise rights to the crossing of public right of ways. In order to deliver electricity to Utica College, CPT was obligated to cross a public right of way. Although substantial legal efforts were required, CPT was eventually granted the permission they needed to bring the project to successful completion.

Philadelphia Navy Yard (PNY) (existing community statistics)	
Customer Base	Commercial, Industrial, and Academic involving over 7 million SF in operation, 150+ businesses and 13,000 employees. The long range development plan anticipates adding as much as 1,500 resident units and growing the total community to as much as 18 million SF.
Utility and Location	Philadelphia Electric Co (Exelon subsidiary); Philadelphia, PA and The Navy Yard Electric Utility (TNYEU) operated privately by PIDC
Status	First phase complete; expanding capacity
Motivation for Microgrid	Economic/ commercial development
Generation / storage assets	8 MW natural gas peaker plant, 800 kW Bloom nitrogen fuel cell generator, and 400 kW community solar (planned expansion to 1 MW)
Obstacles Encountered:	1) Rehabilitating and upgrading the aging distribution network previously installed at the Navy Yard 2) Attracting more industrial and commercial utilization with limited existing generation assets 3) Managing numerous utility, regulatory, state, and local stakeholders
Effective Actions Taken:	1) A. Prioritizing the development and implementation of the PNY network operations center to remotely monitor and control power distribution and generation B. Implementing smart meters and supervisory control and data acquisition (SCADA) technologies 2) A. PNY first step was to create a comprehensive Energy Master Plan, which evaluated current capabilities, current needs, and needs for future development. B. PNY prioritizes microgrid services to largest industrial/ commercial stakeholders.

The Philadelphia Navy Yard (PNY) was once one of the most prominent Naval Yards in the United States. In 2000, Philadelphia Industrial Development Corporation (PIDC) acquired the PNY, a 1,200-acre facility, on behalf of the City of Philadelphia in order to catalyze economic development at a site that had fallen into disuse. By 2004, a comprehensive master plan was drafted to transform the PNY into a sustainable, mixed-use development.

The PNY development team spent years determining the ideal commercial and industrial mix necessary to target. Knowing the desired scale of development and the current capabilities, PNY turned their focus to drafting an updated Navy Yard Energy Master Plan (NYEMP). The updated EMP was finalized in 2013 and outlined initiatives that supported their goals for expansion. The EMP included plans for advanced metering, a network operation center, distribution automation, grid expansion, energy efficiency programs, self-generation and even proposed utility business models – all of which centered around expanding and updating the infrastructure in to a 35 MW hybrid microgrid.

With the acquisition of the Navy Yard, PIDC and the City of Philadelphia acquired the largest, independent and unregulated, non-military electrical grids (i.e. microgrids) in the country (albeit outdated, with limited capacity). By drafting a comprehensive Master Plan and the updated EMP, PNY provided a strong business plan for expanding the microgrid in an economically and financially viable manner. And because of its historical designation, the microgrid expansion faced minimal regulatory hurdles during its construction – allowing for efficient completion of the project. However, due to the nature of the project, the updated EMP alone had to receive buy-in from nearly 60 different stakeholders including property owners, developers, tenants, utilities, etc.

As of 2017, the PNY microgrid served 80 customers with 188 revenue-grade meters, with more than 7 million SF in operation employing 13,000 workers. The microgrid boasts existing capacity of 34 MW via two substations, with a third substation that will provide an additional 10 MW of capacity under construction, thus providing redundancy. Approximately 92% of the total electric usage on the PNY microgrid is currently purchased externally from wholesale energy provider Constellation Energy (a subsidiary of Exelon) and delivered to the PNY by the local utility Philadelphia Electric Company (another subsidiary of Exelon).

To date, capital costs for the microgrid's development, including the various generation assets, is approaching $34 million, but this may increase. Commercial and industrial growth at the PNY is forecasted to result in electric load increasing from 34 MW in 2014 to 60 MW by 2022. Once complete, the PNY microgrid will support the energy needs of 30,000 employees and 1,500 residential units, and over 15 million square feet of mixed-use space.

As of now, the PNY's generation sources include a 6 MW Natural Gas Peaker Plant, a total of 3.2 MW Combined Heat and Power, 0.8 MW of fuel cells, and a 1 MW Solar PV array. To meet load growth, PNY plans to expand the gas peaker with an additional 2 MW by the end of 2018. However, as much as 10 MW of new supply from PECO may ultimately be needed to complement new distributed energy resources (DERs) and demand management efforts.

Potsdam Community Microgrid	
Customer Base	Academic, Hospital, Municipal, Commercial and ~16,000 residents
Utility and Location	National Grid; Potsdam, NY
Status	Conceptual/planning phase
Motivation for Microgrid	Improved resilience during extreme weather
Generation / storage assets	Pre-existing: 1.4 MW CHP generators (x2), 500 kW dams (x2), 2 MW solar New: 3.2 MW hydro, natural gas CHP, and solar PV
Obstacles Encountered:	1) Aging infrastructure and inclement weather 2) Justifying the additional incurred cost in an economically-challenged area
Effective Actions Taken:	1) Staged implementation approach, where stakeholders can approve sequential phases of construction 2) Proposed tiered tariff recovery where those stakeholders who benefit the most from the microgrid also pay the most for the microgrid services.

The Potsdam Community Microgrid currently being planned is meant to serve as a demonstration project for the New York Reforming the Energy Vision program (NY REV).

Potsdam is a remote location in upstate New York, less than 30 miles from the Canadian border, which is challenged by intense storms during the winter. As such, it is quite difficult for a utility to send a service truck to fix infrastructure during an extreme weather event. To make matters worse, Potsdam receives power via long transmission lines that are especially susceptible to extreme weather. Potsdam faced the consequences of these vulnerabilities in 1998 when a winter storm led to a three-week power outage.

For this reason, National Grid is developing plans for a community microgrid to provide increased resilience to many critical facilities in the Potsdam area, such as a hospital, local police and fire departments, water treatment plants, and a number of commercial buildings.

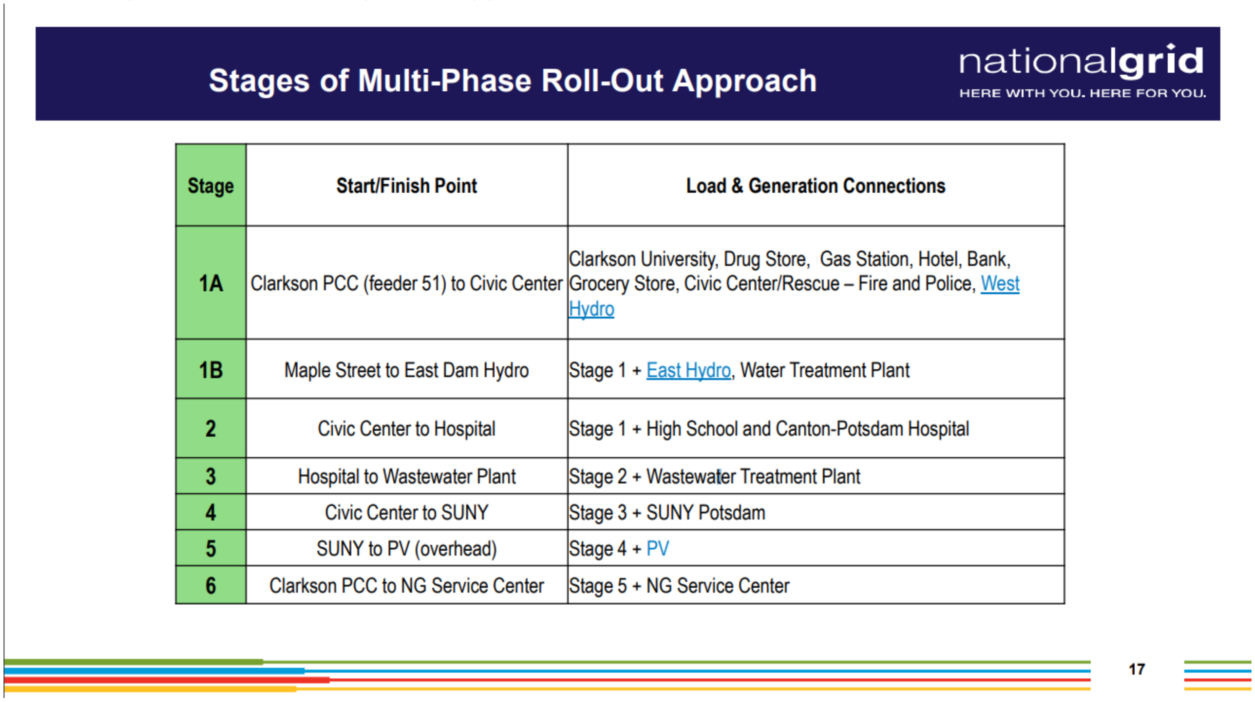
Thus far, the Potsdam microgrid project has received nearly $3 million in combined funding from the National Science Foundation (NSF), the U.S.DOE and the NYSERDA. Part of the cost-benefit/ engineering feasibility study was funded through NYSERDA's Electric Power Transmission and Distribution Smart Grid Program.[xvi] The Potsdam microgrid development project was one of seven projects in New York to receive funding through this program. Also, while the conceptual design was not finished in time to be submitted for New York Prize Stage 2 consideration, it is still the goal of the project to submit a compelling New York Prize Stage 3 funding application. NYSERDA announced that the Stage 3 application deadline has been delayed to the end of 2018, which the Potsdam project team full expects to meet. Any potential addition funding received through NY Prize would help with the feasibility of implementation.

As of May 2018, National Grid finished its engineering designs for the microgrid and rate design for utility owned assets. If the project is successfully brought to completion, National Grid hopes for it to serve as the industry standard for community microgrids.

Probably the two most distinctive aspects of the Potsdam microgrid are:

- Its phased development structure, so as to mitigate "rate shock" via a large one-time lump-sum increase in local electricity prices. As illustrated below, the Potsdam demonstration project has outlined six different proposed stages of implementation.

  The first stage, which is identified as the "smaller footprint", would cost approximately $30 million to construct. The smaller footprint microgrid would connect Clarkson University, the Village Civic Center and the Canton-Potsdam Hospital using the existing hydro power and DERs at Clarkson University. Later stages would sequentially add assets such as the SUNY-Potsdam CHP and the community solar PV as well as tie in other loads like waste water treatment plant and the national grid service center. The phased development would spread the cost to the community over time as each piece is approved.



Stages of Multi-Phase Roll-Out Approach

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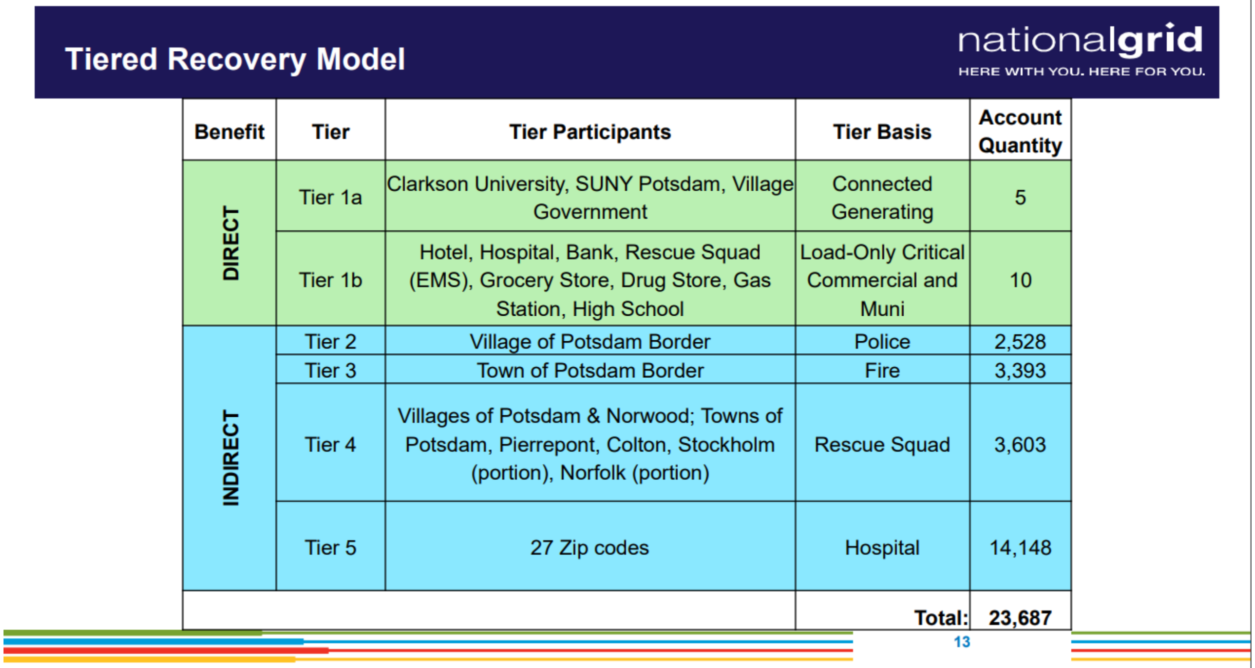
Stage	Start/Finish Point	Load & Generation Connections
1A	Clarkson PCC (feeder 51) to Civic Center	Clarkson University, Drug Store, Gas Station, Hotel, Bank, Grocery Store, Civic Center/Rescue – Fire and Police, West Hydro
1B	Maple Street to East Dam Hydro	Stage 1 + East Hydro, Water Treatment Plant
2	Civic Center to Hospital	Stage 1 + High School and Canton-Potsdam Hospital
3	Hospital to Wastewater Plant	Stage 2 + Wastewater Treatment Plant
4	Civic Center to SUNY	Stage 3 + SUNY Potsdam
5	SUNY to PV (overhead)	Stage 4 + PV
6	Clarkson PCC to NG Service Center	Stage 5 + NG Service Center

- A tiered pricing tariff, under which customers that have the greatest needs (and corresponding willingness to pay) for greater resilience pay more for the microgrid. Future microgrid participants would be assigned tiers based on the benefits received.

  Those participants with direct benefits and load generating capacity would be served at the highest priority (Tier 1a), and those with critical services would be served at a close second priority (Tier 1b). Clarkson University and the Village Government would fall under Tier 1a, while the Hospital, Rescue Squad, High School, Grocery Store (and a few others) fall under Tier 1b. From a pricing standpoint, the Tier 1 participants would pay the highest tariff. The lowest tier (Tier 5) is the residential ratepayers who receive indirect benefits from the microgrid – and they would pay the least in the applied tariff structure.



Tiered Recovery Model

Benefit	Tier	Tier Participants	Tier Basis	Account Quantity
DIRECT	Tier 1a	Clarkson University, SUNY Potsdam, Village Government	Connected Generating	5
	Tier 1b	Hotel, Hospital, Bank, Rescue Squad (EMS), Grocery Store, Drug Store, Gas Station, High School	Load-Only Critical Commercial and Muni	10
INDIRECT	Tier 2	Village of Potsdam Border	Police	2,528
	Tier 3	Town of Potsdam Border	Fire	3,393
	Tier 4	Villages of Potsdam & Norwood; Towns of Potsdam, Pierrepont, Colton, Stockholm (portion), Norfolk (portion)	Rescue Squad	3,603
	Tier 5	27 Zip codes	Hospital	14,148
			Total:	**23,687**

Appendix 2: Northeast United States microgrid dataset

This appendix details the data set of microgrids that was created for this study.

Title of Data: Northeastern United States Microgrid Data Set

Database Constructed by: Josef Benzaoui

Last Updated: July 19th, 2018

Description of Data: This data set provides a comprehensive listing of microgrids in the Northeastern United States, and to the extent possible describes a number of variables or characteristics for each microgrid.

Sources of Data: Various public sources were used in the construction of this data set. Sources of information for each microgrid are listed in the data set record for that microgrid.

Variables Explained:

Cost: This value represents the capital cost of the project, when available. Sometimes only the overall cost of the project (including soft costs) is listed in an article or press release and that value is used instead. If neither the capital nor overall cost of the project is available, the value is listed as 9999.

Amount Awarded: This value represents the total sum of grants awarded to the microgrid project. If no grants were awarded to the project, this value is listed as N/A. If it is uncertain as to whether or not grants were awarded or the amount of grant funding is not available, this value is listed as 9999.

Application Team: This list of organizations represents the team who participated in the grant application. If no grant was applied for, this value is listed as N/A. If an application to a grant program was made but the team members are unknown, then this value is listed as 9999.

Critical Facilities: This list of facilities are those deemed critical to the town/community in which the microgrid exists by the project team. If no critical facilities are a part of the microgrid, this variable is listed as 'none'.

Commercial Buildings: This list of facilities are commercial in nature and supported by the microgrid. If none are supported by the microgrid, this variable is listed as 'none'.

Utility: This is the utility (or utilities) that operate in the area(s) within which the microgrid is located.

Project Status: This value represents the most currently available update on the status of the microgrid. For projects that participated in the NY Prize program:

- If the value is listed as NY Prize Stage 1 Winner, it means the microgrid was a stage one winner but did not go past a feasibility study.
- If the value is listed as a NY Stage 2 Winner, it means the microgrid was a stage two winner but no further updates were available.
- Some stage 2 winners had publicly available information about their progress, such as becoming operational, and are listed as operational.

Generation: This variable lists the most detailed information about the generation technology/assets utilized by the microgrid, or that was planned to be utilized as per the feasibility study.

Contact: This represents the most specific point of contact associated with the microgrid or its feasibility study. If no specific point of contact is available, a general company or municipal representative associated with the project is listed. If no contact is available, the value is listed as 9999.

Contact Info: This represents contact information (phone, email, or both) for the listed point of contact. If no contact information is available, this value is listed as 9999.

State Code: This value is a numerically coded version of the variable called State.

1 = Connecticut
2 = Maine
3 = Maryland
4 = Massachusetts
5 = New Hampshire
6 = New Jersey
7 = New York
8 = Pennsylvania
9 = Rhode Island
10 = Vermont

Project Status Code: This value is a numerically coded version of the variable called Project Status.

1 = Applied for Grant
2 = Failed
3 = Feasibility Study
4 = Grant Funded
5 = NY Prize Stage 1 Winner
6 = NY Prize Stage 2 Loser

7 = Operational
8 = Proposed
9 = Under Development

Multi-User: This is a binary variable that represents whether the microgrid is (or is planned to be) single-user or multi-user. A value of 0 indicates the microgrid is single-user and a value of 1 indicates the microgrid is multi-user. If that information is uncertain or not yet determined (as is the case in some feasibility studies), it is listed as 9999.

User Mix: This is a numerically coded variable that represents the mix of users which are (or are planned to be) supported by the microgrid. If more than one type of user is supported, it is considered mixed-use. If that information is uncertain or not yet determined (as is the case in some feasibility studies), it is listed as 9999.

1 = Industrial
2 = Commercial
3 = Residential
4 = Municipal
5 = Medical
6 = Education
7 = Mixed-use (2 or more of any of the listed user types)
8 = Navy
9 = Military

Generation Mix: This is a numerically-coded variable that represents the generation technologies/sources that are (or are planned to be) incorporated into the microgrid. If that information is uncertain or not yet determined (as is the case in some feasibility studies), it is listed as 9999.

1 = Solar
2 = Wind
3 = Hydro
4 = Natural Gas
5 = Natural Gas with CHP
6 = CHP
7 = Diesel
8 = Mixed
9 = Coal
10 = Fuel Cell
11 = Waste to Energy

Storage: This is a binary variable that represents whether or not the microgrid includes (or is planned to include) storage technologies. A value of 0 indicates no storage and a value of 1 indicates storage. If that information is uncertain or not yet determined (as is the case in some feasibility studies), it is listed as 9999.

Islanding: This is a binary variable that represents whether or not the microgrid has (or is planned to have) islanding capabilities. A value of 0 indicates no islanding capability and a value of 1 indicates islanding capability. If that information is uncertain or not yet determined (as is the case in some feasibility studies), it is listed as 9999.

Project Count: Dummy variable to facilitate counting number of microgrids satisfying particular characteristic.

Appendix 3: Individuals Interviewed

The following table lists the individuals that were interviewed in the course of this research. We would like to thank these individuals for their perspectives and their assistance.

Interviewee Name	**Organization/Company**
Ed Linton	Northern Power Systems
Will Agate	Ameresco (formerly Philadelphia Navy Yard)
Mark Johnson	Clean Energy Blockchain Network
Tom Lovett & Jack Griffin	Veolia SourceOne / Hudson Yards
Dan Dobbs and Luis Ortiz	Anbaric
Galen Nelson	Massachusetts Clean Energy Council
Travis Sheehan	Gridling Global
James Mader	Avangrid
Karen Morgan	Dynamic Energy Networks
Michael DeSocio	New York Independent Service Operator
Mark Feasel	Schneider Electric
Brad Swing	City of Boston
Manuel Esquivel	Boston Planning and Development Agency
John Moynihan	Cogen Power Technologies
Paul Tyno	Boston Niagara Medical Campus
Arunkumar Vedhathiri	National Grid – New Energy Solutions
Michael P. Razanousky	NY State Energy Research & Development Authority
Josh Doolittle and Vishal Patwari	B2Q Associates
Heather Takle	2nd Path Energy

Endnotes

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[i] Dan T. Ton and Merrill A. Smith, “The U.S. Department of Energy’s Microgrid Initiative”, The Electricity Journal, October 2012, Vol. 25, Issue 8. Copyright 2012. https://www.energy.gov/sites/prod/files/2016/06/f32/The%20US%20Department%20of%20Energy%27s%20Microgrid%20Initiative.pdf

[ii] Eto, Joseph H., “The National Cost of Power Interruptions to Electricity Customers – Early Peek at LBNL’s 2016 Updated Estimate” 2016 IEEE PES General Meeting, July 19, 2016. http://grouper.ieee.org/groups/td/dist/sd/doc/2016-09-02 LBNL 2016 Updated Estimate-Nat Cost of Pwr Interruptions to Elec Custs-Joe Eto.pdf

[iii] LBNL reports: Kristina Hamachi LaCommare and Joseph H. Eto. “Cost of Power Interruptions to Electricity Consumers in the United States (U.S.)” LBNL Environmental Energy Technologies Division LBNL-58164, February 2006. Eto, Joseph H., “The National Cost of Power Interruptions to Electricity Customers – Early Peek at LBNL’s 2016 Updated Estimate” 2016 IEEE PES General Meeting, July 19, 2016. “Estimating Power Interruption Costs: A Guidebook for Electric Utilities” LBNL and Nexant, Inc. Michael Sullivan, Myles T. Collins, Josh Schellenberg, Nexant, Inc. and Peter H. Larsen, Lawrence Berkeley National Laboratory. July 2018. EPRI report: “The Integrated Grid: A Benefit-Cost Framework” EPRI Report 3002004878. Final Report, February 2015. NREL reports: “Valuing the Resilience Provided by Solar and Battery Energy Storage Systems” NREL/BR-6A20-70679, January 2018. *Summary of Laws, Nicholas D., Kate Anderson, Nicholas A. DiOrio, Xiangkun Li, and Joyce McLaren. “Impacts of Valuing Resilience on Cost-Optimal PV and Storage Systems for Commercial Buildings.”* Kate Anderson (NREL), Nicholas D. Laws (NREL), Spencer Marr (CUNY), Lars Lisell (NREL), Tony Jimenez (NREL), Tria Case (CUNY), Xiangkun Li (NREL), Dag Lohmann, and Dylan Cutler (NREL), “Quantifying and Monetizing Renewable Energy Resilience” Sustainability Journal 2018, Vol 10, pg 933. http://www.mdpi.com/journal/sustainability

[iv] Eto, Joseph H., “The National Cost of Power Interruptions to Electricity Customers – A Revised Update” 2017 IEEE PES General Meeting, January 10, 2017.

[v] “Measuring the Value of Electric System Resilience: A Review of Outage Cost Surveys and Natural Disaster Impact Study Methods,” Cornell University and EPRI. Technical Update 3002009670, January 2017. *“Draft* - Estimating the Regional Economic Resilience Benefits of Community Microgrids”, Dated June 28, 2018. Prepared for NYSERDA by Industrial Economics, Inc. of Cambridge, MA.

[vi] Wood, Elisa. “Maryland Regulators Reject BGE’s Utility Microgrids; Raise Competition Issues” Microgrid Knowledge July 22, 2016. https://microgridknowledge.com/utility-microgrids/. “Comments of the National Energy Marketers Association - In the Matter of the Merger of Exelon) Corporation and Pepco Holdings, Inc.” State of Maryland Public Service Commission – Case No. 9361. April 6, 2018 https://www.energymarketers.com/Documents/NEM_cmts_Pepco_microgrid_proposal_final.pdf

[vii] Maryland Office of People’s Counsel, Regulatory Activities – Electricity. Maryland.gov, Copyright 2015. http://opc.maryland.gov/RegulatoryActivities/Electricity.aspx.

[viii] Hoedl, Seth. “A Comparison of Legal Issues for Microgrids in Massachussets, New York and D.C.” Emmet Environmental Law and Policy Clinic, Slide 12. June 29th, 2015. http://environment.law.harvard.edu/wp-content/uploads/2015/08/masschusetts-microgrids_overcoming-legal-obstacles.pdf

[ix] New York State Energy Research and Development Authority. “Microgrids: An Assessment of the Value, Opportunities, and Barriers to Deployment in New York State” NYSERDA Electric Power Transmission and Distribution Reports- R&D Technical Reports, page 23. September 2010. https://www.nyserda.ny.gov/About/Publications/Research-and-Development-Technical-Reports/Electric-Power-Transmission-and-Distribution-Reports

[x] https://legiscan.com/NH/text/HB1338/id/1656666

[xi] Boston Planning and Development Agency. “Smart Utilities Policy for Article 80 Development Review”. June 2018. http://www.bostonplans.org/planning/planning-initiatives/boston-smart-utilities-project

[xii] Microgrid Knowledge. Microgrid Knowledge Conference Series. May 2018. https://microgridknowledge.com/microgrid-2018-conference/

[xiii] “BGE’s Public Purpose Microgrid Proposal” *via electronic filing;* Baltimore Gas & Electric, December 18, 2015. https://www.bge.com/MyAccount/MyBillUsage/Documents/BGE%20Microgrid%20Proposal%20Filing%20wATT_121815_F.pdf.

[xiv] Wood, Elisa. “Maryland Regulators Reject BGE’s Utility Microgrids; Raise Competition Issues” Microgrid Knowledge July 22, 2016. https://microgridknowledge.com/utility-microgrids/. “Comments of the National Energy Marketers Association - In the Matter of the Merger of Exelon) Corporation and Pepco Holdings, Inc.” State of Maryland Public Service Commission – Case No. 9361. April 6, 2018 https://www.energymarketers.com/Documents/NEM_cmts_Pepco_microgrid_proposal_final.pdf

[xv] Wood, Elisa. “Maryland Utility Proposes $44.2M Pilot for Public Purpose Microgrids” Microgrid Knowledge, October 3, 2017. https://microgridknowledge.com/public-purpose-microgrids-pepco/. “Comments of the National Energy Marketers Association - In the Matter of the Merger of Exelon) Corporation and Pepco Holdings, Inc.” State of Maryland Public Service Commission – Case No. 9361. April 6, 2018 https://www.energymarketers.com/Documents/NEM_cmts_Pepco_microgrid_proposal_final.pdf

[xvi] Rizzo, Alan. “Smart Energy Grid to Keep Potsdam, N.Y., Powered During Emergencies” Emergency Management, July 30, 2014. http://www.govtech.com/em/disaster/Smart-Energy-Grid-Potsdam-NY.html